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Research Article

The Effects of GeoGebra-Assisted Instruction on Achievement, Attitudes, and Students' Opinions in Fractions*

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Abstract – This study aimed to investigate the impact of GeoGebra-supported instruction on fractions on student achievement and attitudes toward mathematics, as well as to evaluate student opinions. In the quantitative part of the study, changes in achievement and attitude were identified using a quasi experimental design applied to a single group. In the qualitative part, student opinions were examined. The sample of the study consisted of 40 sixth-grade students attending a public middle school in the center of Kars province. The study lasted 20 class hours. Quantitative data were collected using a fractions achievement test and the Attitude Scale Towards Mathematics (Önal, 2013), while qualitative data were collected using semi-structured interview forms. The t-test was used in the quantitative data analysis, and content analysis was used in the qualitative data analysis. The results showed that GeoGebra-supported teaching was effective in increasing student achievement and attitude. It was also found that the majority of students saw understanding the subject better with GeoGebra and making the lesson more enjoyable as advantages. It was determined that most students did not mention any disadvantages. Most students suggested solving more questions related to the topic in class.

Keywords: Fractions, GeoGebra, academic achievement, attitude towards mathematics, student opinions.

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Introduction

The Programme for International Student Assessment (PISA) and also Trends in International Mathematics and Science Study (TIMSS) exams are administered in Türkiye. One of the reasons for conducting such exams and studies is to determine the educational level of countries compared to other countries. TIMSS and PISA results in our country are not at the desired level (Gürler, 2021). At this point, there are critical questions that mathematics educators are advised to investigate; for example, how teachers can better integrate their knowledge into teaching, and how student interaction with the material should be (Ersarı, 2021). At the same time it has been stated that technology-supported methods may be preferred over traditional methods to change the exam results (Zengin, 2019). It is evident that technology support plays a pivotal role in the development of fundamental mathematical competencies, as articulated by the Ministry of Education (MoNE, 2018). One of the most widely utilised software in this content is GeoGebra. In this nation, the utilisation of GeoGebra software is advocated within educational curricula. Moreover, the software has been incorporated into educational materials, as evidenced by its presence in textbooks (Gezmiş & Akkaya, 2024). Its suitability for use in and out of the classroom has been demonstrated (Majerek, 2014), and it has been shown that it contributes significantly to students' learning of mathematics (Arbain & Shukor, 2015). GeoGebra provides learners with an independent learning environment and experience (Ishartono et al.,2022). GeoGebra also helps students understand mathematical concepts and provides a better and more interactive learning environment (Siswanto et al., 2024). GeoGebra has a positive effect as a dynamic visualisation tool for improving success (Zhang et al., 2025). Research literature indicates that GeoGebra increases success more than traditional methods (Adelabu et al., 2022; Alabdulaziz et al., 2021; Birgin & Akar, 2022; Hidayat et al., 2023; Hosseini et al., 2022; Mosese & Ogbonnaya, 2021; Syarifuddin et al., 2023; Taş, 2016; Uwurukundo et al., 2022a; Zengin, 2019). GeoGebra also has an effect on developing positive attitudes towards mathematics (Dankal, 2017; Demirbilek & Özkale, 2014; Murni et al., 2017; Rabi et al., 2021; Topuz, 2017; Uzun, 2014).

One of the mathematical topics where GeoGebra is used is fractions. Fractions represent a foundational topic of paramount importance for students. This is due to their ubiquity in various fields of measuring, as well as in advanced mathematics and algebra (Van De Walle et al., 2013). Fractions represent one of the most important topics in primary mathematics, forming the basis for numerous concepts in the mathematics curriculum, including decimals, rational numbers, and ratios (Arslan-Kılcan, 2006). In the Republic of Türkiye, this subject is taught in the sixth grade, as well as in other grades. A review of the sixth grade learning outcomes for fractions (MoNE, 2018) reveals that the initial topics addressed pertain to the comparison and ordering of fractions, in addition to their representation on a number line. Moreover, the curriculum is observed to prioritise the execution of fundamental mathematical operations, including addition, subtraction, multiplication, and division with fractions. Subsequent to this stage, the emphasis transitions to problem-solving and estimation with fractions. The comprehensive treatment of the topic of fractions at this grade level, and its role in establishing a foundation for subsequent grade levels, renders the engagement with this topic imperative.

Fractions are difficult for many reasons. Firstly, the visual representation of fractions does not correspond to that of natural numbers or integers. Secondly, the way in which fractions are represented differs from that of other mathematical concepts. Finally, students are unable to form a specific template in their minds (Orhun, 2007). In order to facilitate a more profound comprehension and articulation of the subject matter, it is imperative to employ efficacious methodologies. GeoGebra-supported education is one such method. Some studies have been conducted using GeoGebra, the results of which are available for consultation on the topic of fractions (Bulut et al., 2016; Fidan, 2025; Gürler, 2021; Koç-Kök, 2024; Macuacua Junior, 2024; Nashiroh & Zainuddin, 2023; Poon, 2018; Prihandini et al., 2023; Ünlütürk-Akçakın, 2016).

This study was conducted to evaluate the impact of GeoGebra-supported instruction on students' achievement regarding fractions and mathematics attitudes and to evaluate their opinions on the matter. It was hypothesised that the provision of students with the opportunity to work with GeoGebra could influence their opinions, thereby transforming their negative attitudes towards mathematics. The present study therefore sought to evaluate the impact of utilising GeoGebra in the instruction of the subject on achievement, attitude, and student perceptions.

Attitudes Towards Mathematics

According to Alken (1974), mathematics attitude is a skill related to mathematics performance. As posited by Gürbüz et al. (2013), the attitude towards mathematics is identified as a factor affecting mathematical competence. A number of factors have been recognized as having a significant impact on attitude towards mathematics. Yaşar et al. (2014) identified these factors as emotions, behaviours, enjoyment, the significance of mathematics in life and its role in society and academic achievement. As posited by Damrongpanit (2019), mathematics attitue is the most significant factor in explaining the achievements of students. This is because a positive attitude formed in the learning environment increases success, while a negative attitude causes a decline (Tuncer et al., 2015). As posited by Moenikia and Zahed-Babelan (2010), the mathematical attitude of an individual has been shown to serve as a statistically significant predictor of academic motivation, intelligence quotient, and mathematical achievement.

