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Research Article

DEVELOPMENT AND IMPLEMENTATION OF A FIVE-TIER DIAGNOSTIC TEST TO IDENTIFY STUDENT MISCONCEPTIONS ON FRACTIONS: A SIGNIFICANT STEP TOWARDS IMPROVING MATHEMATICS EDUCATION

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Abstract
Misconceptions in fractions, a significant challenge in mathematics education, occur when students' conceptions do not align with scientific conceptions, yet they firmly believe in the correctness of their conceptions. These deeply rooted misconceptions are difficult to eliminate and not easily identified with conventional instruments. Therefore, this study aims to develop a valid and reliable five-tier diagnostic test instrument to identify students' misconceptions about fractions effectively. The design of this development research involves qualitative and quantitative methods using the 4D model (define, design, develop, disseminate). Sixty-eight seventh-grade students were involved in quantitative instrument quality testing; data were analyzed using SPSS. The final result of the development of this instrument was 12 questions declared valid and reliable. Furthermore, the instrument was applied to 30 seventh-grade students in different schools to identify their misconceptions about fractions. Based on the analysis of the combination of students' answers, it was obtained that 36.4% of students understood the concept, 8.9% were in the false positive category, 7.2% were false negative, 9.7% lacked knowledge, and 37.8% had misconceptions. It was found that the most dominant description of misconceptions (33%), namely, students assume that the smaller the denominator of a fraction, the smaller the value of the fraction. Then, it was also found that students' thinking, in general, causes misconceptions to occur. The practical implication of the results of this study is that teachers can use the instrument and identify misconceptions to develop more effective teaching methods, thereby improving mathematics education by helping students avoid and anticipate misconceptions.

Keywords: Five-Tier Diagnostic Test, Fraction, Misconception

INTRODUCTION

Understanding concepts is the most essential stage that students must achieve to make it easier to continue to the next level of understanding mathematics. If one mathematical concept is not mastered, other higher or related concepts will be complex for students to understand (Fatonah, U., & Wicaksana, 2023; Fakhroni, & Puotier, 2023; Kastira & Irwan, 2023; Wulansari, Oktamaypasha, & Setiaji, 2023; Saputri et al., 2024; Syahputra & Edwards, 2024). A good understanding of concepts is the foundation for developing good problem-solving skills. Students with good problem-solving abilities will use their conceptual understanding to solve problems (Saputra & Mustika, 2022; Joy, She, & McCrory, 2023; Salsabila et al., 2023; Wulandari, Yolviansyah, & Misastri, 2023; Binti M & Adeshina, 2024). When students' conceptions do not match scientific concepts but are still confident in their understanding, they can be said to have misconceptions (Maison, Kurniawan et al., 2022; Sandra et al., 2022; Novianti et al., 2023; Sari, Omeiza, & Mwakifuna, 2023). Therefore, it is crucial to evaluate concept understanding by identifying various types of misconceptions that students may experience.

This misconception can occur in mathematics learning, one of which is in fraction material. Fraction material is a prerequisite for understanding mathematical concepts at the next level of material, so understanding the concept of fractions is very necessary. However, the reality in the field is that students still experience errors in understanding the concept of fractions (Pedersen & Bjerre, 2021; Ulfa et al., 2021; Kharis, Namatsi, & Sengai, 2023; Asamoah et al., 2024; Fitria et al., 2024). This is shown from the results of observations conducted from one of the junior high schools in Jambi city, and it was found that when asked about the result of the addition of the fraction of $\frac{1}{3}+\frac{2}{3}$. They answered that the result was $\frac{3}{6}$, then $\frac{1}{2}+\frac{2}{6}$ was equal to $\frac{3}{8}$. This result was obtained from the addition between the numerators and between the denominators; they still equate the concept of addition in integers and fractions. Here, it can be seen that there has been a procedural misconception; namely, they do not understand the concept of adding fractions, both for the same and different denominators. In addition, misconceptions regarding the concept of fractions have also been carried out by several previous researchers (Alkhateeb, 2020; Dash, 2020; Jarrah et al., 2022) show that the most common mistakes students make in the concept of fractions are conceptual and procedural errors, namely when comparing, ordering, and performing fractional number calculation operations.

