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Investigation of studies on fraction teaching in primary school

Dilek ERDOĞAN[1*] Enver ÖZKAN[2] Nesibe ÖZKAN[3]

[1]Assistant Principal of Secondary School, Ministry of National Education, İzmir, Türkiye.
[2]Primary School Principal, Ministry of National Education, İzmir, Türkiye.
[3]Nurse of Education, Ministry of Health, İzmir, Türkiye

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Abstract

This study aimed to examine articles and theses written on 'Fraction Instruction in Primary School' and determine the overall state of these studies. Studies conducted within the framework of this purpose were examined according to the year they were published, their types, the distribution of participants at the class level, research methods, and topics. In this study, the document analysis method was used, a qualitative research method. Sixty studies were examined, which were determined according to criteria such as the study context being Turkey, the studies conducted with primary school students, and the fact that fraction teaching was at the centre of the studies. These studies consisted of 25 articles, 28 master's theses, and seven doctoral theses when examined according to their types between 2002 and 2022. The distribution of these studies according to the years in which they were published revealed that the highest number of studies was conducted in 2019. It was concluded that most of the studies were conducted with fourth graders. Quantitative research methods have been predominantly used in most studies, followed by qualitative research methods and, to a lesser extent, mixed research methods. In terms of topic, most studies have focused on determining the effects of instructional practises and methods on fraction learning achievement. There has also been a concentration on the topics of 'Students' Representations and Modelling in Fraction Instruction' and 'Students' Conceptual Misconceptions and Learning Difficulties in Fraction Instruction.' It is believed that this research will be valuable in identifying existing gaps and proposing innovative solutions for future studies in this area.

1 Introduction

Technology has become a focal point in several aspects of our lives. Even during the pandemic, education continued with the help of technology, highlighting the importance of science. Mathematics in particular has gained increasing significance in the modern world. Mathematics, which has become a part of daily life, is a discipline that facilitates life. The foundation of technology is built on logical thinking skills and the development of logical thinking is based on mathematics.

Mathematics: 'The common name of science that examines the properties of quantities based on numbers and measures, such as arithmetic, algebra, and geometry, is riyaziye (Turkish Language Institution [TLI], 2020). Mathematics is a way of reasoning and thinking with calculation and

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*Correspondency: dilekerdo@gmail.com

measurement techniques that use the concept of numbers (Pesen, 2021, p. 2). According to Altun (2006), 'mathematics' is defined as 'an abstracted form of life.' The purpose of teaching mathematics is to enable individuals to gain skills in research, problem-solving, and critical perspective development.

The importance of mathematics in our educational system has increased daily. Our educational system aims to cultivate people with integrated knowledge, skills, and competencies. At both national and international levels, competencies that encompass a variety of skills required in personal, social, academic and professional life have been defined within the Turkish Competencies Framework (TCF). Eight key competencies were determined in the TCF: 'Communication in the mother tongue, communication in foreign languages, mathematical competence and competencies in science / technology, digital competency, learning to learn, social and citizenship competencies, taking initiative and entrepreneurialism, cultural awareness and expression'. One of these competencies is 'mathematical competency', which consists of developing a mathematical thinking style to solve a series of problems encountered in daily life and practise [Ministry of National Education (MoNE), 2018]. The Mathematics Curriculum was changed in 2013 as a requirement of the 4+4+4 education model in our country, and was updated with the last change made in 2018 and took its current form. Examining the general objectives of the mathematics curriculum aims to educate students who develop mathematical literacy skills. Within the framework of these objectives, the Primary School Mathematics Curriculum comprises four learning domains: numbers and operations, geometry, measurement, and data-handling. While all learning domains are covered at each grade level, certain sub-domains are introduced in specific grades (MoNE, 2018). Many mathematical concepts have emerged due to the need to solve everyday problems faced by people. 'Numbers,' the first concept to appear in mathematics, were used to indicate multiplicities. These numbers, which correspond to natural numbers from a formal perspective, have been used for a long time, but have proved insufficient to address problems encountered in daily life as knowledge progressed. This has led to the emergence of fractions and, subsequently, rational numbers with the expansion of fractions (Acar, 2010).

Fractions are given as a sub-domain within the number and operations learning domain of the mathematics curriculum. The curriculum follows a spiral approach in which new achievements are added each year, building on the previous year.

When the primary school mathematics programme is examined, by starting with 'whole and half fractions' in the 1st grade in the fraction sub-learning area, awareness is created in the students. In the 2nd grade, 'the relationship between the whole and half and the quarter' is emphasised. In the third grade, the division operation focusses on the concepts of 'part-whole relationship' and 'unit fraction.' In the 4th grade, definitions of 'simple, compound, and integer fraction' are defined. It aims to solve appropriate problems by adding and subtracting the denominators with equal fractions. As is understood, the concept of 'fraction' in formal education is one of the concepts that are aimed to be taught from the first grade. Since mathematical knowledge and skills develop from the basic level to the upper level, incomplete learning in the behaviours aimed at the student in this period will also make it difficult for him to understand mathematics at the next level (Ukdem, 2021).

