# Developing the Diagnostic Test of Misconceptions of Fractions

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**Abstract**

This research aimed to develop a valid and reliable test to be used to detect sixth grade students' misconceptions and errors regarding the subject of fractions. A misconception diagnostic test has been developed that includes the concept of fractions, different representations of fractions, ordering and comparing fractions, equivalence of fractions, representation of fractions on the number line, and addition, subtraction, multiplication and division of fractions. Studies in the literature on misconceptions in fractions were examined and 22 misconceptions were listed. An open-ended test consisting of 23 questions was created in which students justified their answers to the questions. The developed test was applied to 215 sixth grade students studying in a public secondary school in Istanbul. The average item difficulty index of the test was calculated as 0.37. The test was found to be of average difficulty. The average discrimination index of the test was measured as 0.69. This value shows that the test items are quite successful in distinguishing between students who know and those who do not. In addition, when the discrimination values of the test items were taken into consideration separately, there was no need for item removal or item change since there were no items below 0.30. The KR-20 reliability coefficient was calculated for the first stage of the test and was calculated as 0.93. A graded classification system was used for the first part and second part of the test. To determine that the two stages work in harmony, the Cronbach Alpha reliability coefficient was calculated and found to be 0.95. These results prove that the developed test is highly valid and reliable.

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**Keywords:** fraction, misconception, test, development, validity, reliability

## Introduction

Misconception can be defined as the inconsistency between the concepts we want students to learn and the structure they create in their own minds (Michael, 2002). In other words, it is the state of chaos that occurs as a result of the student's knowledge contradicting scientific realities and incorrect meanings being attributed to scientifically accepted knowledge (Vamvakoussi & Vosniadou, 2010). Misconceptions may persist for a long time without being revealed unless efforts are made to reveal them. However, the process of revealing misconceptions is also very difficult. In addition, misconceptions can prevent new learning due to the fact that they are structures that exist in students' minds and are not directly observed (Kose et al., 2003).

The fact that mathematics has a spiral structure within itself and has a structure built on pre-learning forming the basis of new knowledge to be learned, causes students to fall into misconceptions very often and makes it necessary to reveal the misconceptions they have (Cetin, 2009). Another important reason why students often make mistakes in mathematics is that mathematics has an abstract structure and contains too many abstract concepts. Naturally, it is a very difficult process for students to make sense of many interconnected abstract concepts and build on their previous learning. Therefore, it is very important to identify and eliminate students' misconceptions about mathematical concepts.

One of the subjects within mathematics where students often make misconceptions is fractions. Fractions have a very complex structure in themselves. The reasons for this complexity are that the properties of whole numbers cannot be applied to fractions, that fractions cannot be counted directly due to the infinite number of fractions expressing the same size, and that they have different meanings and different forms of representation (Schneider & Siegler, 2010). In this context, the difficulties experienced in fractions and the misconceptions that students have have been the subject of many studies and have been deemed valuable to investigate. However, although many studies have been found, no study has been found that covers the detection of misconceptions about fractions in a comprehensive manner. A valid and reliable test study developed to detect misconceptions and errors that may be encountered regarding the fractions covered in their entirety is very important.

## Method

This study was conducted among 215 sixth grade students in a state school in Istanbul during the 2022-2023 academic year.

### The Steps of Developing the Diagnostic Test of Misconceptions of Fractions

### Setting the Objective of the Study

As a result of the literature review, it has been found out that many studies have been conducted to diagnose the misconceptions about fractions (Haser & Ubuz, 2002; Ersoy & Ardahan, 2003; Soylu & Soylu, 2005; Pesen, 2008; Biber et al., 2013; Demiri, 2013; Kar & Isık, 2014; Altıparmak & Ozudogru, 2015; Sengül, 2015; Kula Unver, 2016; Okur & Cakmak Gurel, 2016; Onal & Yorulmaz, 2017; Trivena et al., 2017; Karaoglan Yılmaz, Gokkurt Ozdemir & Yasar, 2017; Can, 2019; Macit, 2019; Burr et al., 2020; Ozaltun Danacı & Orbay, 2020; Celik et al., 2022; Jarrah et al., 2022). Each of these studies deals with some parts of the subfields of the subject fractions. For instance, along with the studies which are not concerned with the subfield of the division of fractions (Soylu & Soylu, 2005; Biber et al., 2013; Okur and Cakmak Gurel, 2016), it has been encountered a study focusing only a subtraction fractions (Kar & Isık, 2014) and concentrating only on the subfield of finding fractions on a number line (Pesen, 2008). Hence, any study concerned with the subject of the fractions as a whole could not be found. In this study, a broad framework was formed by being included the subfields of the fractions such as its concepts, different representations, ordering and comparing, equivalent fractions, finding a fraction on a number line, addition and subtraction as well as multiplication and division