According to Elçi (2008), mathematical attitude is related to learning methods. Vandecandelaere et al. (2012) stated that mathematical attitude is related to the student's pleasure of mathematics in the learning environment. Mathematical attitudes can be positively developed using technology, specifically GeoGebra (Romero-Albaladejo & García-López, 2024). Indeed, studies showing that mathematical attitudes change positively with the use of technology are found in the literature (Aktümen & Kaçar, 2008; Kaya & Keşan, 2018; Koğ & Başer, 2012). Examples of studies showing that mathematical attitudes develop with GeoGebra-supported teaching include Uzun (2014) and Topuz (2017) on geometry, Kaya (2015) on algebra, Dankal (2017) on inequalities, and Murni (2017) on problem solving. Similarly, Küçük and Gün (2023) used it in transformation geometry, Etcuban and Leonard (2025) in algebraic function graphs, and Uwurukundo et al. (2022b) in 3D geometry instruction to develop attitudes. Several studies in the literature have investigated the effect of GeoGebra use on students' mathematical attitudes on fractions (Gürler, 2021; Koç Kök, 2024). However, these studies reported no statistically significant change in students' attitudes following the implementation. Considering the strong relationship between mathematical attitude and academic achievement, and taking into account the findings of previous research, the present study aims to re-examine the effect of GeoGebra use on students' attitudes toward fractions.

Fractions and Related Research

Fractions are defined as the way of writing parts of whole numbers (Pinilla, 2007). However, the concept of fractions has various meanings. Figure 1 presents Lamon's (2012) framework for fractions:

Part-whole	Measure	Operator	Quotient	Ratios
• 2 parts out of 3 equal parts • Comparison of the number of equal parts (2) out of the total number of equal parts (3) the whole was divided	• 2-1/3 unit • A distance equivalent to 2 intervals of length 1/3	• 2/3 of something • Notion of shrinking and enlarging; for example, of something indicates you are carrying out a process of multiplying by 2 and then dividing by 3	• 2 divided by 3 • Viewed as a result of division; notion of partitioning or sharing (e.g., amount each person gets when 2 wholes are shared equally among 3 people)	• 2 to 3 • Can be a part-part or part-whole relationship based on the context; (part-part: 2 boys to 3 girls; part-whole: 2 boys to 3 total of 3 students)

Figure 1 Different Meanings of Fractions (Adapted from Lamon, 2012, by Reeder and Utley, 2017)

The first meaning of a fraction is a part-whole. Doğan (2018) states that this means the whole is divided into some equal parts. In terms of measurement, it refers to determining the distance of a point away from the starting point at specific intervals (Lamon, 2001). In the sense of measure, a division operation is performed, and emphasis is placed on the numerical value that emerges when a is divided by b (Kieren, 1993). The meaning of ratio shows the relationship between quantities (Post et al., 1998). The quotient meaning indicates that it can be considered a compound operation resulting from multiplication or the combination of two separate but related operations (Charalambous & Pitta-Pantazi, 2007).

Fractions are among the fundamental topics that students encounter after learning the four basic operations in the first stage of primary education and that they will frequently use in their subsequent school life (Bulut et al., 2016). In general, the topic of fractions is a turning point in primary education when many students begin to experience problems in mathematics (Clements et al., 2004). Students' learning of whole numbers is inconsistent with the topic of fractions. For this reason, the topic is difficult to understand (Clements et al., 2004; McNamara & Shaughnessy, 2010). This is because what is learned about whole numbers is generalized to the topic (Van de Walle et al., 2013). Furthermore, the rules for operations with fractions are different from those for operations with whole numbers (Pinilla, 2007). On the other hand, although understanding the various meanings of fractions is considered fundamental to understanding fractions, students also experience difficulties at this point (Isnawan et al., 2022). According to Wong and Evans (2008), students understand fractions as a measure (measure meaning) when they can coordinate the reference unit, symbolic representation, and figural representations simultaneously. Dewi et al. (2017)

emphasized that introducing fractions is initially related to dividing an object. It was also noted that the majority of students encounter epistemological barriers when attempting to comprehend the meaning of the topic. Students' tendency to think of fractions only as numbers with a numerator and denominator contributes to these barriers. Martinez and Blanco (2021) found that when examining students' problem-solving situations related to fractions, the trend generally relates to part-whole and part-set problems. According to Li (2008), teachers need to carefully consider what students should learn beyond procedural steps.

Technology-supported practices are being used to overcome these challenges. For example, the use of virtual manipulatives (Finti et al., 2016; Fokides & Alatzas, 2023; Gaetano, 2014; Mendiburo & Hasselbring, 2014) and interactive multimedia tools (Goodwin, 2008) are some of these. Additionally, studies have also shown the use of Hawgent Dynamic Math Software (Wijaya et al., 2020) and 3D printers (Kavas, 2021). Another technology used is GeoGebra (Bulut et al., 2016; Fidan, 2025; Gürler, 2021; Koç-Kök, 2024; Macuacua Junior, 2024; Nashiroh & Zainuddin, 2023; Poon, 2018; Prihandini et al., 2023; Ünlütürk-Akçakın, 2016). Ünlütürk-Akçakın (2016) examined the motivation and achievement of fourth-grade students in the topic using traditional methods and GeoGebra. The findings suggested that the experimental group demonstrated higher levels of success in comparison to the control group. However, no statistically significant differences were observed in terms of motivation levels.

The literature also includes studies examining mathematical attitudes toward fractions. For example, Dündar (2015) examined the effect of educational games, Hensberry et al. (2015) examined the effect of interactive simulations, and Ipek and Yaman (2021) examined the effect of digital teaching materials on their attitudes. Dündar (2015) observed no change in attitudes in his study. However, Hensberry et al. (2015) stated in their research with fourth-grade students that attitudes towards mathematics improved positively. Similarly, Ipek and Yalman (2021) found a significant difference in attitudes towards mathematics in their study. Similarly, Ahn and Kim (2015), Pilli and Aksu (2013), and Özdemir and Özçakır (2019) reported that activities involving multiple representations, the educational software Frizbi Matematik 4, and augmented reality applications, respectively, had positive effects on students' attitudes toward fractions. Gürler (2021) conducted an experimental study that found sixth-grade students' success increased with GeoGebra-supported education. However, it was also stated that the process had no significant effect on attitudes. Similarly, Koç-Kök (2024) examined the success and attitudes of fifth-grade students with GeoGebra-supported teaching and stated that success increased but attitudes did not change. Similarly, Uygun (2008) stated that computer-supported teaching software increased achievement. Nevertheless, a substantial discrepancy in mathematical attitudes was not observed.