In our country, many students worry that mathematics is difficult, that they cannot succeed in mathematics, and develop negative attitudes toward mathematics (Batdal, 2006). Behaviours, students' attitudes toward mathematics lessons, and the content of mathematics lessons. Ertem

(2018) determined that the factors that cause fear in mathematics lessons are society, family, school, classroom environment, students' cognitive level, teachers' behaviors, students' attitudes towards mathematics lessons, and the content of mathematics lessons. Negative attitudes and beliefs about mathematics increase mathematics anxiety (Baloğlu, 2001). The Ministry of National Education started the Mathematics Mobilisation in 2022 to popularise mathematics, and it continues to support it with digital materials at https://matematik.eba.gov.tr/ by carrying out studies to make mathematics the students' favourite subject and to transfer mathematics to students' daily lives.

Many researchers have stated that fractions are one of the richest, most complex, and difficult subjects in the primary school mathematics curriculum (Alacaci, 2015, p.63; Behr et al., 1983, p.91; Behr et al., 1984, p.323; Bulgar, 2003, p.319; Cramer et al., 2002, p.111; Hasemann, 1981, p.71; McNulty et al., 2011, p.282; Olkun, Toluk-Uçar, 2014, p. 131; Siebert, Gaskin, 2006, p.394; Smith, 2002, p.3, cited by Kamacı, 2021).

The concept of 'fraction' is one of the first abstract concepts that primary school students encounter in maths lessons (Pesen, 2007). It is not easy for primary school students to construct mathematical symbols consisting of abstract concepts in their minds and use them in their daily lives, as they are in the concrete operational stage. Because the mental development of individuals ranges from concrete to abstract, it is difficult to directly perceive mathematical concepts. Students always understand concrete more easily than their abstracts. For example, students begin learning mathematics using gamified real-life situations, concrete objects, and visuals, and then move on to using mathematical symbols (Olkun et al., 2006, p.11).

Due to the abstract nature of the fraction concept, studies show that 'fraction' causes students to have difficulty learning this concept (Ardahan & Ersoy, 2002; Ersoy & Ardahan, 2003; Haser & Ubuz, 2002; Işık & Kar, 2012). It is very important to understand the concept of fraction well, since it is at the top of abstract topics in primary school mathematics lessons. The correct method preferred in teaching the concept of 'fraction', which is among the abstract concepts in the primary school curriculum, positively affects future mathematics achievement of the student (Şiap & Duru, 2010).

Apart from being an abstract concept, it is frequently stated in the literature that fractions are difficult and complex. Orhun (2007); He stated that the subject of fractions is a difficult subject for students to order and add fractions with unequal denominators, multiplying a fraction by an integer, making too many mistakes in finding a fraction that is visually equivalent to a fraction, and difficulties in expressing visual concepts formally. Fraction: Since it is interpreted with different concepts, such as part-whole, measurement, division, processor, and ratio, students have difficulty in learning among the subjects. (Charalambous & Pitta-Pantazi, 2005; Doğan & Işık-Tertemiz, 2020; Hansen, 2014; Lamon, 1999; Yenilmez & Ev-Çimen, 2019, cited by Divrik & Pilten, 2021). The subject of fractions was difficult for the students to grasp. One of the reasons why it is difficult to understand is that fractions do not have much place in students' daily lives. The permanence of the learnt information is directly proportional to its use in daily life. Information learnt about fractions is forgotten in a short time, as it is not used much in students' daily lives (Albayrak, 2000, cited by Kocaoğlu & Yenilmez, 2010).

It is not possible for students to progress in mathematics and take more advanced courses without understanding the nature of the fractions (ESRC, 2006 as cited by Yiğit 2008).

Understanding and using fractions correctly increases the level of mathematical competency and facilitates the understanding of advanced mathematics topics. Studies in fraction teaching help develop effective strategies to help students better understand and successfully use fractions. This increases student achievement. Fractions are an essential part of maths learning and can present challenges to many students.

Fractions have become an important field research in recent years as a result of the incomprehension of fractions by students, and it can be seen that many studies on this subject are examined in the literature (Akman, 2019; Altay, 2017; Bunar, 2011; Çelebioğlu, 2017; Divrik, 2021; Işık & Kar, 2015; Kazak, 2012; Okur & Çakmak, 2016; Özer, 2018, Ukdem, 2021).

Fraction teaching studies have evaluated and improved the effectiveness of various teaching approaches. Research on the development of new teaching strategies, materials, and methods offers teachers the opportunity to teach fractions more effectively. This helps to improve teaching processes and increases student success. Studies on fractions help reveal connections that allow students to better understand mathematical concepts. This contributed to the development of a conceptual understanding of mathematics. Methods and materials based on scientific research were used to improve teachers' knowledge and skills in teaching fractions. This helps teachers teach fractions more effectively.

However, no studies have been conducted on fractional teaching. This study aimed to determine the general status of studies in this field by examining articles and theses written on ' teaching fractions in primary schools'.

The contributions of this study to the literature are as follows:

Bringing together and analyzing the existing research in the field of fraction teaching in primary schools provides an overview of the work done in this field and is thought to provide an idea for new research on this subject.

It is thought that this study can determine which methods and subjects are prioritised in research in the field of fraction teaching in primary schools by examining the research conducted according to different publication years, study types, class levels of participants, research methods and topics.

A comprehensive review of research in the field of fraction teaching in primary schools can be an important resource for educators and education administrators. It is believed that this study can provide an idea to teachers, students, and other stakeholders about different research approaches and issues related to fraction teaching.

Providing an overview of research in the field of fraction teaching in primary schools can help identify current knowledge deficiencies in this area and the priorities for future research. This study will contribute to more comprehensive, reliable and effective research in the field of fractional teaching in primary schools. In addition, it is believed that it will draw attention to fraction teaching and contribute to the Mathematics Mobilisation Project initiated by the Ministry of National Education in 2022.

