



## Examination of pre-service teachers' perceptions of the concept of fraction using the word association test

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### Abstract

In this study, it is aimed to examine the perceptions of the mathematics teacher candidates regarding the concept of fraction. 32 teacher candidates participated in the research carried out in the screening model. The word association test was used as a data collection tool and the obtained data were analyzed by content analysis method. According to the results of the analysis, it is seen that the perceptions of teacher candidates regarding the concept of fraction are mostly concentrated in the themes of meanings of fractions, operations in fractions, and representation of fractions. In addition, the themes of numbers, notation, and other mathematical topics in which it is used are other themes that emerged. It was seen that the teacher candidates expressed the quotient meaning at most, they did not mention the percent meaning. It was seen that they mostly expressed the addition operation in fractions and the type of compound fraction. As a result, it is seen that pre-service teachers' perceptions about the concept of fraction are limited. Pre-service teachers can be given a more comprehensive and relational education on the concept of fraction.

**Keywords:** Fractions, Meanings of fractions, Pre-service teacher, Representation of fractions, Word association test.

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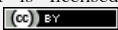
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### Contribution of this paper to the literature

Unlike other studies, teacher candidates studying at a small university participated in this study and the word association test was used. According to the findings, it is thought that this study will contribute to the education of teacher candidates.

## 1. Introduction

Mathematics is divided into five basic subject areas: numbers and operations, algebra, geometry, measurement and data analysis, and probability (National Council of Teachers of Mathematics (NCTM), 2000). The subject of fractions is one of the abstract concepts that students in the sub-learning field of numbers encounter constantly throughout their education life (Özdemir & Özçakır, 2019). Although it is a concept that is frequently used in daily life (quarter, whole, half, etc.), it is a subject where students have learning difficulties (Alkhateeb, 2019; Bentley & Bossé, 2018; Biber, Abdulkadir, & Aktaş, 2013; Charalambous & Pitta-Pantazi, 2007; Doğan & Yeniterzi, 2011; Küçük & Demir, 2009).

### 1.1. Literature Review

According to the studies carried out in the field of mathematics education, learning fractions is seen as difficult for all students due to their multi-faceted structure (Namkung & Fuchs, 2019; Namkung, Fuchs, & Koziol, 2018; National Center for Education Statistics, 2017; Torbeyns, Schneider, Xin, & Siegler, 2015). According to Olkun and Uçar (2007) fractions are heavier and more complex than most of the mathematics subjects in primary school. Because students perceive fractions as numbers and have difficulty in associating them with the numbers they have learned before. Olkun and Uçar (2007) stated that fractions differ from counting numbers in two ways. The first of these is that while we can represent the surrounding entities with a natural number, we need 2 natural numbers to represent fractions by quotient and measuring. The second is "How many?" in questions whose answers are natural numbers. While asking the question "How much?" is to ask the question. The fact that the rules that are valid in natural numbers are not always valid in fractions causes this subject to be difficult for students to understand.

Another reason is the different meanings fractions have (Division, processor, ratio, part-whole and measurement), and it is important for students to gain experience with these different meanings in order to fully understand fractions (Van de Walle, Karp, & Bay-Williams, 2012; Van de Walle, Lovin, Karp, & Williams, 2013). In addition, there are three different fraction models, namely area model, cluster model and number line model within the scope of part-whole meaning in fractions (Marmur, Yan, & Zazkis, 2020). In the area model, the determined part of a given whole is in question. For example, it is a model of scanning half of a triangle divided into two equal parts. In the cluster model, an amount of object is determined as a whole and the desired part is expressed as a fraction. In the number line model, the number line model is divided into the determined length units and the specified part expresses a fraction (Kamacı, 2021; Marmur et al., 2020). In addition to these difficulties, fractions are closely related to concepts such as rational numbers, decimal notation, ratio, operations and algebra (Kieren, 1988; Saxe, Gearhart, & Nasir, 2001). Kerslake (1995) stated that being successful in fractions is a criterion for success in mathematics and this situation causes students to be anxious about fractions, because fractions are related to many subject areas.