The topic of fractions constitutes a foundation for many other mathematical concepts; therefore, it needs to be learned effectively. One way to determine whether this learning has occurred is to monitor students' academic achievement. One of the factors influencing mathematical achievement is students' attitudes toward mathematics. In order to foster positive mathematical attitudes, technological methods and techniques are frequently employed in mathematics education. One of the technological tools used in mathematics instruction is GeoGebra. A review of the relevant literature reveals that there is a limited number of studies focusing on the teaching of fractions through GeoGebra in terms of both academic achievement and mathematical attitude. These studies generally report an increase in academic achievement, whereas no significant change in students' attitudes toward mathematics has been observed. Nevertheless, it is believed that providing students with opportunities to engage with mathematics through GeoGebra may influence their perceptions and help transform negative attitudes toward mathematics.Therefore, the present study aims to examine the effect of GeoGebra-supported instruction on the academic achievement and mathematical attitudes of sixth-grade students using a single-group research design, as well as to evaluate students' opinions regarding the instructional process.

Research Problem and Sub-Problems

How does GeoGebra supported instruction affect sixth-grade students' achievement, attitudes, and opinions regarding fractions? The sub-problems of the research are:

1) What is the effect of GeoGebra-supported instruction on sixth-grade students' achievement in fractions?

2) What is the effect of GeoGebra-supported instruction on sixth-grade students' attitudes toward mathematics?

3) What are the students' opinions on GeoGebra-supported instruction?

Method

Research Model

This study was designed as a mixed research model. According to Creswell & Plano Clark (2011), in this model, quantitative and qualitative methods are used together to understand and solve the research problem. In this study quantitative approaches were used to examine the effect of teaching with GeoGebra on students' achievement and mathematics attitudes, while qualitative approaches were used to determine student opinions. In the quantitative part, single-group quasi-experimental design was used. Fraenkel et al. (2012) stated that in this design, a pre and post-test were applied to a group to measure the effect of the variable. When the adequacy of true experimental models cannot be ensured due to the lack or inadequacy of controls, quasi-experimental models can be used (Karasar, 2012). This design was used because the study was conducted in the only class where the researcher taught at the school. In the study, the Fractions Achievement Test which was developed by the researcher and the Mathematics Attitude Scale developed by Önal (2013) were used before the study (pre-test) and after the study (post-test) to examine the change between them. In the qualitative part, student opinions regarding the methods applied were obtained. According to Yıldırım and Şimşek (2008), qualitative research uses data collection methods such as interview, document analysis and observation. In this way, events and perceptions are presented realistically in a natural environment.

Participants

The research group consists of 40 students continuing their education in the sixth grade at a state middle school in central Kars during the 2023-2024. The topic of fractions is covered in detail at the sixth-grade level. Therefore, this grade level was chosen for this study.The study was conducted in only one class. The researcher conducting the study works as a teacher at the school in question; therefore, the researcher determined the study group using the convenience sampling method.

Data Collection

Data collection tools are the Fractions Achievement Test, the Attitude Scale Towards Mathematics (Önal, 2013), and the Student Opinion Form.

Fractions Achievement Test

The Fractions Achievement Test was prepared based on the MoNE (2018)'s learning outcomes. There are eight learning outcomes at this grade level, and 20 hours have been allocated for these learning outcomes (MoNE, 2018). The Achievement Test was developed using questions from the State Boarding and Scholarship exams administered by the MoNE to 5th and 6th graders between the 2018-2023 academic years, specifically those questions appropriate for the 6th grade fractions topic and learning outcomes. After identifying the questions that appeared on the exam related to the topic, a pool of these questions was created. Then, the questions were reviewed by researchers and 2 content experts, and 25 were selected. Initially, this test contained 25 questions. Using pilot study data is the most accurate way to obtain meaningful results in the achievement test. For these data, a study can be conducted on a sample size of n=30, 50, or 100 (Koç-Kök, 2024). The test was administered to 108 students outside the intervention group, and item difficulty and discrimination indices were calculated. The calculated values of the test items are presented in Table 1:

Table 1 Achievement Test Item Difficulty Index and Item Discrimination Index

Item number	Item difficulty index	Item discrimination index
1	.51	.51
2	.40	.51
3	.53	.03
4	.14	.29
5	.42	.70
6	.48	.81
7	.83	.25
8	.48	.88
9	.50	.90
10	.35	.48
11	.38	.40
12	.42	.40
13	.03	.30
14	.25	.29
15	.64	.62
16	.25	.51
17	.33	.44
18	.50	.77
19	.27	.18
20	.31	.40
21	.33	.44
22	.33	.29
23	.40	.51
24	.46	.55
25	.35	.48

Items with a difficulty index of 0.29 or less are considered difficult, those between 0.30 and 0.49 are of medium difficulty, those between 0.50 and 0.69 are easy, and those between 0.70 and 1 are very easy (Hasançebi et al., 2020). As seen in Table 1, accordingly, item 7 is very easy, items 1, 3, 9, 15, and 18 are easy, items 2, 5, 6, 8, 10, 11, 12, 17, 20, 21, 22, 23, 24, and 25 are of medium difficulty, and items 4, 13, 14, 16, and 19 are difficult. If the item discrimination index is 0.19 or lower, it is recommended that the item in question be withdrawn from the testing process, as it has been demonstrated to exhibit a marked weakness.. between 0.20 and 0.29, the item can be corrected and used, between 0.30 and 0.39, it is moderately discriminative, and 0.40 and above, the item is regarded as being of a high standard. (Hasançebi et al., 2020). Accordingly, items 1, 2, 5, 6, 8, 9, 10, 11, 12, 15, 16, 17, 18, 20, 21, 23, 24, and 25 are highly discriminative items, item 13 is moderately discriminative, items 4, 7, 14, and 22 are low, and items 3 and 19 are very low. Based on expert opinion, items 3, 4, 7, 14, 19, and 22 were removed from the test. The final version of the test consists of 19 questions and was used twice: as a pre and post-test.

The distribution of items for the Fractions Achievement Test according to the learning outcomes related to the 6th grade fractions sub-area is given in Table 2.

Table 2 Distribution of Items According to Learning Outcomes

Learning outcomes	Items
1	1,2,4,16,18
2	3,4,5,6
3	8,12,15
4	10
5	9,13,14
6	7
7	19
8	8,9,11,12,13,14,17,19

As seen in Table 2, the test includes at least one item from each learning outcome, which did not affect content validity. Furthermore, some items address more than one learning outcome. For example, item 8 addresses both Learning Outcome 3 (performs and explains the meaning of multiplication of a natural number by a fraction) and Learning Outcome 8 (solves problems requiring operations with fractions).