1.1 Aim of the research

The aim of this study is to evaluate articles and theses published in the field of fraction teaching in primary schools in terms of thematic, methodological and statistical analysis techniques and to shed light on future academic studies on this subject. Accordingly,

- What is the distribution of studies published on Fraction Teaching in Primary School between 2002-2022 according to their types and years?
- What is the distribution of studies published on Fraction Teaching in Primary School between 2002-2022 according to study groups (class levels)?
- What is the distribution of studies published on fraction teaching in primary school between 2002-2022 according to their methods?
- What is the distribution of studies published on Fraction Teaching in Primary School between 2002-2022 according to their subjects? The answers to these questions were also sought.

2 Method

This section describes the research design, study group, data collection tool, data collection, and data analysis.

2.1 Research design

This study used a qualitative research method. Data were collected by document analysis, which is a qualitative research method. Document analysis includes the analysis of written materials that contain information on cases targeted for investigation (Yıldırım & Şimşek, 2016).

2.2 Research documents

This study examines studies on fraction teaching in primary schools in the context of Türkiye. To determine the studies to be analysed, the researchers determined three basic criteria in accordance with the objectives of the study and these conditions are stated below;

1. Studies should be conducted in the context of Turkey, which means that the sample consists of research conducted in Turkey.
2. Studies should be conducted with primary school students.
3. The central focus of these studies is fraction instruction.

Data for the research were obtained from sources with full text access on the Web, including theses available at the National Thesis Centre between 2002 and 2022, the National Union Catalogue (TOKAT), the TR-Index, Ulakbim Discovery, and articles published in journals on Dergipark. The search was carried out using the keywords ‘primary school,’ ‘fraction instruction,’ and ‘fractions.’

As a result of the necessary examinations, 60 studies were found, including seven doctoral dissertations, 28 master’s theses, and 25 articles. Among the examined theses, four have also been published as articles, and out of the 25 articles, 21 are original research papers, while one article is an article study to develop a curriculum in the field of master’s thesis. Four of these five articles were included in the data at the research type and publication year stage, but were not included in the other data. Appendix 1 provides the journals in which the articles were published and the universities in which thesis were conducted.

2.3 Data collection

‘The Publication Classification Form’ was used to analyse the theses and articles included in the research. This form was adapted from the studies of Sözbilir et al. (2012) in line with the purpose of the research. The Publication Classification Form, designed to encompass all research conducted on Fraction Teaching in Primary Schools in Turkey, has undergone some

modifications. The form examines the research under four main headings to reveal the type of research and year of publication, grade levels of the sample used in the research, methodology employed in the research, and topics covered in the studies.

2.4 Data analysis

In this study, descriptive and content techniques were used to analyse the data. Content analysis aims to link concepts and relationships so that data can be explained. The data are conceptualised first and then organised logically according to emerging concepts, thus identifying the themes that explain the data. In descriptive analysis, summarised and interpreted data are processed in more detail for content analysis, and concepts and themes that cannot be noticed as a result of the analysis can be determined using a descriptive approach (Yıldırım & Şimşek, 2016). Therefore, it was deemed appropriate to use descriptive and content analyses together in the research. The data obtained using the descriptive analysis method were classified and interpreted according to predetermined themes. The four sub-dimensions, namely, themes for the examination of theses and articles, were determined in advance by the researchers, and based on these themes, questions were prepared. The themes included the type of research, year of publication, grade levels of the sample used in the research, the research methodology used, and the subject matter of the research. The process of analysing and interpreting theses and articles was carried out in three stages: (1) naming, coding, extraction and category development; (2) validity and reliability; and (3) reporting.

During the process of labelling, coding, deducting, and developing categories, the following points were considered important.

During the coding process, based on the type of research and year of publication, the distribution of studies conducted in the form of Doctoral Theses, Master's Theses, and Articles were coded according to their publication years and types. After confirming the distribution of these studies in terms of their types by three researchers conducted between 2002 and 2022, an analysis of the distribution is presented.

While coding according to the Class Level of the Sample; With the transition from the Ministry of National Education to the 4+4+4 system, primary school classes were formed from the 1st, 2nd, 3rd, and 4th grades in the 2012-2013 academic year. Studies conducted in the 1st, 2nd, 3rd, 4th and 5th grade levels before the 2012-2013 academic year and studies conducted in the 1st, 2nd, 3rd, and 4th grade levels of primary school after the 2012-2013 academic year were included in the research. The studies were grouped and coded as follows: 1st grade, 2nd grade, 3rd grade, 4th grade, 5th grade, Combined and other classes. The 'Other Classes' category includes studies conducted simultaneously at multiple class levels.

When coding according to the Research Method, the methods used in the examined studies were categorised into three main headings: (1) quantitative method, (2) qualitative method, and (3) mixed method. When coding according to the research method, if the researcher explicitly stated the method used in the study, it was considered as indicated. If the researcher did not specify the method, the decision on the method was based on the overall content of the study. When coding according to the Research Topics, based on the literature review, the studies were categorised into seven main topics and coded accordingly.