### Determining the Subject

Fractions have an extensive coverage on the Math curriculum from the first to the sixth grade. (MEB, 2018) In addition, fractions are known to be closely associated with the other Math subjects such as division, proportion, decimals, percentages, rational numbers and algebra, and constitute a basis for Math class. In the light of these reasons, the subtopics of the fractions unit were incorporated into the scope of the diagnostic test developed in the study.

### Creating the Item Pool and Receiving Expert Opinions

An item pool in which there are some questions that best represent twenty-two listed misconceptions has been created by utilizing the conducted studies on fractions in the literature. Three experts'-who have a Phd-degree and academic studies on fractions- and four Math teachers' opinions have been taken into consideration in the study. Considering the expert opinions, some number lines have been added to make the questions to be used in order to reveal the misconceptions about showing fractions on number lines much clearer.

With expert opinion, side lengths have been added to a question which represents the demonstration of fractions with the domain model in order to make it clearer and more understandable. It has been decided that only one question was found sufficient for some misconceptions whereas a couple of questions should be included in the diagnosis test for some other misconceptions.

Regarding the views about some objectives such as the competence of the questions in revealing the so-called misconceptions, and the appropriateness or comprehensibility of questions for students' level, the test was put into its final form.

**The Content Validity of the Test**

In order to provide the content validity of the test, all the misconceptions of the students dealt in the fraction unit in the 6$^{th}$ grade within the literature have been identified, and at least one question has been written for revealing each misconception.

**The Implementation of the Test**

The diagnostic test of misconceptions was implemented to 215 sixth graders attending a state secondary school in Bagcilar, the district of Istanbul province, in the spring semester of 2022-2023 academic year, and its item analysis was done via the data obtained. The grading of the students' answers to the test items is required so that the item analysis can be done.

In the event of students' providing the correct answer, they will be awarded with "1" point while the incorrect answers will be given "0" point. The difficulty and discrimination of the items were tried to be identified in respect to these points.

**The Item Difficulty and The Item Discrimination Indexes**

To determine the item difficulty and the item discrimination indexes, the high and low groups which the pilot scheme was implemented to should be first identified. Firstly, the total scores obtained from the testing results are arranged from the highest to the lowest. Starting with the most successful person, the selected students covering 27 % constitute the high group while starting with the most unsuccessful person, the selected students covering 27 % constitute the low one. The rest of 46 % is excluded from the statistics.

Item difficulty index can range from 0 to 1; the higher the value, the easier the question; on the other hand, the lower the value, the more difficult the question. The item difficulty index can be expected to be 0.50, but it is more normal for the average difficulty index to be 0.50, since both easy and difficult questions should be included in a test (Bayrakceken , 2011; p. 313). The item difficulty index has been calculated for each question with the formula below:

$$\frac{C_H + C_L}{N_H + N_L}$$

$C_H$: The number of students in 27 % high group who answered the question correctly

$C_L$: The number of students in 27 % low group who answered the question correctly

$N_H$: Number of students in the high group

$N_L$: Number of students in the low group

The item difficulty index values to be used for the evaluation of items are given in the table below:

**Tablo 2** Evaluation of item difficulty index

| Difficulty index (DIF) | Interpretation |
|---|---|
| >0.30 | Difficult |
| 0.30 - 0.50 | Average/Moderate |
| 0.50 - 0.70 | Easy |
| 0.70 - 1 | Very easy |

The discrimination index is the way of differentiating between a high performing responder and a low performing responder for a given item. In a nutshell, it is a measure of the differentiation between those who know and those who do not. It ranges from -1 to 1. As the discrimination index approaches to 0, it can be claimed that the discrimination is low, while approaching to 1 indicates high discrimination. The fact that the index is positive indicates that the item functions correctly, and the high group's percentage of the correct responses is higher than the lower one. The fact that the discrimination index is negative points out that the so-called item does not function correctly, and the low group's correct answers are higher than the high one's; therefore, it should be omitted from the test.