Attitude Towards Mathematics Scale

The Attitude Towards Mathematics Scale (Önal, 2013) can be used with 5th, 6th, 7th, and 8th grade students. This scale, consisting of 22 items and 4 sub-dimensions, includes 10 items in the Mathematics Interest section, 5 items in the Mathematics Anxiety section, 4 items in the Mathematics Study section, and 3 items in the Mathematics Necessity section. The Anxiety sub-dimension includes reverse items. This scale, prepared on a 5-point Likert scale (1 = strongly disagree - 2 = disagree - 3 = undecided - 4 = agree - 5 = strongly agree), was subjected to factor analysis by Önal (2013) to assess its construct validity. Cronbach's alpha coefficient for the entire scale was calculated as 0.90 and for the factors constituting the scale were determined to be 0.89 for Interest, 0.74 for Anxiety, 0.69 for Study, and 0.70 for Necessity. The primary reason for choosing this scale in this study is its suitability for middle school students. Other reasons for its selection include the sufficient number of questions (22 items) and its 5-point Likert scale. Furthermore, the items are clear and understandable.Permissions for scale use were obtained from the scale owner via email.

Student Opinion Form

This study aimed to examine students' opinions according to the use of GeoGebra. For this reason a semi-structured interview form was prepared based on expert opinions. This interview form consisted of three questions to identify the advantages and disadvantages of teaching fractions with GeoGebra support, as well as student suggestions.

Process

The research was conducted in a sixth-grade class through face-to-face education. At the beginning of the study, the Fractions Achievement Test was used as a pre-test to measure students' levels in fractions. Similarly, the Attitude Towards Mathematics Scale (Önal, 2013) was used as a pre-test to measure the current group's attitudes toward mathematics. The implementation was carried out over approximately 4 weeks, with 5 class hours per week, using GeoGebra and worksheets. Before starting the study, the GeoGebra software was introduced to the students, and how to use it in lessons was explained within one lesson hour. Students were given the opportunity to explore with GeoGebra during the lessons. In the study group, lessons were conducted with a student-centered approach and through a process in which the students actively participated. GeoGebra-supported instruction was implemented under the supervision of the researcher using a smart board. Some students were given the opportunity to use the software on the board, ensuring their active participation in the lesson.The lesson plan and worksheets for the study group were prepared by the researcher in accordance with GeoGebra. The GeoGebra materials to be used during the application were obtained from the www.geogebra.org website and used in the lessons. Eleven worksheets and eleven GeoGebra materials were used in the study. An example figure of the material used to order equal fractions is presented in Figure 2:

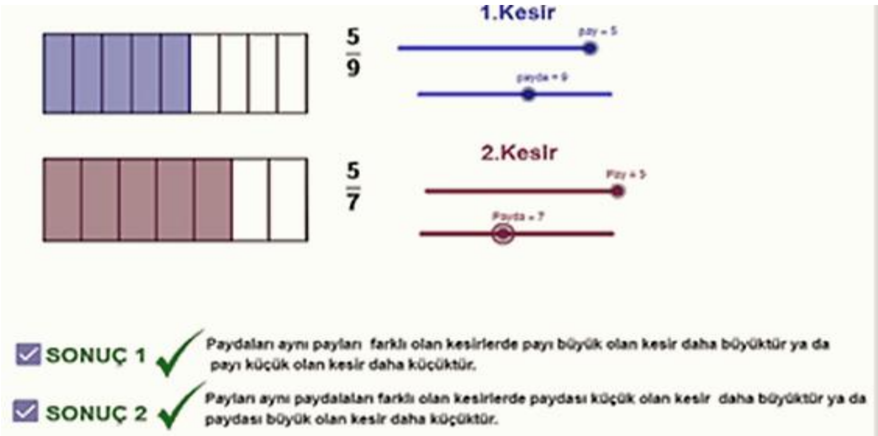
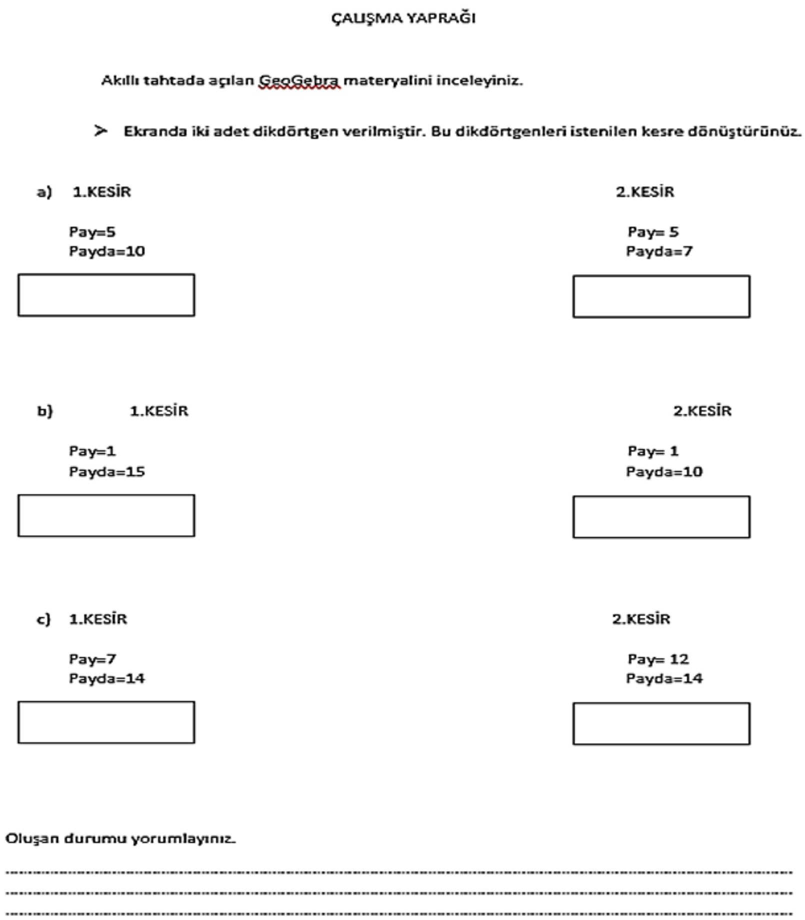


Figure 2 An Image from the GeoGebra Material for Ordering Fractions with Equal Numerators (URL 1)

In this activity, students were given a worksheet at the beginning of the lesson. The figure of the worksheet is presented in Figure 3.



ÇALIŞMA YAPRAĞI

Akıllı tahtada açılan GeoGebra materyalini inceleyiniz.

➢ Ekranda iki adet dikdörtgen verilmiştir. Bu dikdörtgenleri istenilen kesre dönüştürünüz.

a) 1.KESİR
Pay=5
Payda=10

2.KESİR
Pay= 5
Payda=7

b) 1.KESİR
Pay=1
Payda=15

2.KESİR
Pay= 1
Payda=10

c) 1.KESİR
Pay=7
Payda=14

2.KESİR
Pay= 12
Payda=14

Oluşan durumu yorumlayınız.
....
....
....