1. The effect of practise and method on the success of fraction learning
2. Determining the relationships between learning achievement and fraction teaching

3. Representations and models used by students in fraction teaching
4. Errors made by students in fraction teaching
5. Conceptual misconceptions of students in fraction teaching
6. Learning difficulties in fraction teaching
7. Other

2.5 Validity and reliability

The member control process was conducted by the researchers to determine the internal validity criterion of the study. It should be revealed whether the studies carried out by the member control process are categorised correctly and systematically and whether there is a repetitive source (Cohen et al., 2007:107). In this study, the data analysis was conducted simultaneously by three researchers. During the analysis process, the data were first coded and categorised, and then the main themes were determined by examining the relationships between the emerging categories. Three researchers evaluated duplicate sources. Regular communication was maintained throughout the analysis process to ensure an accurate interpretation of the data by comparing and discussing the findings. This increased the reliability and validity of the results.

The data obtained through the Publication Classification Form adapted for theses and articles were recorded, and these data were analysed with frequency and percentage using Excel. The findings obtained from this study were interpreted on the basis of data in the literature.

3 Findings

Data obtained from all examinations and analyses are presented in subheadings, including type of research and publication year, distribution according to study groups (class level of the sample), research methods and research topics.

3.1 Type of research and year published

This research aimed to answer the question 'How is the distribution of studies published on fraction teaching in primary school between 2002-2022 according to their types and years?'. The distribution of the doctoral theses, master's theses, and article studies examined according to the years in which they were published and their types is presented in Table 1.

Table 1 Distribution of studies by years and types of publication

Year	Doctoral dissertation	Master's thesis	Article	Total
2002	0	0	1	1
2003	0	2	0	2
2004	0	0	1	1
2005	0	1	1	2
2006	0	1	0	1
2007	1	0	2	3
2008	0	4	1	5
2009	0	2	0	2
2010	1	0	4	5
2011	0	1	0	1
2012	0	1	0	1
2013	0	1	1	2
2014	2	4	1	7
2015	0	1	2	3

2016	0	0	0	0
2017	0	1	3	4
2018	1	1	1	3
2019	2	5	2	9
2020	0	0	0	0
2021	0	2	2	4
2022	0	1	3	4
Total	7	28	25	60
%	11.667	46.667	41.667	100

When the types of research published between 2002-2022 are examined in Table 1, it is seen that it consists of 25 articles, 28 master's theses, and seven doctoral theses. However, since the articles of four of the Master's theses were published, the number of original articles was 21. When the distribution of the studies by year was examined, it was seen that while there were no studies in 2016 and 2020, most publications were published in 2019, followed by 2014, 2010 and 2008, respectively. While 26 studies have been published since 2002, including the 2012-2013 academic year, 34 studies have been published after 2013.

3.2 Grade level of the sample

The research was aimed at answering the question 'How is the distribution of studies published on fraction teaching in primary school between 2002 and 2022 according to study groups (class levels)?' The grade levels of the students in the research sample are presented in Figure 2. In some of the studies analysed in this research, more than one class group was studied. In this study, frequency increments were performed separately for each grade level. For example, if a study was about 3rd, 4th, and 5th grade students, all three of the 3rd, 4th and 5th grade frequencies increased in this study. If a different study was related to fourth and eighth grade students, only a part of the study related to this research (4th grade) was conducted. Therefore, the number of studies in Table 2 may have differed from the number of studies analysed. However, studies conducted in combined grade levels were not included in the frequencies of other grade levels.

Table 2 Distribution of participants in research by class levels

Class-level	**n**	**%**
1st grade	0	0
2nd grade	0	0
3rd grade	6	9.52
4th grade	36	57.14
5th grade	15	23.8
Combined classes	1	1.6
Other classes	5	7.94
Total	63	100

When examining Table 2, it can be observed that most of the studies were conducted with students in the 4th grade (57.14%), while no studies were found for the 1st and 2nd grade levels between 2002 and 2022. Studies conducted with students in the 5th grade (23.8%) outnumbered studies conducted with students in the 3rd grade (9.52%). This suggests that there is a higher concentration of research at the fourth grade level since 'Fraction Teaching in Primary School' is higher at the fourth grade level in terms of subject density.

3.3 Research method

'How is the distribution of studies published on fraction teaching in primary schools between 2002-2022 according to their methods?' An answer was sought, and the findings were grouped through the 'Publication Classification Form' used as a data collection tool. In the methods section of the form, the studies were classified as quantitative, qualitative, or mixed. The methods used in these studies are listed in Table 3.

Table 3 Distribution of studies by method

Methods	n	%
Quantitative research	35	62.5
Qualitative research	13	23.21
Mixed research	8	14.29
Total	56	100

As shown in Table 3, 35 of the 56 analysed studies (62.5%) used quantitative research methods, 13 (23.21%) used qualitative research methods and eight (14.29%) used mixed research methods. The experimental design was used primarily in studies that used quantitative research methods. Both qualitative and quantitative research methods have been used in studies that have used mixed research methods. In one of these studies, a mixed research method was used, a quasi-experimental design was used as a quantitative method, case analysis was used as a qualitative method, an embedded mixed method was used in three studies, a design of a parallel convergent mixed research method was used in one study, a cross-sectional design was used as a quantitative method in one study, and semistructured interviews were used as a qualitative method. In one study, a weak experimental design was used as a quantitative method, an interview technique was used as a qualitative method, and a mixed-variation method was used in one study; In this context, the content analysis method, the case study, and the clinical interview technique were used. When examining Figure 3, it can be observed that the quantitative research method was predominantly used in the studies conducted on fraction teaching in primary schools in Turkey between 2002 and 2022, while the mixed research method was used the least.