However, it is one of the concepts that teachers and pre-service teachers have difficulties in teaching (An, Kulm, & Wu, 2004; Izsák, 2008). Stoddart, Connell, Stofflett, and Peck (1993) in his study with pre-service teachers, determined that pre-service teachers had a good procedural accuracy rate (37-98%) on fractions, while they could only achieve an accuracy rate of 5-10% in a conceptual sense. In another study, Faulkenberry (2003) determined that pre-service mathematics teachers' procedural knowledge about rational numbers is high, conceptual knowledge is medium, and pedagogical content knowledge is low. In the study of Dede and Argün (2004) it was determined that the participants were not even aware that there was a relationship between the concept of fractions and the concept of rational numbers. As a matter of fact, the existing mental schemas of the pre-service teachers, who are on the way to becoming a teacher, about the concept of fraction, which has an important place in numbers and operations, and difficulties in learning and teaching, are important.

In this study, it was aimed to determine the perceptions of the third grade students studying in the primary school mathematics teaching department about the concept of fractions by using the word association test.

## 2. Methods

In the research within the scope of the screening model, the Word Association Test (WAT) was preferred as the measurement tool. The Word Association Test is widely used in studies to investigate cognitive structure (Timur & Taşar, 2011). In such studies, the answers to the key concepts are used to define the concepts in the cognitive structure of the participants, to determine the relationships between the concepts and to reveal the thoughts about the concepts (Doğan, Yücel, & Güngör, 2018). Word Association Test has been widely used in the fields of educational sciences recently (Akyurt, 2019; Balbag, 2018; Bostan & Çelik, 2021; Kaya, Aladağ, & Akkuş, 2021).

There are two types of assessment in the word association test. In the first type of assessment, points are awarded according to the correct answers of the student. Second assessment; It is aimed to create a frequency table regarding the number of repetitions of the words associated with the given concept and to see the cognitive structure and conceptual relationships of the test group according to the frequency table (Tokcan & Yiter, 2017). The second evaluation method was used in this study.

### 2.1. Research Sample

In this study, easy sampling method, which is one of the non-random sampling methods, was used in order to collect data faster, less costly and easier (Çeliköz & Erişen, 2017; Gülerterkin, Genç, & Gümüş, 2016). In this context, 32 pre-service mathematics teachers studying at a university in Anatolia participated in the research.



According to the data obtained, the most frequently repeated words among teacher candidates' answers to the concept of "fraction" are quotient (f=16), numerator-denominator (f=13), compound fraction (f=11), quarter (f=10), half (f=10), decimal (f=10), simple fraction (f=10), ratio-proportion (f=9), part-whole (f=9), fraction line (f=9), percentages ( f=9), whole (f=8), number line (f=7), numbers (f=7), addition (f=7), subtraction (f=7), ordering (f=7), exact was determined as a numbered fraction (f=7).