Figure 3 An Image Related to the Worksheet

The worksheet asks students to create fractions from rectangles with equal numerators and varying denominators, following the instructions. Students were able to create these fractions using sliders on a smartboard with the GeoGebra, and they were able to see the models they created. By adjusting the numerators and denominators as desired, they were able to see the corresponding models for the fractions they created. This allowed them to compare the fractions and then rank them. In short, this worksheet and GeoGebra material allow for both ordering and comparing fractions with equal numerators and different denominators.

In the study group, lessons were taught with a student-centered approach and a process that involved active student participation. GeoGebra-supported instruction was implemented using a smartboard under the supervision of the researcher. Some students were given the opportunity to stand up and use the software, ensuring active participation in the lesson.

At the end of the study, the students were re-administered the Fractions Achievement Test and the Attitude Towards Mathematics Scale (Önal, 2013). They also completed a written opinion form. They were given 40 minutes to respond the form.

Data Analysis

The study includes both quantitative and qualitative data. Quantitative data analysis involved the fractions achievement test and the attitudes towards mathematics scale. SPSS 28 software was used for quantitative data analysis. The aim of the quantitative part of the study is to determine the effect of GeoGebra-supported instruction on sixth-grade students' achievement in fractions and their attitudes towards mathematics. Therefore, descriptive statistics were first calculated for the pre-test and post-test scores of the Fractions Achievement Test and the attitudes towards mathematics (and its sub-dimensions). This was done to determine whether the data for both scales showed a normal distribution and to provide a descriptive overview of the overall situation. After determining normality, descriptive statistics were used to decide on the appropriate test. Descriptive statistics for the Fractions Achievement Test are presented in Table 3.

Table 3 Descriptive Statistics for Fractions Achievement Test Scores

Score	Min	Max	$\bar{X}$	ss	Skewness	Kurtosis
Pre-test	5	90	35.38	20.08	1.058	1.437
Post-test	10	95	52.40	21.42	0.092	-0.488

As seen in Table 3, students' pre-test scores ranged from 5 to 90. The mean pre-test score was 35.38, with a standard deviation of 20.08. Students' post-test scores ranged from 10 to 95, with a mean of 52.40 and a standard deviation of 21.42. The skewness and kurtosis values of the test scores were examined within the limits of -2 and +2 (George & Mallery, 2016), and it was determined that the distribution was normal for both types of scores. In addition, normality was also examined using Shapiro Wilk (Table 4).

Table 4 Shapiro Wilk Normality Test for Fractions Achievement Test

Scores	χ2	p
Pre-test	0.974	0.56
Post-test	0.982	0.752

According to Table 4, neither score was found to be statistically significant ($p>0.05$). Pre and post-test scores for mathematics achievement were normally distributed. Descriptive statistics for the Attitude Towards Mathematics Scale (Önal, 2013) are presented in Table 5.

Table 5 Descriptive Statistics for the Pre and Post-Test Scores of the Attitude Towards Mathematics Scale

Test	Dimensions	Min	Max	$\bar{X}$	ss	Skewness	Kurtosis
Pre-test	Interest	26	50	41.85	6.09	-0.571	-0.275
	Anxiety	5	25	16.30	5.97	-0.424	-0.666
	Study	10	20	17.33	2.97	-0.937	-0.17
	Necessity	8	15	13.05	1.92	-0.92	0.257
	Attidue	59	110	88.53	12.04	-0.188	-0.211
Post-Test	Interest	36	50	43.88	4.17	-0.057	-0.906
	Anxiety	6	25	17.80	5.36	-0.499	-0.503
	Study	15	20	18.45	1.52	-0.686	-0.457
	Necessity	10	15	14.18	1.26	-1.485	1.718
	Attidue	77	110	94.30	9.28	0.244	-0.959

The attitude toward mathematics scale scores and sub-scale scores were obtained by summing the items. Item scores were reverse-translated before obtaining item scores. Higher scores indicate higher overall attitudes toward mathematics, as well as higher levels of interest, study, and necessity, and lower levels of anxiety.

As seen in Table 5, general pre-test scores for attitude toward mathematics ranged from 59 to 110, with a mean of 88.53 (SD=12.04). Pre-test scores for the interest subscale ranged from 26 to 50, with a mean of 41.85 (SD=6.09); scores for the anxiety subscale ranged from 5 to 25, with a mean of 16.30 (SD=5.97); scores for the study subscale ranged from 10 to 20, with a mean of 17.33 (SD=2.97); and scores for the necessity subscale ranged from 8 to 15, with a mean of 13.05 (SD=1.92). The general post-test scores for attitudes towards mathematics ranged from 77 to 110, with a mean of 94.30 (sd=9.28). Post-test scores for the interest subscale ranged from 36 to 50, with a mean of 43.88 (sd=4.17); for the anxiety subscale, scores ranged from 6 to 25, with a mean of 17.80 (sd=5.36); for the study subscale, scores ranged from 15 to 20, with a mean of 18.45 (sd=1.52); and for the necessity subscale, scores ranged from 10 to 15, with a mean of 14.18 (sd=1.26). The skewness and kurtosis values of the pre and post-test scores for the general and all subscales of attitudes towards mathematics were examined within the limits of -2 and +2 (George & Mallery, 2016), and the distribution was determined to be normal for both score types. Additionally, the Shapiro Wilk test was used to for normality (Table 6).

Table 6 Shapiro Wilk Normality Test for Attitude Towards Mathematics Scale

Test	Dimensions	$\chi 2$	p
Pre-test	Interest	0.957	0.129
	Anxiety	0.962	0.317
	Study	0.978	0.473
	Necessity	0.968	0.341
	Attidue	0.981	0.736
Post-test	Interest	0.948	0.067
	Anxiety	0.949	0.071
	Sudy	0.969	0.35
	Necessity	0.946	0.057
	Attidue	0.953	0.094

If the Shapiro Wilk Normality Test result is statistically significant, the scores do not show a normal distribution (Pallant, 2007). According to Table 6, all scores were determined to be statistically non-significant ($p>0.05$). All pre and post-test scores of the scale were normally distributed. The dependent samples t-test, a parametric method, was used to compare pre and post-test scores in quantitative data. This method is used to compare two different continuous and normally distributed measurements within a single group (Pallant, 2017). Pallant (2007) stated that the effect size expresses how much of the variability in the dependent variable is explained by the independent variable. One of the frequently used effect size values is the $\eta 2$. The effect size of students' achievement post-test scores was examined, and the $\eta 2$ effect size value was used to determine the difference between the overall pre and post-test scores of attitude towards mathematics. Cohen (1992) stated that $\eta 2$ close to 0.14 indicates a large effect, close to 0.06 indicates a moderate effect, and close to 0.01 indicates a small effect. A significance level of $p<0.05$ was used for statistical analyses. The reliability analysis results for the attitude scale are presented in Table 7.