3.4 Research topics

An answer was sought for the question 'How is the distribution of studies published on fraction teaching in primary schools between 2002-2022 according to their subjects?' While the studies examined were categorised and coded according to their subjects, if the target included more than one subject area, the frequency increased for each category. Therefore, the total number in the table and the total number of studies differed. The distribution of the studies according to subjects is presented in Table 4.

Table 4 Distribution of studies by subject

Subject	n	%
The effect of practise and method on the success of fraction learning	30	49.18
Determining the relationships with fraction learning achievement	3	4.92
Representations and models used by students in fraction teaching	7	11.47
Errors made by students in fraction teaching	4	6.56
Conceptual misconceptions of students in fraction teaching	9	14.75
Learning difficulties in fraction teaching	5	8.2
Others	3	4.92
Total	61	100

In Table 4, when studies on fraction teaching in primary schools in Turkey between the years 2002-2022 are examined within the subject framework, 30 (49.18%) of the studies are 'The effect of practise and method on the success of fraction learning'. In the analysed studies, it was observed that of the total, nine studies (14.75%) focused on concept misconceptions, seven studies (11.47%) explored the use of representations and modelling by students in fraction teaching, five studies (8.2%) investigated learning difficulties in fraction teaching, four studies (6.56%) examined the errors made by students in fraction teaching, three studies (4.92%) aimed to determine the relationship between learning achievement and fraction teaching, and three studies (4.92%) covered other topics related to fraction teaching.

In three of the thesis articles examined, the determination of relationships with fractional learning success was examined. Orhun (2007) examined students' success in fractions according to gender in terms of formal arithmetic and visualisation. Çetin and Çite (2022) examined the senses of fraction numbers in terms of gender, school starting age, preschool education period, and the type of games played by children, while Özkan (2009) investigated the perceived importance of mathematics learning outcomes and the level of achievement of these outcomes.

In seven of the thesis articles examined, students' use of representation and modelling in fraction teaching was investigated. Şiap and Duru (2004) investigated the ability to use geometric models in fractions; Tabak et al. (2010) tried to determine modelling skills in fractions; Ertuna (2013) tried to determine the level of students' ability to associate symbolic and graphical representations of equivalent fractions; Kamacı (2021) conducted research on students' representations and modelling performance related to different types of fractions and unit fractions; Kayhan (2010) conducted research on determining mental models while converting fraction types; Kılıç and Özdaş (2010) investigated what kind of representations they use in ordering and comparing fractions; Yurtbakan and İskenderoğlu (2022) studied the determination of modelling situations in students' analysis of fractions. When examining these studies, it was found that primary school students have low achievement in number line modelling in the context of fractions, struggle with learning, and are more successful in modelling squares and rectangles from geometric shapes.

Four of these studies investigated the errors made by students in teaching fractions (Divrik & Pilten, 2021; Kocaoğlu & Yenilmez, 2010; Önal & Yorulmaz, 2017; Yurtseven, 2012). When these studies are examined, it is seen that they frequently make mistakes in fractions in primary school, dividing the whole into equal parts; they operate like natural numbers when sorting fractions, adding the numerator and denominator in the same fraction, and writing them as natural numbers; in the subtraction process, they consider the numerator and denominator separately and subtract the smaller number from the larger number, not being able to establish a part-whole relationship in determining the unit fraction, not knowing the difference between the unit fraction and the number of fractions, and making mistakes while writing the fraction number, reading it, and drawing the model; they are unable to establish a conceptual relationship between the shaded part and the whole part, making mistakes in dividing the shaded part into the unscanned part.

Nine of these studies examined misconceptions in fraction teaching (Biber et al., 2013; Epcacan & Ay, 2019; İnce, 2008; Kocaoğlu & Yenilmez, 2010; Pesen, 2007; Pesen, 2008; Şengül, 2005; Uslu, 2006; Yurtsever, 2012).When these studies are examined, it is found that primary school students have misconceptions about the concepts of ordering, addition, subtraction, and multiplication of fractions, they add or subtract without considering denominator equality while doing addition-subtraction, they have misconceptions when representing fractions on a number line and they

make errors when writing the numerical value of a fraction on the number line, they often fall into the misconception of substituting the numerator and denominator interchangeably when finding the whole amount of a known fraction of a quantity, they have a tendency to perceive the numerator and denominator of the exact symbolic representation a/b as separate numbers, even though they are part of the same fraction, they have errors in the symbolic and model representations of verbal expressions in the reading of fraction numbers and in dividing the whole into equal parts; they have misconceptions when converting given fractions into decimal fractions, writing the equality of decimal fractions, and writing the comparison of decimal fractions in terms of magnitude.

Between 2002-2022, five studies were identified on the learning difficulties encountered in fraction teaching in primary schools. Among these studies, Epcacan and Ay (2019) examined learning difficulties and misconceptions about fractions; Haser and Ubuz (2002) examined the learning difficulties of students while using their knowledge and skills regarding fractions in conceptual and operational situations; Pesen (2007) and Pesen (2008) investigated learning difficulties, common mistakes, and misconceptions in the representation of fractions on the number line; and Soylu and Soylu (2005) investigated learning difficulties in fraction addition, subtraction, multiplication, ordering, and fraction problems. When these studies are examined, it is seen that students have difficulty in understanding the meaning of the fraction; they have difficulty in showing the verbal expression with the fraction symbol and showing the integer fraction shown by the models with the symbol; they tend to continue the operation habits they have acquired in natural numbers in multiplication, addition, and subtraction operations in fractions; they have difficulty establishing a connection between division operations and fractions; they struggle to perceive the symbolic representation of a/b as a single number on the number line; and they have difficulty partitioning fractions into equal parts, understanding the concept of equivalence, and ordering fractions with different denominators. They struggled to apply the previously learnt rules to new rules concerning fractions. They face challenges in understanding fractional problems and determining the correct operations and order of operations.