$$\frac{C_H - C_L}{N_H \; or \; N_L}$$

$C_H$: The number of students in 27 % high group who answered the question correctly

$C_L$: The number of students in 27 % low group who answered the question correctly

$N_H$: Number of students in the high group

$N_L$: Number of students in the low group

The discrimination index values to be used for the evaluation of items are given in the table below:

**Tablo 3** Evaluation of item discrimination index

| Discrimination Index (DI) | Interpretation |
|---|---|
| <0,40 | Very good items; accept |
| 0,30 - 0,39 | Reasonably good but subject to improvement |
| 0,20 - 0,29 | Marginal items usually need and subject to improvement |
| >0,19 | Poor items to be rejected or improved by revision |

**Reliability**

The misconception diagnostic test consists of two parts. While the first part contains open-ended questions that will reveal students' misconceptions, the second part contains an explanation of how the student solved the question. Since the criterion in the first part was that students should receive '1' point if they answered correctly and '0' point if they answered incorrectly, the reliability of this section was calculated with Kr-20. The Kr-20 reliability coefficient, which can be applied when all items are scored with 0 and 1, was calculated with the following formula (Tan, 2020; p. 99).

$$\frac{K}{K-1}.(1-\frac{\Sigma\, s_j^2}{s_x^2})$$

K: Number of questions

$s_x^2$: Variance of the entire scores

$s_j^2$: variance for each of the item

Σ= Indicates to sum

**Results**

In this section, the validity and reliability analyzes of the misconception diagnosis test developed for the sixth grade fractions topic are included.

**Ensuring Content Validity**

In order to ensure the content validity of the study, it is necessary to specify which subsections the questions prepared before the application belong to within the relevant subject. In order to reveal this situation, a table of specifications was created for the list of misconceptions obtained from the relevant literature. While preparing the table of specifications, 4 mathematics teachers and 3 experts in the field tried to determine the misconceptions obtained and the best question types that would reveal these misconceptions. It can be said that the content validity of the test was ensured.

**Tablo 4** Table of symptoms of the misconception diagnostic test

| | Misconceptions in the fractions | Question No |
|---|---|---|
| 1 | Students think that fractional parts do not have to be equal in size | 1 |
| 2 | Students think that fractional parts must be the same | 2 |

| | | |
|---|---|---|
| 3 | While representing compound fractions as part-whole, students divide the whole into parts equal to the numerator and take parts equal to the denominator. | 3 |
| 4 | Students think that the same fractions stated correspond to an equal quantity, regardless of the referenced whole. | 4 |
| 5 | When representing a simple fraction on a number line with larger numbers outside the 0-1 range, instead of dividing the 0-1 range into equal parts equal to the denominator, students divide the entire length into equal parts equal to the denominator. | 5 |
| 6 | When representing fractions on the number line, students divide the range 0-1 into parts equal to one more than the denominator. | 6 |
| 7 | While representing the fraction on the number line, students divide the range 0-1 into parts equal to one less than the denominator. | 6 |
| 8 | Students think that fractions with larger denominators are larger if the numerators are equal. | 7 |
| 9 | When comparing fractions, students order only the numerator or only the size of the denominator. The numerator and denominator are separate numbers. Student cannot see fractions as a single number | 8, 9 and 10 |
| 10 | Students compare equivalent fractions according to whether their numerators and denominators are larger and cannot perceive equivalent fractions. | 11 |
| 11 | Students apply the standard algorithm without finding a common denominator or manipulate numerators and denominators when adding or subtracting fractions. | 12 and 13 |
| 12 | Students do not expand the numerator when equalizing the denominator | 12 and 13 |
| 13 | When adding or subtracting fractions, students perform operations by adding the expansion coefficient with the numerator and | 12 and 13 |

| | | |
|---|---|---|
| | denominator. | |
| 14 | When adding or subtracting fractions with equal numerators and different denominators, students add or subtract the denominators among themselves and write them as they are, without performing any operations between equal shares. | 14 |
| 15 | Students multiply numerators and multiply denominators without multiplying | 15 |
| 16 | Students think multiplication as an operation that increases the value of a number in all cases. | 16 |
| 17 | Students think that whole number fractions are separated by the multiplication sign for the whole number part and the fraction part. | 17 and 18 |
| 18 | Students think division as an operation that always reduces the value of a number. | 19 |
| 19 | To find half of a fraction, students divide the fraction by $\frac{1}{2}$ instead of dividing by 2 | 20 |
| 20 | When dividing fractions, students divide the numerators and do not divide the denominators. | 21 |
| 21 | When dividing fractions, students reverse and multiply the first fraction. | 22 |
| 22 | Students multiply and divide whole number fractions without converting them into improper fractions. | 23 |