Table 7 Attitude Scale Reliability Results

Dimension/Sub-dimensions	Cronbach Alfa		Item number
	Pre-test	Post-test	
Attidue	0.866	0.906	22
Interest	0.811	0.89	10
Anxiety	0.854	0.761	5
Study	0.748	0.849	4
Necessity	0.732	0.835	3

Cronbach's alpha coefficient was used to assess the reliability of both pre-test and post-test measurements of attitudes toward mathematics and their subdimensions. As seen in Table 7, the reliability coefficient for the pretest of the attitude toward mathematics scale was 0.866, with subscales ranging from 0.732 to 0.854. The reliability coefficient for the post-test of the attitude toward mathematics scale was 0.906, with subscales ranging from 0.761 to 0.89. Since all reliability coefficients were above 0.70 and the reliability of both the pre-test and post-test measurements of attitudes toward mathematics and their subdimensions was high.

For analysing qualitative data content analysis was used. Content analysis can be viewed as a method for counting and identifying categories and codes in a text (Alanka, 2024). The researcher and two field education experts independently created codes based on student opinions according to the interview forms. In the analysis of student responses, codes were created and their frequencies were presented. Internal consistency was achieved when agreement between coders was at least 80% (Miles & Huberman, 1994; Patton, 2002). The agreement percentage for question 1 was 85%, for question 2 87%, and for question 3 81%. Additionally, excerpts from student opinions were presented to ensure transparency in the study.

Validity and Reliability

Validity and reliability are two concepts that emerge in scientific research as factors aimed at ensuring the credibility of the results (Yıldırım, 2010). Internal validity is defined as the clear relationship between observed variables, meaning that it is not caused by anything else (Fraenkel et al., 2012). In this study, the selection of the study group and the research processes were carefully planned to ensure internal validity. When selecting the study group, the classroom where the researcher teaches at the school was chosen. The aim here was to minimize the influence of different variables on the research process and to ensure that the variability originated solely from GeoGebra. One of the data collection tools was the Fractions Achievement Test. During the development of the test item difficulty and discrimination indices were calculated by administering it to 108 students before administering it to the study group (Table 1). Following expert opinions, some items were removed from the test. The final version of the test consists of 19 questions. Furthermore, the materials and worksheets used in the research were determined with expert opinions.

The reliability result for the Attitude towards Mathematics Scale (Önal, 2013) is presented in Table 7. Additionally, Önal (2013) conducted a factor analysis to determine the construct validity of the scale.

Finally, a form was created, shaped by expert opinions, to identify student opinions. Some student responses on the form were directly quoted and presented in the study. External validity in research relates to the generalizability of findings (Miles et al., 2014). To increase the external validity of the study, the aim was to ensure the generalizability of the research results. The free, easy-to-use, and understandable nature of the GeoGebra application used in the study facilitated its accessibility to everyone. To ensure the structural validity of the tools used in the study, opinions of experts were consulted during the test development process and were designed in accordance with the curriculum. The tests were designed to measure student achievement and attitudes towards mathematics. Experts agreed that the interview form was appropriate. The tests were administered under the same conditions before and after GeoGebra-supported instruction and repeated to reliably assess the impact of the intervention. The internal consistency of the mathematics attitude test used in the study indicates high reliability. This supports that the tests used in the study can provide reliable results. Communication with the research group was maintained throughout the research period.

Findings

This section includes findings about students' achievement and attitudes toward mathematics and student opinions.

Findings on the Effect of GeoGebra on Students' Achievement

Dependent samples t-test was used to determine the difference of the pre and post-test achievement scores and is presented in Table 8.

Table 8 Achievement Scores t-test Results

Scales	Group	N	$\bar{X}$	ss	$t_{(39)}$	p	η^2
Achievemet	Pre-test	40	35.38	20.08	-6.385	.000*	0.51
	Post-test	40	52.40	21.42			

*p<0.05; t: Dependent groups t-test statistic; η2: Eta squared effect size

As seen in Table 8, a statistically significant difference was found between the students' achievement pre and post-test scores ($t(39)=-6.385$, $p<0.05$). The η2 value, which indicates the magnitude of this difference, was 0.51, indicating a high level of effect. The post-test achievement scores were significantly higher than the pre-test.

Findings on the Effect of GeoGebra on Students' Attitudes Toward Mathematics

Dependent group t-test was used to determine the differences between pre and post-test scores and are shown in Table 9.

Table 9 Attitude Scores t-test Results

Scales	Group	N	$\bar{X}$	ss	$t_{(39)}$	p	η^2
Interest	Pre-test	40	41.85	6.09	-2.278	0.028*	0.12
	Post-test	40	43.88	4.17			
Anxiety	Pre-test	40	16.30	5.97	-2.289	0.028*	0.12
	Post-test	40	17.80	5.36			
Study	Pre-test	40	17.33	2.97	-3.29	0.002*	0.22
	Post-test	40	18.45	1.52			
Necessity	Pre-test	40	13.05	1.92	-3.6	0.001*	0.25
	Post-test	40	14.18	1.26			
Attidue	Pre-test	40	88.53	12.04	-4.266	.000*	0.32
	Post-test	40	94.30	9.28			

*$p<0.05$; t: Dependent groups t-test statistic; η2: Eta squared effect size

As seen in Table 9, a statistically significant difference was found on students' general pre and post-test scores for their attitudes toward mathematics ($t(39)=-4.266$, $p<0.05$). The difference between the pre and post-test scores for the subscales of attitude toward mathematics, interest ($t(39)=-2.278$, $p<0.05$), anxiety ($t(39)=-2.289$, $p<0.05$). Study ($t(39)=-3.29$, $p<0.05$), and necessity ($t(39)=-3.6$, $p<0.05$), was also significant. The η2 effect size for the difference between the test scores for general attitude toward mathematics was 0.32, indicating a significant effect. Similarly, the η2 value for the difference between the test scores for the interest subscale of attitude toward mathematics was 0.12, 0.12 for the anxiety subscale, 0.22 for the study subscale, and 0.25 for the necessity subscale, indicating a generally high effect across all subscales. Sixth-grade students' post-test scores for both the general and all subscale attitudes toward mathematics were higher than those for the pre-test.

Findings on Student Opinions Regarding GeoGebra-Supported Instruction

Findings obtained from student opinions are presented under three headings: advantages, disadvantages, and recommendations:

Findings regarding the advantages of teaching with GeoGebra-Supported Instruction

Data for this subscale were analyzed and presented in Table 10.