When we look at studies on fraction teaching in primary schools in Turkey between 2002 and 2022, it is seen that the subject most studied is 'The effect of the practise and method on the success of fraction learning.' In 7 of these 30 studies, the effect of practise and method on the success of fraction learning, as well as the effect on attitude, and in 1, the effect on motivation was investigated. The methods and applications in which the effects of the application and method on the success of fraction learning were analysed are presented in Table 5.

Table 5 Distribution of methods and applications that examine the effects of applications and methods in research on fraction success

Methods and applications	**n**	**%**
Realistic mathematics education	6	20
Computer-assisted instruction	6	20
Drama	2	6.67
Solved examples method	2	6.67
Cooperative teaching	1	3.33
Concept cartoons	1	3.33
Visual material	1	3.33
Teaching with music and stories	1	3.33
Game-supported teaching approach	1	3.33

Scenario-based learning approach	1	3.33
Using concrete and virtual manipulatives	1	3.33
Inquiry-based teaching approach	1	3.33
Supplementary resource usage	1	3.33
3B printers	1	3.33
Instruction supported by a mobile application	1	3.33
Programmed instruction	1	3.33
Computer-supported collaborative learning cluster-assisted individualization technique	1	3.33
Total	30	100

When examining Table 5, it is observed that in the studies analysing the effect of implemented methods and practises on fraction achievement, the following methods and practises were investigated: Realistic Mathematics Education Method in six studies (20%), Computer-Assisted Instruction in six studies (20%), Drama in two studies (6.67%), and Solved Examples Method in two studies (6.67%).In each of the other 14 studies (3,333%), cooperative teaching, concept cartoons, visual material, teaching with music and stories, game-supported teaching, project-based learning approach, scenario-based learning approach, concrete and virtual manipulatives, inquiry-based teaching approach, supplementary resource usage, 3D printers, mobile application-supported instruction and programmed instruction, and cluster-assisted individualized technique were used.

In the context of the subjects, three studies were identified under the title of 'other' subjects from the theses and articles examined between 2002-2022, and İncebacak and Bal (2019) aimed to develop a lesson plan suitable for inquiry-based teaching methods. Özçakır and Sümen (2022) examined students' mental structures in fractions, whereas Özer (2018) examined examples and exercises on fractions in primary school mathematics textbooks.

4 Discussion, conclusion, and recommendations

This research was carried out in order to analyse the previous articles and theses about 'Examination of Studies on Teaching Fractions in Primary School' and to determine the general status of these studies.60 studies covering the years 2002-2022 were reached. These studies consisted of 25 articles, 28 master's theses, and 7 doctoral theses. When examining the distribution of research by year, most publications are seen to have been published in 2019, followed by 2014, 2010, and 2008, and no studies were found in 2016 and 2020. Since our country entered the pandemic process in 2020 and switched to distance education, there has been no study on fraction teaching. A total of 27 studies were published, including the academic year 2012-2013. Subsequently, 34 studies were published, indicating an increase in the number of studies on this subject. This increase in research activity and interest is attributed to the change in mathematics curriculum due to the transition of the Ministry of National Education to the 4 +4 +4 educational system. Although there has been an increase in research, it is believed that current studies are still insufficient. It is important to show more interest in the subject, encourage researchers willing to conduct new research, and allocate more resources to further studies. In doing so, it is believed that it would be beneficial for fraction teaching and contribute to a better understanding of the topic.

It was observed that there were relatively fewer doctoral theses than master's theses in the investigated studies. A review of the literature reveals several similar studies supporting this

finding (Albayrak & Çiltaş, 2017; Aykan & Çalışkan, 2022; Sevencan, 2019; Yazıcıoğlu & Genç, 2021; Toptaş & Gözel, 2018). This is thought to be due to the small number of doctoral students and the comprehensive and time-consuming nature of writing doctoral theses.

Between 2002 and 2022, in the studies conducted on 'fraction instruction in primary schools in Turkey,' the most commonly used research method was quantitative research, while the least used method was mixed methods research. This finding is consistent with several similar studies found in the literature (Çiltaş et al., 2012; Coşkun et al., 2014; Kabaca & Erdoğan, 2017; Yaşar & Papatğa, 2015; Ulutaş & Ubuz, 2008). It is less preferred because it is difficult and time consuming to use both qualitative and quantitative methods together in a mixed method. Çiltaş et al., (2012), in their study, concluded that there are a very limited number of studies using mixed methods in mathematics education research in our country, and it is believed that by giving more place to the mixed method in research, new studies and results on fraction teaching will shed more light on.

Between 2002 and 2022, in terms of grade levels of samples in studies on fraction instruction, it was observed that most studies were conducted with fourth-grade students. No studies were found for the 1st and 2nd grade levels and only one study was found for the combined grade level. Studies conducted with fifth-grade students are more numerous than those conducted with third-grade students. This is likely because fraction instruction tends to start intensively in the fourth grade, leading to a concentration of research on this grade level. Kılıçkaya and Toptaş (2017) support this finding in their study of problem-solving. Additionally, research is believed to follow the trend of placing less emphasis on fractional topics as the grade level decreases. Although operations with fractions are more concentrated in the 4th grade, fraction concepts are still included in lower grade levels, such as the 1st, 2nd and 3rd grades. Therefore, more research should focus on these grade levels.