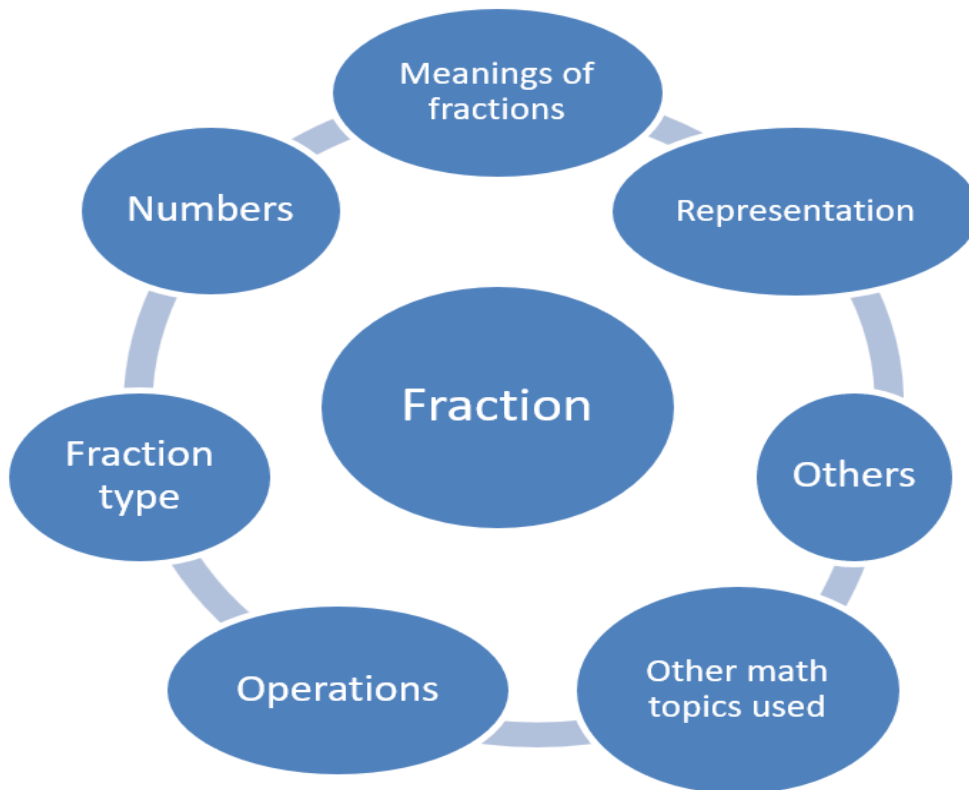


Figure 2. Themes determined according to the concepts obtained from the word association test.

As seen in Figure 2, according to the answers obtained, 6 themes were determined from the words specified for the concept of "fraction": Meanings of Fractions, Numbers, Fraction Types, Operations, Other Mathematics Subjects Used and Notation. In addition, the other theme was created for the concepts that do not fall into these themes. The words that emerged as a result of the word association test WAT, the themes that these words included and their frequencies are given in Table 1.

Table 1. Words, themes and frequencies resulting from the word association test.

Main theme	Main theme frequency (f)	Main theme percent (%)	Concept	Frequency (f)	Percent (%)
Meanings of fractions	72	29.26	Quarter (Part-whole meaning)	10	4.06
			half (Part-whole meaning)	10	4.06
			full (Part-whole meaning)	8	3.25
			Missing	1	0.40
			Proportion	9	3.65
			Part whole	9	3.65
			Volumetric analysis	6	2.43
			Length measurement	1	0.40
			Measuring area	2	0.80
			Quotient	16	6.50
Impression	57	15.04	Fraction line	9	3.65
			Numerator-denominator	13	5.28
			Modelling	3	1.21
			Number line	7	2.84
			Fraction problems (Verbal notation)	5	2.03
Numbers	26	10.56	Numbers	7	2.84
			Decimal number	10	4.06
			Natural number	2	0.80
			Cyclic	2	0.80
			Rational number	4	1.62
			Number sense	1	0.40
Transactions	49	19.91	Impact	5	2.03
			Divide	5	2.03
			Collection	7	2.84
			Extraction	7	2.84
			Flip it over	1	0.40
			Denominator equalization	3	1.21
			They exclude	1	0.40
			0/Number=0	1	0.40
			Sort (Big, Small, Even)	7	2.84
			Extension	5	2.03
			Simplification	5	2.03

Main theme	Main theme frequency (f)	Main theme percent (%)	Concept	Frequency (f)	Percent (%)
			To compare	2	0.80
Fraction type	55	14.22	Unit fraction	5	2.03
			Compound fraction	11	4.47
			Integer fraction	7	2.84
			Simple fraction	10	4.06
			Equivalent fraction	2	0.80
Other math topics used	26	10.16	Possibility	3	1.21
			Statistics	2	0.80
			Graphic	1	0.40
			Percentages	9	3.65
			Chart	1	0.40
			Slope	1	0.40
			Trigonometry	2	0.80
Other	2	0.81	Algebraic expression	6	2.43
			Maths	1	0.40
Total	246	100	Forever	1	0.40
			28 Part-whole meaning	246	100
			1 Missing		
			9 Proportion		
			9 Part whole		
			6 Volumetric analysis		
			1 Length measurement		
			2 Measuring area		
			16 Quotient		
			9 Fraction line		
			13 Numerator-denominator		
			3 Modelling		
			7 Number line		
			5 Fraction Problems (Verbal notation)		
			7 Numbers		
			10 Decimal number		
			2 Natural number		
			2 Cyclic		
			4 Rational number		
			1 Number sense		
			5 Impact		
			5 Divide		
			7 Collection		
			7 Extraction		
			1 Flip it over		
			3 Denominator equalization		
			1 They exclude		
			1 0/Number=0		
			7 Sort (Big, Small, Even)		
			5 Extension		
			5 Simplification		
			2 To compare		
			5 Unit fraction		
			11 Compound fraction		
			7 Integer fraction		
			10 Simple fraction		
			2 Equivalent fraction		
			5 Possibility		
			2 Statistics		
			1 Graphic		
			9 Percentages		
			1 Chart		
			1 Slope		
			2 Trigonometry		
			6 Algebraic expression		
			1 Maths		
			1 Forever		