Table 10 Codes, Categories, and Frequencies Regarding the Advantages of Geogebra-Supported Instruction

Categories	Codes	f
Teaching process	Making the lesson fun	18
	Active participation	3
	Gamifying the lesson	3
	Question solving - practice	2
	Opportunity for reinforcement	1
	Visualization	1
	Being interesting	1
	Teaching lessons through activities	1
Teaching outcome	Better learning-understanding	19
	Making math / the subject enjoyable	9
	Increasing success	4
	Easier - better comprehension	3
	Solving questions easily/understanding/not struggling	2
	Retention	1

As seen in Table 10, students stated that they viewed "Better learning - understanding" (f=19) as the most advantageous option. This code was followed by "Making the lesson fun" (f=18). Another code with a high frequency was " Making math / the subject enjoyable " (f=9). Retention, Opportunity for reinforcement, Visualization, Being interesting, and Using Activities for the lesson all had equal frequency (f=1). Excerpts from students' opinions are presented:

"It helped us learn fractions better. It's like a very fun game" (S2/ Better learning-understanding/ Making the Lesson Fun / Gamifying the lesson).

"GeoGebra makes math fun and makes it more memorable. Because it makes math fun, I think many people who don't like it like it." (S5/ Making the Lesson Fun / Retention/ Making math -the subject enjoyable).

Findings regarding the disadvantages of teaching with GeoGebra-supported instruction

Data for this sub-problem were analyzed and presented in Table 11.

Table 11 Codes, Categories, and Frequencies Regarding the Disadvantages of Geogebra-Supported Instruction

Categories	Codes	f
Technical glitches	Not working properly or crashing	2
	Screen light strains eyes	1
	Difficulty opening the app	1
Other	No disadvantages	27
	Not exam-oriented	1

As seen in Table 11, the students most frequently answered no disadvantages (f=27). The answers not exam-oriented, difficulty opening the app, and Screen light strains eyes (f=1) were equally common. Excerpts from student opinions are presented:

"There are no disadvantages. On the contrary, there are many advantages" (S6/ No disadvantages).

"The application is difficult to open and can crash very easily" (S22/ Not working properly or crashing).

Findings Regarding Students' Suggestions

Data related to the sub-problem were analyzed and presented in Table 12.

Table 12 Codes and Frequencies Regarding Suggestions for a Better Understanding of the Topic

Categories	Codes	f
According to GeoGebra	Continuity of the GeoGebra	4
	Turning the GeoGebra into a game	4
	GeoGebra explaining the subject matter - being audio-based	3
Other teaching methods	Other software	3
	Use of models and materials	2
	Group work - Competition	1
Other	No suggestions	8
	More question solving	5
	Being a reinforcement tool	3
	Using smart board	3
	Calorfull worksheets	1
	Listening to the lesson quietly	1

As seen in Table 12, the students most frequently responded "No suggestions" (f=8). This was followed by More question solving (f=5). Excerpts from five students' opinions are presented:

"I think they could provide colored paper, just like the GeoGebra application. This way, the colors would help us understand more." (S10/Colorful worksheets).

"Everything was great, but if GeoGebra had a voice, we could understand it better because it would explain the topic when we did it." (S14/ GeoGebra explaining the subject matter - being audio-based).

Conclusions and Suggestions

This study, which aimed firstly to examine the effect of teaching fractions with GeoGebra support on student achievement, was conducted with a single class, and the change between pre and post-test scores was determined. According to the research results, the students' achievement post-test score average was significantly higher than the pre-test (Table 8). In general, it was observed that GeoGebra-supported teaching contributed positively to the teaching of fractions and made the learning environment more effective. This result can be explained by the integration of GeoGebra into the teaching process not merely as a presentation tool, but through constructivist activities that encourage active student participation. Students exploring fraction concepts through dynamic visualizations, engaging in trial and error, and constructing their own learning processes contributed to a deeper understanding of the subject. This, in turn, paved the way for students to grasp the topic more meaningfully and improve their academic achievement. GeoGebra is a learning environment that develops students' calculation skills and provides visualization in the topic of fractions (Prihandini et al., 2023). Furthermore, the literature indicates that GeoGebra's provision of discovery-based learning environments in fractions contributes to students solving fraction problems more effectively (Afiana & Andrijati, 2024). According to Romero-Albaladejo and García-López (2024), the constructiveness, navigability, and interactivity provided by GeoGebra cause a number of changes in students. For example, behaving flexibly and persistently in problem solving and realizing the importance of accuracy for making correct judgments are a few of these. These characteristics can be said to be the key mechanisms explaining the increased success achieved in this study. It is also believed that GeoGebra's dynamic nature contributes to increased achievement. This is because this feature, which is included in the materials and supported by the use of worksheets, allows students to practice more. However, students' ability to observe change, interpret it, make assumptions, and test those assumptions contributed to their achievement. This process has improved success by supporting students' conceptual learning. The research results are consistent with studies showing that GeoGebra enhances student achievement through features such as visualization, exploration capabilities, student-centered activities, and dynamism (Aşıcı, 2014; Dündar, 2015; Gürler, 2021; Kavas, 2021; Koç-Kök, 2024; Uygun, 2008; Ünlütürk Akçakın, 2016).

Statistically significant differences were found between the pre and post-test scores for students' attitudes toward mathematics in general and all sub-dimensions (Table 9). The anxiety sub-dimension items were reverse-coded; therefore, an increase in the anxiety sub-dimension indicates a decrease in anxiety. It was concluded that GeoGebra positively influenced students' attitudes toward mathematics. This change can be explained by the integration of GeoGebra into the teaching process through interactive and student-centered activities. The use of colorful and dynamic materials that appeal to students visually, their active participation in the lesson, their easier understanding of the subject matter, and their sense of accomplishment have been effective in developing positive attitudes towards mathematics. Furthermore, students' reduced anxiety stems from the dynamic nature of the materials, which allows for more trial and error experiences leading to correct answers. In general, there are studies showing that GeoGebra teaching contributes positively to mathematics lessons (Dankal, 2017; Molla, 2024; Topuz, 2017; Tuzer-Ünsal, 2018; Uzun, 2014). There are also studies indicating that technology-supported applications do not lead to a significant difference in attitudes towards mathematics (Dündar, 2015; Gürler, 2021; Koç-Kök, 2024; Uygun, 2008). The reasons why a positive change in attitude is not seen in every study may be related to contextual factors such as the way the technology is integrated, whether the implementation period is too short or too long, the characteristics of the materials, or the subject matter of the mathematics taught. While this study differs from these studies in terms of positively affecting students' attitudes toward mathematics, it is similar to studies where the attitude changed positively (Hensberry et al., 2015; Ipek & Yaman, 2021; Özdemir & Özçakır, 2019; Pilli & Aksu, 2013). Furthermore, this study is similar to the research showing that both attitude and success increase with GeoGebra (Salami & Spangenberg, 2024). This research shows that the change in students' attitudes towards mathematics is also supported by the students' opinions. When examining student opinions regarding the positive aspects of GeoGebra, students stated that GeoGebra instruction contributed most to better learning of the subject, making the lesson more enjoyable, increasing their interest in the subject, improving their success, helping them remember the subject, and making the lesson more interesting (Table 10). These statements indicate that affective (love, interest, enjoyment, motivation) and cognitive (ease of understanding, retention, achievement) factors work together to explain the increase in attitude scores. In line with these views, Topuz and