Between 2002 and 2022, studies conducted on 'Fraction Education in Primary Schools in Turkey' were analysed based on their topics, and the majority of the studies (49.18%) focused on the effect of practise and method on the success of fraction learning. Other topics included misconceptions (14.75%), students' use of representation and modelling in fraction teaching (11.47%), difficulties in fraction teaching (8.2%), errors made in fraction teaching (6.56%), determining the relationship between learning achievement and fractions (4.92%), and other topics (4.92%).

When examining the impact of applied methods and approaches on fraction learning success, six studies focused on realistic mathematics education, six on computer-assisted instruction, two on drama, and two on the solved example method. In the other 14 studies, the following methods and approaches were examined for their impact on fractional learning: Collaborative Teaching, Concept Cartoons, Visual Materials, Teaching through Music and Stories, Game-Based Instruction, Project-Based Learning Approach, Scenario-Based Learning Approach, Use of Concrete and Virtual Manipulatives, Inquiry-Based Teaching Approach, Use of Supplementary Resources, 3D printers, mobile-assisted instruction, programmed instruction, computer-assisted collaborative teaching, and clustered individualized techniques. These studies have aimed to investigate how these methods and approaches influence fractional teaching and instructional outcomes. When fractions, which are abstract concepts, are considered at the primary school level, learning difficulties occur. The studies examined found an increase in student achievement through the use of instructional methods, particularly technology-supported fractional teaching and realistic mathematics education methods. A similar result was found in a study by Sarıer (2020), who investigated the effects of active teaching methods on maths achievement. The

different methods used in this study were found to enhance mathematics achievements. Overall, student achievement in mathematics is generally low and, as a result, students develop a negative attitude towards mathematics, making it a dreaded nightmare for many students. Among the reasons for this situation, the methods used in mathematics teaching play a significant role (Baykul, 2003, as cited by Sarıer, 2020). Therefore, it is believed that incorporating different methods and techniques in fraction teaching by classroom teachers will facilitate learning and, consequently, improve achievement.

When research on misconceptions was examined, it was found that primary school students had misconceptions in the areas of ordering, addition, subtraction, and multiplication of fractions. They often perform addition and subtraction operations without considering the equality of denominators. They exhibit misconceptions in representing fractions on the number line and have difficulty writing the numerical value of a given fraction on the number line. They tended to perceive the numerator and denominator as different numbers when determining the entire amount of a known fraction. They have misconceptions in the verbal and symbolic representation of fraction numbers, partitioning a whole into equal parts, converting given fractions into decimal fractions, writing equality of decimal fractions, and determining the order of magnitude of decimal fractions. These findings are based on research conducted in this field. Similar misconceptions have been identified in studies conducted at the secondary school level in Turkey (Altıparmak & Özüdoğru, 2015; Kara, 2021; Okur & Gürel, 2016; Özaltun et al., 2020). Although most studies have focused on identifying misconceptions, there is a lack of research on interventions to address these misconceptions. However, further studies are required in this regard. Furthermore, it is anticipated that this study will shed light on the efforts of classroom teachers and secondary school mathematics teachers to address misconceptions that persist from primary to secondary school.

When examining studies on errors made by students in fraction teaching, it was found that students made a significant number of computational errors in fractions during primary school. They make errors because of misconceptions about partitioning the whole into equal parts. They tended to think of and operate with fractions as if they were natural numbers when ordering fractions. In addition, they mistakenly added numerators and denominators within the same fraction and wrote the result as a natural number in the addition operations. In subtraction operations, the numerators and denominators are separated, the numbers are subtracted separately, and sometimes a smaller number is subtracted from a larger number. They struggle to determine the unit fraction and fail to establish a relationship between the unit fraction and the fraction number. Errors were also observed in the writing, reading and drawing of fraction numbers models. They had difficulty conceptualizing the relationship between the shaded part and the entire part, and they made division errors by dividing the unshaded part instead of the shaded part. Özer et al. (2020) corroborated these findings, indicating that similar errors persist in fraction teaching during secondary school.

When examining studies on students' learning difficulties in fraction teaching, it has been identified that students struggle to understand the meaning conveyed by fractions; they have difficulty representing verbal expressions using fraction symbols and representing proper fractions shown in models using symbolic notation. In multiplication, addition, and subtraction operations with fractions, they tend to apply the operation habits they have developed with whole numbers; they have difficulty establishing a connection between division operations and fractions; they find it challenging to perceive the symbolic representation of a/b on the number line as a single number; they face difficulties in partitioning fractions into equal parts, understanding the concept of

equivalence, and ordering fractions with different denominators; they struggle to apply previously learnt rules about fractions to later-learnt rules; and they encounter difficulties in understanding fraction problems and determining the correct operations and order of operations. These difficulties in fraction teaching have been identified in studies conducted in the context of the challenges encountered in fraction teaching. Similar results were found in studies conducted at the secondary school level (Ersoy & Ardahan, 2003; Işık & Kar, 2012). It is thought that learning difficulties in this subject will decrease if primary and secondary school mathematics teachers proceed by considering the identified fraction learning difficulties.