According to Table 1, it is seen that the concept of fraction is mostly formed in the minds of teacher candidates as the meanings of fractions (29.26%), operations (19.91%) and notation themes. The most striking part about the theme of fraction meanings was the part-whole (51.38%) and quotient (22.22%) meanings. While the concepts of the meaning of ratio (12.50%) and the meaning of measurement (12.50%) were in question, the meaning of processor was not encountered. Pre-service teachers mostly mentioned operations between fractions themselves. As a matter of fact, the other most used theme was transactions. The most striking thing here is that although addition and subtraction are the operations that come to mind the most (14.28%), the denominator equalization, which is important in these two types of operations, occurs to a much lesser extent (6.12%). It is seen that comparison occurs less between sorting (14.28%), expansion (10.20%), simplification (10.20%) and comparison (4.08%) compared to other operations.

Divide	Model
All	Data Analysis
Number	Table
Half	Impact
Quarter	Collection
Decimal	Extraction
Share	Compound Fraction
Denominator	Simple Fraction
Rational Number	Integer Fraction
Fraction Line	is small
Number Line	is greater
	Equal

Group 3. The words that the 3rd group associated with the concept of fraction

Decimals	Simple Fraction
Cyclic Number	Compound Fraction
Pie Slice	Size Ranking
Divide	Four Transactions
Share	Numbers
Denominator	Possibility
Fraction Line	Statistics
Full Half	Number Line
	Finding space

Group 12. The words that the 12rd group associated with the concept of fraction

Figure 3. Word examples associated with the concept of fraction by teacher candidates.

In Figure 3, there are words written by 2 groups in the word association test related to the concept of fraction.

While the emphasis on the numerator-denominator (35.13%) stands out in the theme created about the representation of fractions, the fraction line (24.32%) maintains its importance. Modeling (8.10%) was the least used display format. In the fraction type theme, the most frequently mentioned words were compound fraction (31.42%) and simple fraction (28.57%), while equivalent fraction (5.71%) was much less expressed. In the theme of numbers, the number most associated with fractions was decimals (38.46%). It is noteworthy that in this theme, rational numbers (15.38%) are encountered less frequently than decimal numbers. Number sense (3.84%) was the least used word.

When its relationship with other mathematics subjects is considered, it is seen that the subject it is most related to is percentages (36%), while the other most frequently used subject is algebra (24%). Graph, table and slope (4%) were the least expressed words. Since the words mathematics and infinity could not be associated with any category, they were considered in the other category.

#### 4. Discussion, Conclusion, and Suggestions

In this study, primary school mathematics teacher candidates' perceptions of the concept of "fraction" and their conceptual relationships were examined through the Word Association Test. The fact that there are a wide variety of themes that emerged as a result of the research showed that the pre-service teachers who practiced structured the concept of fraction under many concepts in their minds and they reached a rich mental structure about fractions. However, there are concepts that do not appear or that occur more or less than other concepts in a similar category.