Birgin (2020) concluded in their study that teaching materials facilitate learning and strengthen visual mental imagery. Other contributions include relating the subject matter to daily life and enabling discovery through easier drawings. They stated that GeoGebra has benefits such as saving time in the learning process and enabling more accurate drawing (Yücel & Önal, 2023) and that they liked its learning acceleration features (Tuzer-Ünsal, 2018). Furthermore, similar studies have indicated that visual and dynamic elements increase retention (Orçanlı & Orçanlı, 2016) and are enjoyable (Kutluca & Zengin, 2011; Çelen, 2020). Additionally, Awaji (2022) stated that using GeoGebra requires less writing and drawing, facilitates learning through the using, and requires less effort. As a result, students enjoy the lessons and develop a positive attitude toward mathematics. The use of GeoGebra in fractions also ensures that students are more involved in the process and more eager to do calculations (Poon, 2018). It also allows for more visualization (Yao & Gan, 2024). Naidoo and Hajaree (2021) noted that students found the applications of technology in mathematics lessons enjoyable and interesting. The research results were consistent with similar student views in the literature. Indeed, these results demonstrate that GeoGebra's interactive, dynamic, and visualization capabilities enrich students' mathematics learning experience and positively support their attitudes towards mathematics.

When examining student opinions regarding the negative aspects of teaching methods, the responses given by students include the application being prone to malfunction, the application being difficult to open, the screen being tiring on the eyes, and the application not being exam-oriented (Table 11). Kutluca and Zengin (2011) also stated that students had difficulty using the input field. Topuz and Birgin (2020) concluded that teaching with GeoGebra was a waste of time for students. Again, studies have shown that there are technical problems and that the subject is taught more quickly using traditional methods. One of the limitations of GeoGebra, as identified by researchers, is the difficulty experienced by students and teachers with no previous programming experience when attempting certain commands on the input bar (Wassie & Zergaw, 2019). This study also encountered problems from time to time due to the school's technical infrastructure. Furthermore, students take an exam after middle school and are placed in high school based on their scores. For this exam, students may prefer existing methods that involve solving many problems. However, GeoGebra applications prioritize understanding and visualizing the subject matter rather than solving many problems. Therefore, it can be said that students expressed these aspects as negative points.

When examining students' suggestions regarding teaching methods, it was observed that most responded that they had no suggestions. This indicates that students are largely satisfied with GeoGebra-supported education (Bedada & Machaba, 2022). Among their responses, suggestions included more problem-solving and colored worksheets (Table 12). The fact that the GeoGebra application is colorful and the given worksheets are black and white has overshadowed the attention-grabbing feature of the worksheet. For this reason, it is recommended that the worksheet be colorful. This is because worksheets are an important factor in increasing student success (Keskin & Işık, 2024).

Based on the findings and conclusions of the research, the following suggestions are presented.

1. Based on GeoGebra's effect on increasing achievement in fractions, it is recommended that dynamic software be used more in different subjects to increase success in mathematics lessons.

2. Based on the research finding that GeoGebra positively changes attitudes toward mathematics, it is recommended to utilize GeoGebra in attitude development.

3. In line with student opinions, it is recommended to use dynamic software such as GeoGebra for its features that make the lesson more enjoyable and engaging.

4. It is recommended that preparatory work be carried out to improve students' technological skills.

5. It is recommended that similar studies be conducted in an environment with a small number of classes and a computer lab.

6. Since the research was conducted with a single group of 40 students, the findings are not highly generalizable to other situations. Therefore, it is recommended that future research be conducted with experimental and control groups.

7. Participants' views were evaluated in terms of advantages, disadvantages, and suggestions. It may be recommended to obtain more extensive information about the teaching method by increasing or diversifying the interview questions.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

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CRediT author statement

Author 1: Conceived and designed the study, collected and analysed the data, and wrote the original draft of the manuscript.

Author 2: Conceived and designed the study, participated in the entire research process, provided consulting services, contributed to data analysis, interpretation, literature review, and methodology, and supervised and guided the entire process.

Both authors have read and approved the final version of the manuscript.

Research involving Human Participants and/or Animals

Ethical approval for this study was granted by the Social and Human Sciences Ethics Committee of Kafkas University on October 6, 2023 (Meeting No. 50, Decision No. 11), following the official letter of the Directorate of the Institute of Science dated September 29, 2023 (No. E-35069).

Kesirler Konusunda GeoGebra Destekli Öğretimin Başarı, Tutum ve Öğrenci Görüşlerine Etkisi

Özet:

Araştırmada GeoGebra destekli öğretimin kesirler konusunda öğrenci başarı ve matematiğe yönelik tutumuna etkisi incelenmiştir. Ayrıca öğrenci görüşlerini değerlendirmek de amaçlanmıştır. Araştırmanın nicel kısmında tek gruba uygulanan zayıf deneysel desenle başarıya ve tutuma ilişkin değişim tespit edilmiştir. Nitel kısımda ise öğrenci görüşleri incelenmiştir. Araştırmanın örneklemi Kars il merkezindeki bir devlet ortaokulu altıncı sınıfta öğrenim gören 40 öğrencidir. Araştırma 20 ders saati sürmüştür. Nicel veriler kesirler başarı testi ve Matematiğe Yönelik Tutum Ölçeği (Önal, 2013), nitel veriler yarı yapılandırılmış görüşme formları ile toplanmıştır. Nicel veri analizinde t testi, nitel veri analizinde içerik analizi kullanılmıştır. Sonuçta GeoGebra destekli öğretimin öğrenci başarısını ve tutumunu artırmada etkili olduğu bulunmuştur. Ayrıca öğrencilerin çoğunluğunun GeoGebra ile konuyu daha iyi anlama ve dersin eğlenceli olmasını avantaj olarak gördükleri tespit edilmiştir. Çoğu öğrencinin dezavantaj belirtmediğini ve daha fazla soru çözümünü öneri olarak sundukları belirlenmiştir.

Anahtar kelimeler: Kesirler, GeoGebra, akademik başarı, matematiğe yönelik tutum, öğrenci görüşleri.

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