It is believed that both studies on students' errors in fraction teaching and efforts to address their learning difficulties are insufficient. It is believed that conducting research on the elimination of these results, considering the errors and learning difficulties in teaching fractions, will be of great benefit in the learning of fractions. Furthermore, considering the findings of this study, it is believed that increasing the digital resources on the http://matematik.eba.gov.tr website, which was created as part of the mathematics campaign initiated by the Ministry of National Education to foster a love for mathematics and improve achievement, would contribute to success in the field of fractions.

It is believed that this research will be useful for future studies on fraction teaching in primary schools in terms of identifying deficiencies in this field and developing new solutions for these deficiencies.

This study was conducted on fraction teaching in the context of Turkey. For primary school students, a new study can be conducted by adding secondary and high school grade levels and studying abroad to this study.

5 Statement of researchers

5.1 Researchers' contribution rate statement

Each researcher contributed equally to this research.

5.2 Conflict statement

The authors have no conflicts of interest to declare. The publication rights of this article have been transferred to the Pedagogical Perspective Journal.

5.3 Support and thanks

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Appendix-1 Journals where Articles are Published, University Information, and Years of Publication of Theses.

Type	Information about Published Universities - Institutes or Journal:	Publication year
Doctoral Thesis	Adnan Menderes University Institute of Social Sciences	2014
Doctoral Thesis	Amasya University Institute of Social Sciences	2019
Doctoral Thesis	Gazi University Institute of Educational Sciences	2010
Doctoral Thesis	Marmara University Institute of Educational Sciences	2018
Doctoral Thesis	Ondokuz Mayıs University Institute of Educational Sciences	2019
Doctoral Thesis	Uludağ University Institute of Educational Sciences	2014
Doctoral Thesis	Uludağ University Institute of Social Sciences	2007
Master's Thesis	Abant İzzet Baysal University Institute of Educational Sciences	2013
Master's Thesis	Abant İzzet Baysal University Institute of Educational Sciences	2014
Master's Thesis	Abant İzzet Baysal University Institute of Social Sciences	2005
Master's Thesis	Abant İzzet Baysal University Institute of Social Sciences	2008
Master's Thesis	Afyon Kocatepe University Institute of Social Sciences	2022
Master's Thesis	Balıkesir University Institute of Science and Technology	2014
Master's Thesis	Bilkent University Institute of Educational Sciences	2015
Master's Thesis	Dicle University Institute of Social Sciences	2009
Master's Thesis	Dokuz Eylül University Institute of Educational Sciences	2011
Master's Thesis	Dokuz Eylül University Institute of Educational Sciences	2009
Master's Thesis	Ege University Institute of Social Sciences	2019
Master's Thesis	Ege University Institute of Social Sciences	2008
Master's Thesis	Ege University Institute of Social Sciences	2019
Master's Thesis	Ege University Institute of Science and Technology	2008
Master's Thesis	Ege University Institute of Social Sciences	2008
Master's Thesis	Fırat University Institute of Educational Sciences	2019
Master's Thesis	Gazi University Institute of Educational Sciences	2003
Master's Thesis	Gazi University Institute of Educational Sciences	2003
Master's Thesis	Gaziosmanpaşa University Institute of Educational Sciences	2014
Master's Thesis	Kastamonu University Institute of Social Sciences	2018
Master's Thesis	Necmettin Erbakan University Institute of Educational Sciences	2021
Master's Thesis	Niğde Ömer Halisdemir University Institute of Educational Sciences	2019
Master's Thesis	Middle East Technical University Institute of Social Sciences	2012
Master's Thesis	Recep Tayyip Erdoğan University Institute of Social Sciences	2017
Master's Thesis	Selçuk University Institute of Science and Technology	2006
Master's Thesis	Yıldız Teknik University Institute of Social Sciences	2021
Master's Thesis	Yıldız Teknik University Institute of Social Sciences	2019
Master's Thesis	Yüzüncü Yıl University Institute of Educational Sciences	2014
Article	Adıyaman University Journal of Educational Sciences	2017
Article	Dicle University ZiyaGökalp Journal of Educational Sciences	2010
Article	E- Kafkas Eğitim Araştırmaları Dergisi, Journal of Educational Research	2022
Article	Ege Eğitim Dergisi	2015
Article	Eğitim KuramVeAraştırmaDergisi (Ekuad)	2021
Article	Eğitim ve Bilim (Education and Science)	2002

Article	Eğitim ve Bilim (Education and Science)	2007
Article	EğitimVeToplumAraştırmalarıDergisi/Jres	2017
Article	E-Journal Of New World Sciences Academy	2010
Article	Erzincan Journal of the Faculty of Education	2005
Article	International Journal of Scientific And Technological Research	2019
Article	İlköğretim Online	2017
Article	İnönü University Journal of Educational Sciences	2007
Article	İnönü University Journal of Educational Sciences	2008
Article	Kastamonu Eğitim Dergisi	2022
Article	Kastamonu Eğitim Dergisi	2004
Article	Kastamonu Eğitim Dergisi	2010
Article	Mehmet Akif Ersoy University Journal of the Faculty of Education	2018
Article	Ministry of National Education (MEB)	2021
Article	Mustafa Kemal University Institute of Social Sciences Journal	2015
Article	Necmettin Erbakan University, Ahmet Keleşoğlu Journal of the Faculty of Education	2022
Article	Trakya University Journal of the Faculty of Education	2013
Article	Turkish Journal Of Primary Education	2019
Article	Turkish Studies - International Periodical For The Languages, Literature And History Of Turkish Or Turkic	2014
Article	Uludağ University Journal of the Faculty of Education	2010