**Item Analyzes**

After the test was finalized, the developed test was administered to 215 sixth grade students for item analysis. Considering the total scores of the students from the test, a ranking was made from the student with the highest score to the student with the lowest score. In line with this ranking, 27% low and high groups were determined. The item difficulty index and item discrimination index of the test were calculated according to the lower and upper groups.

**Tablo 5** Values of item difficulty and discrimination indexes of the test

| Question No | Difficulty Index | Discrimination Index |
|---|---|---|
| 1 | 0,18 | 0,33 |
| 2 | 0,42 | 0,50 |
| 3 | 0,34 | 0,69 |
| 4 | 0,25 | 0,40 |
| 5 | 0,34 | 0,69 |
| 6 | 0,47 | 0,91 |
| 7 | 0,46 | 0,81 |
| 8 | 0,25 | 0,50 |
| 9 | 0,20 | 0,40 |
| 10 | 0,29 | 0,59 |
| 11 | 0,44 | 0,88 |
| 12 | 0,56 | 0,98 |
| 13 | 0,54 | 0,98 |
| 14 | 0,52 | 0,97 |
| 15 | 0,50 | 0,90 |
| 16 | 0,27 | 0,53 |
| 17 | 0,40 | 0,79 |
| 18 | 0,38 | 0,76 |
| 19 | 0,22 | 0,45 |
| 20 | 0,22 | 0,43 |
| 21 | 0,46 | 0,88 |
| 22 | 0,39 | 0,78 |
| 23 | 0,32 | 0,64 |
| Mean | 0,37 | 0,69 |

Since the average item difficulty value was measured as 0.37, it was decided that the test was of medium difficulty. However, considering the item discrimination of the test, there was no need for item removal or item replacement since there were no items below the value of 0.30 (Buyukozturk, Kılıc Cakmak, Akgun, Karadeniz, and Demirel, 2020; p. 128).

**Reliability**

KR-20 Kuder-Richardson reliability coefficient was used to measure the internal consistency of the items. This reliability coefficient, which can be applied when all items are scored with 0 and 1, was calculated with the formula $\frac{K}{K-1}.(1-\frac{\Sigma s_j^2}{s_x^2})$ (Tan, 2020; p. 99). The Kr-20 reliability coefficient was found to be 0.93. The test generally has high internal consistency.

Considering the reliability coefficient of all test items, the Cronbach Alpha reliability coefficient should be calculated. Students' answers to the test received different scores according to the evaluation criteria shown in table below. Cronbach Alpha reliability coefficient can be calculated when the rating score type of the items that make up the test is used (Buyukozturk, Kılıc Cakmak, Akgun, Karadeniz, and Demirel, 2020; p. 115).

**Tablo 6** Rubric of the items that make up the test

| State of items | Score |
|---|---|
| Correct Answer - Correct Reason | 3 |
| Correct Answer - Partially Correct Reason | 2 |
| Correct Answer - Wrong Reason | 1 |
| Wrong Answer - Correct Reason | 2 |
| Wrong Answer - Partially Wrong Reason | 1 |
| Wrong Answer - Wrong Reason | 0 |
| Blank | 0 |

According to the table above, solving the problem correctly and providing correct justification corresponds to 3 points. In addition, 2 points were preferred for correct analysis of the problem and implicit and incomplete explanations without full justification. Answering the question correctly does not indicate that the students has no deficiencies in the sub-topic that represents the question. Therefore, the students may have randomly found the correct solution to the problem. Although some questions in the test tend to do this, 1 point is reserved for questions where the correct answer is given but supported by incorrect justifications. Similarly, if the students provided the correct justification for the wrong answer in case they could make a mistake due to lack of attention to a question that they knew how to solve, they received 2 points. In addition to answering the question incorrectly, some students may make incomplete or incorrect inferences about the subject. Since it is thought that insufficient information, incomplete explanations, and completely empty and irrelevant answers should be prevented, 1 point is allocated to this section. The misconception diagnosis test in this study includes 23 open-ended questions that need to be justified. Considering table 5, students can get a total of 69 points if he solves all the questions correctly with the right justification. If the students answers all questions incorrectly with incorrect justification or leaves all questions blank, they may receive 0 points.