It is seen that the perceptions of the pre-service teachers who applied regarding the concept of fraction are mostly concentrated in the themes of meanings of fractions, operations in fractions, and representation of fractions. It was seen that the pre-service teachers who applied mostly presented words about the meaning of fractions, quotient and part-whole. This situation shows that although the concept of fraction has 5 different meanings, they restrict it to the meaning of part and whole and perceive fraction as conceptually limited. Similarly, Marmur et al. (2020) in their study with pre-service teachers found that the meaning they have the most is the part-whole meaning of the fraction, similar to this study. In the study carried out by Taştepe and Yanık (2021) it is seen that one of the meanings most used by 9th grade students when writing equations for algebraic fractional expressions is the part-whole meaning. Starting from pre-school, teaching focused on the part-whole meaning of fractions rather than other meanings may cause limited learning in students (Behr, Harel, Post, & Lesh, 1992; Haser & Ubuz, 2002; Okur & Cakmak, 2016; Toluk-Uçar, 2009). As seen in this study, this situation also manifests itself at the university level. The reason why the part-whole meaning is encountered more intensely at many levels may be related to the fact that students learn the part-whole meaning more easily or that teachers tend to teach the part-whole meaning of fractions more (Simon, Placa, Avitzur, & Kara, 2018). In this regard, the curriculum or textbooks may also be one of the situations that should be examined separately. The meaning of the processor, on the other hand, is not expressed at all. Similarly, Özçakır (2022) observed in the research she conducted with primary school students that they had deficiencies in percent meaning.

Another remarkable result obtained from this research is that although addition and subtraction are the most frequently expressed operations, less emphasis is placed on equating the denominator, which is a fraction-specific operation. Looking at the operations between the fractions themselves, comparison was the least expressed operation. Although there is no study on this subject, it can be examined how longitudinally and in what intensity these acquisitions are included in the curriculum. In addition, students' attitudes towards operations such as simplifying, expanding, ordering and comparing fractions can be effective in this regard.

Although decimal numbers are the number type with which fractions are most associated in this study, it is remarkable that rational numbers are rarely mentioned. As stated by many researchers, fractions are closely related to concepts such as decimal notations, ratio, operations and algebra, especially rational numbers (Kieren, 1988; Saxe et al., 2001). It is noteworthy that the least number that comes to mind when talking about fractions is the rational number, especially for students who encounter rational numbers intensively in mathematics courses at university level. The subject that the fraction is most associated with was determined as percentages and especially algebra. While the reasons for algebra to come to the fore are various, it is thought that the most important one is related to the fact that the pre-service teachers are at the university level.

As a result, pre-service teachers who applied have a rich perceptions about the concept of "fraction". However, there are deficiencies in the meaning of fractions, especially in percent meaning. Comparison of fractions and

equivalent fractions were the operations that came to mind the least about operations in fractions. There are also deficiencies in the relationship of fractions with rational numbers. It is noteworthy that one of the subjects they associate fractions most with is algebra. It is thought that investigating these deficiencies or remarkable situations at different levels and with different methods can be effective in terms of both learning and teaching.

In the continuation of this research, the word association test for different concepts in mathematics can be applied. Or, the perceptions difference between the two applications can be investigated by applying a word association test in the form of a pre-test and a post-test to the pre-service teachers who applied and applying a well-planned training aimed at improving conceptual knowledge between these two applications. In addition, the perceptions of students in different age groups or teachers with different experiences regarding the concept of fraction can be investigated by applying the word association test.

## 5. Limitations

This research was limited to primary school mathematics teacher candidates. Another limitation of the study is that only the fraction concept was discussed. In addition, the perceptions of pre-service teachers were tried to be determined only by applying the word association test.