**Tablo 7** Cronbach's alpha values of the test

| Question No | Scale Mean if Item Deleted | Corrected Item-Total Correlation | Cronbach's Alpha if Item Deleted |
|---|---|---|---|
| 1 | 21,82 | 0,46 | 0,95 |
| 2 | 21,66 | 0,39 | 0,95 |
| 3 | 21,88 | 0,68 | 0,95 |
| 4 | 21,85 | 0,54 | 0,95 |
| 5 | 22,18 | 0,72 | 0,95 |
| 6 | 21,73 | 0,77 | 0,95 |
| 7 | 21,53 | 0,63 | 0,95 |

| | | | |
|---|---|---|---|
| 8 | 22,33 | 0,66 | 0,95 |
| 9 | 22,43 | 0,63 | 0,95 |
| 10 | 22,28 | 0,72 | 0,95 |
| 11 | 21,91 | 0,72 | 0,95 |
| 12 | 21,21 | 0,73 | 0,95 |
| 13 | 21,41 | 0,76 | 0,95 |
| 14 | 21,39 | 0,73 | 0,95 |
| 15 | 21,43 | 0,69 | 0,95 |
| 16 | 22,30 | 0,55 | 0,95 |
| 17 | 22,07 | 0,70 | 0,95 |
| 18 | 21,98 | 0,64 | 0,95 |
| 19 | 22,44 | 0,54 | 0,95 |
| 20 | 22,37 | 0,53 | 0,95 |
| 21 | 21,64 | 0,72 | 0,95 |
| 22 | 22,038 | 0,71 | 0,95 |
| 23 | 22,27 | 0,70 | 0,95 |

In order to determine the reliability of the misconception diagnosis test, Cronbach's Alpha coefficient was calculated and this value was found to be 0.95 for the entire test. It has been determined that the misconception diagnosis test is highly reliable in revealing students' misconceptions about fractions.

**Discussion and Conclusion**

The aim of this study is to develop a valid and reliable test to be used to reveal misconceptions about sixth grade fractions. Some steps were followed during the test development process. After the purpose of the test was determined, the topic was selected. Then, the creation of the item pool and receiving expert opinions were completed. After the purpose of the test was determined, the topic was selected. Then, the test was given its initial version and the consultation with experts was completed. In order to ensure the content validity of the test, a table of specifications containing the relevant misconceptions was created. Following the application, item analyzes were conducted. Finally, the reliability analysis of the test was performed and the test was given its final form. In the literature, many misconception detection test development studies have been carried out using similar steps (Kiris, 2008; Kaplan et al., 2011; Ozdes, 2013; Sahiner, 2018; Kaya, 2018; Oksuz & Basısık, 2019; Baran Bulut et al., 2021).

Although the difficulty values of the items in the created test varied between 0.18 and 0.56, the average difficulty index was found to be 0.37. Test items are generally expected to have item difficulty values of 0.50 (Karip, 2008). This shows that the difficulty value of the test is close to what it should be. The discrimination values of the test items vary between 0.33 and 0.98. The average discrimination value of the test was calculated as 0.69. This proves that the test items have high discrimination power. In addition, since there were no items with a discrimination value below 0.30, no items were removed (Buyukozturk et al., 2020; p. 128).

Since the developed test included two stages, reliability analysis was conducted for both stages. Since the students' answers were scored as 1 and 0 in the first stage, the KR-20 Kuder-Richardson reliability coefficient was used and this value was calculated as 0.93. Cronbach Alpha reliability coefficient was used to determine whether the second stage of the test and the first stage worked in harmony. This value was calculated as 0.95 for the entire test. These results prove that the developed test is highly reliable.

### *Recommendations*

Since the subject of fractions forms the basis of many subjects, its applicability can be measured not only to secondary school students but also to high school students and mathematics teacher candidates.

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