## References

- Akyurt, H. (2019). Measuring tourism education perceptions of undergraduate tourism students with the word association test method: Giresun university example. *Turkish Journal of Tourism Studies*, 3(3), 759-774.
- Alkhateeb, M. A. (2019). Common errors in fractions and the thinking strategies that accompany them. *International Journal of Instruction*, 12(2), 399-416. <https://doi.org/10.29333/iji.2019.12226a>
- An, S., Kulm, G., & Wu, Z. (2004). The pedagogical content knowledge of middle school, mathematics teachers in China and the US. *Journal of Mathematics Teacher Education*, 7(2), 145-172. <https://doi.org/10.1023/b:jimte.0000021943.35739.1c>
- Balbag, M., Z. (2018). Cognitive structures of science teacher candidates regarding the concepts of speed and speed: Word association test (KIT) application. *Journal of Dicle University Ziya Gökalp Faculty of Education*, 33, 38-47.
- Behr, M. J., Harel, G., Post, T., & Lesh, R. (1992). Rational number, ratio and proportion. In D. A. Grows (Ed.), *Handbook of research on mathematics teaching and learning research perspectives*. In (pp. 296-333). Reston: National Council of Teachers of Mathematics.
- Bentley, B., & Bossé, M. J. (2018). College students' understanding of fraction operations. *International Electronic Journal of Mathematics Education*, 13(3), 233-247. <https://doi.org/10.12973/iejme/3881>
- Biber, A. Ç., Abdulkadir, T., & Aktaş, O. (2013). Students' misconceptions about fractions and the effects of these misconceptions on solutions to fraction problems. *Journal of Trakya University Faculty of Education*, 3(2), 152-162.
- Bostan, S. A., & Çelik, A. (2021). Determining the effect of inquiry-based learning on secondary school 5th grade students' ideas using word association test. *Journal of Science, Education, Art and Technology*, 5(2), 138-159.
- Çeliköz, M., & Erişen, Y. (2017). Opinions of educational scientists working in the field of CIP on constructivism: A mixed method research. *Journal of Education and Teaching Research*, 6(2), 286-304.
- Charalambous, C. Y., & Pitta-Pantazi, D. (2007). Drawing on a theoretical model to study students' understandings of fractions. *Educational Studies in Mathematics*, 64(3), 293-316. <https://doi.org/10.1007/s10649-006-9036-2>
- Dede, Y., & Argün, Z. (2004). Starting point of mathematical thinking: The role of mathematical concepts. *Educational Administration in Theory & Practice*, 39, 338-355.
- Doğan, M., & Yeniterzi, B. (2011). The readiness of primary school 7th grade students about rational numbers. *Selcuk University Ahmet Keleşoğlu Faculty of Education Journal*, 31, 217-237.
- Doğan, S., Yücel, G. M., & Güngör, O. (2018). Investigation of cognitive structures of tourism vocational school students towards social media by using word association test. *Tourism Academic Journal*, 5(1), 166-176.
- Faulkenberry, E. E. D. (2003). *Secondary mathematics preservice teachers' conceptions of rational numbers*. Doctoral Dissertation. Oklahoma State University Faculty of the Graduate College, Oklahoma.
- Gülertekin, G. S., Genç, V., & Gümüş, M. (2016). The effect of emotional intelligence on work stress and work life balance in hotel businesses. *Batman University Journal of Life Sciences*, 6(2/1), 97-112.
- Haser, C., & Ubuz, B. (2002). Conceptual and operational performance in fractions. *Journal of Education and Science*, 27(126), 53-61.
- Izsák, A. (2008). Mathematical knowledge for teaching fraction multiplication. *Cognition and Instruction*, 26(1), 95-143.
- Kamacı, Y. (2021). *Examination of the representations and modeling performances used by primary school 4th grade students for fraction types and unit fractions*. Master Thesis. Yildiz Technical University.
- Kaya, B., Aladağ, C., & Akkuş, A. (2021). Determining the opinions of geography teacher candidates about karst topography using the word association test and drawing-writing technique. *International Journal of Geography and Geography Education*, 44, 55-74. <https://doi.org/10.32003/igge.874465>
- Kerslake, V. B. (1995). *Community awareness of safe food handling practices and food poisoning: Knowledge and experience*. Wellington, New Zealand: University of Victoria.
- Kieren, T. E. (1988). Personal knowledge of rational numbers: Its intuitive and formal development. In M. J. Behr & J. Hiebert (Eds.), *Number Concepts and Operations in the Middle Grades*. In (pp. 162-181). Reston, VA: National Council of Teachers of Mathematics.
- Küçük, A., & Demir, B. (2009). A study on some misconceptions encountered in teaching mathematics in 6th-8th grades in primary education. *Journal of Dicle University Ziya Gökalp Education Faculty*, 13(1), 97-112.
- Marmur, O., Yan, X., & Zazkis, R. (2020). Fraction images: The case of six and a half. *Research in Mathematics Education*, 22(1), 22-47. <https://doi.org/10.1080/14794802.2019.1627239>
- Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, California: Sage.
- Namkung, J., & Fuchs, L. (2019). Remediating difficulty with fractions for students with mathematics learning difficulties. *Learning Disabilities: A Multidisciplinary Journal*, 24(2), 36-48. <https://doi.org/10.18666/ldmj-2019-v24-i2-9902>
- Namkung, J. M., Fuchs, L. S., & Koziol, N. (2018). Does initial learning about the meaning of fractions present similar challenges for students with and without adequate whole-number skill? *Learning and Individual Differences*, 61, 151-157. <https://doi.org/10.1016/j.lindif.2017.11.018>
- National Center for Education Statistics. (2017). *The condition of education 2017*. Retrieved from <https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2017144>
- National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics*. Reston, VA: Author.
- Okur, M., & Cakmak, G. Z. (2016). Secondary school 6th and 7th grade students' misconceptions about fractions. *Journal of Erzincan University Faculty of Education*, 18(2), 922-952.
- Olkun, S., & Uçar, Z. T. (2007). *Activity based mathematics teaching in primary education* (3rd ed.). Ankara: Maya Academy.
- Özçakır, S. Ö. (2022). Examining the mental structures of fourth grade students on fractions. *E-Caucasian Journal of Educational Research*, 9, 1-19. <https://doi.org/10.30900/kafkasegt.948020>
- Özdemir, D., & Özçakır, B. (2019). An analysis of the effects of augmented reality activities in teaching fractions on 5th grade students' math achievement and attitudes. *Adiyaman University Journal of Educational Sciences*, 9(1), 21-41.
- Saxe, G. B., Gearhart, M., & Nasir, N. I. S. (2001). Enhancing students' understanding of mathematics: A study of three contrasting approaches to professional support. *Journal of Mathematics Teacher Education*, 4(1), 55-79.

- Simon, M. A., Placa, N., Avitzur, A., & Kara, M. (2018). Promoting a concept of fraction-as-measure: A study of the learning through activity research program. *The Journal of Mathematical Behavior, 52*, 122-133. <https://doi.org/10.1016/j.jmathb.2018.03.004>
- Stoddart, T., Connell, M., Stofflett, R., & Peck, D. (1993). Reconstructing elementary teacher candidates' understanding of mathematics and science content. *Teaching and Teacher Education, 9*(3), 229-241. [https://doi.org/10.1016/0742-051x\(93\)90040-n](https://doi.org/10.1016/0742-051x(93)90040-n)
- Taştepe, M., & Yanık, H. B. (2021). Examination of the development of conceptual knowledge: In the context of equations containing algebraic fractional expressions. *International Journal of Social and Educational Sciences, 16*(2021), 83-103. <https://doi.org/10.20860/ijoses.967628>
- Timur, B., & Taşar, M. F. (2011). Developing pre-service science teachers' cognitive structures about technology: Word association test (WAT). *Western Anatolia Journal of Educational Sciences, 1*, 131-138.
- Tokcan, H., & Yiter, E. (2017). Investigation of cognitive structures of 5th grade students related to natural disasters by word association test (KIT). *Ahi Evran University Journal of Kırşehir Education Faculty, 18*(1), 115-129.
- Toluk-Uçar, Z. (2009). Developing pre-service teachers understanding of fractions through problem posing. *Teaching and Teacher Education, 25*(1), 166-175. <https://doi.org/10.1016/j.tate.2008.08.003>
- Torbeyns, J., Schneider, M., Xin, Z., & Siegler, R. S. (2015). Bridging the gap: Fraction understanding is central to mathematics achievement in students from three different continents. *Learning and Instruction, 37*, 5-13. <https://doi.org/10.1016/j.learninstruc.2014.03.002>
- Van de Walle, J. A., Karp, K. S., & Bay-Williams, J. (2012). *Elementary and middle school mathematics: Teaching developmentally* (8th ed.). Boston, MA: Allyn and Bacon.
- Van de Walle, J. A., Lovin, L. H., Karp, K. H., & Williams, J. M. B. (2013). *Teaching student-centered mathematics: Pearson new international edition PDF eBook: Developmentally appropriate instruction for grades pre K-2* (Vol. 1): Pearson Higher Ed.
- Yıldırım, A., & Şimşek, H. (2011). *Qualitative research methods in the social sciences*. Ankara: Distinguished Publications.
- Yıldırım, A., & Şimşek, H. (2016). *Qualitative research methods in the social sciences*. Ankara: Seçkin Publishing.