This misconception problem is deep-rooted and difficult to eliminate (Kibirige & Mamashela, 2022; Safitri et al., 2023; Çelen, 2023; Anggraeni, Rassy, & Sereesuchat, 2023). Misconceptions can cause them to continue to make mistakes in solving problems, not because they do not understand how to solve problems but because they believe and apply the wrong basic concepts. If not addressed immediately, students' misconceptions will continue to the next level of education and can even continue until the student is an adult (Fitriani et al., 2023; Maison et al., 2023; Naimah, Villamor, & Al Wosabi, 2024). One of the initial steps that needs to be taken in overcoming this misconception is identification. Identification of student conceptions, including misconceptions that occur in students, can be done using diagnostic test instruments (Andriani et al., 2021; Dewi, 2022; Maison, Kurniawan, et al., 2022). Various diagnostic test instruments have been used to measure misconceptions, including concept maps, interviews, multiple-choice tests, and open-ended questionnaires (Mukhlisa, 2021; Azahra & Wasis, 2023). Many other researchers have used the four-tier test to identify misconceptions (Kiray & Simsek, 2021; Maison, Asma, et al., 2022). It is stated that by using this four-tier test one can find out in depth the level of students' understanding of a concept. However, dealing with misconceptions will be more effective if the cause of the misconception is known. In this regard, the five-tier test has been developed (Banawi et al., 2022; Fitriani et al., 2023; Rokhim et al., 2023) which states that the novelty of the five-tier test provides a more comprehensive approach and organized structure in exploring students' understanding, thereby helping teachers and researchers better understand where students' difficulties lie in understanding concepts. This test has five tiers with the first tier being a question of answer choices, the second tier being confidence in the answer, the third tier being a choice of reasons, the fourth tier showing confidence in the reasons, and the fifth level being a questionnaire about the source of students' answers in answering (Kusuma, 2020; Fitriani et al., 2023; Maison et al., 2023).

Multiple-choice tests are one of the most widely used diagnostic test instruments to identify misconceptions because they are easy to apply (Ramadany, 2020; Suwarni, 2021; Soeharto, 2021). However, multiple-choice questions have several limitations in determining whether students give the correct answer on a test consciously or just by chance. Several researchers have developed related to this statement, multiple-choice tests into diagnostic levels consisting of several levels, namely two-tier (Tukiyo et al., 2023), three-tier (Asih & Saptono, 2021), four-tier (Ekacitra et al., 2021; Istiyono, 2022; Maison et al., 2021), to five-tier (Fitriani et al., 2023; Maison et al., 2023).

The five-tier test is one of the latest developments that has been carried out on multi-tier multiple-choice tests. The five-tier diagnostic test is developed from the four-tier diagnostic test. The first tier is in the form of multiple-choice questions, the second tier in the form of confidence in the answer, the third tier in the form of a choice of reasons, the fourth tier shows confidence in the reasons, and the fifth level in the form of a questionnaire about the source of students' answers in answering (Azahra & Wasis, 2023; Maison et al., 2023; Fernande, Sridharan, & Kuandee, 2024). This five-tier test can identify the profile of misconceptions and the causes of students' misconceptions. The novelty of this five-tier provides a more comprehensive approach and organized structure in exploring students' understanding, thus helping teachers and researchers better understand where students' difficulties lie in understanding concepts (Rosita et al., 2020; Wijaya & Mufit, 2023).

Research related to the use of five-tier diagnostic tests has been conducted by several previous researchers, including research by Inggit et al., (2021) entitled "Identifikasi Miskonsepsi Dan Penyebabnya Menggunakan Instrumen Five-Tier Fluid Static Test(5tfst) Pada Peserta Didik Kelas XI Sekolah Menengah Atas". This study was conducted in one public school in Bandung City and two schools in Kuningan Regency with a total of 217 students. The study results showed that the Five-Tier Fluid Static Test (5TFST) instrument with the CDQ analysis technique can identify what misconceptions students experience and their causes. Furthermore, research by Maison et al., (2019) on identifying student misconceptions on work and energy material to find out the misconceptions experienced by 288 students in the class. The study results showed that, on average, students experienced misconceptions about work and energy material with a percentage of <30%, namely 24% (low category). Furthermore, Elvia et al., (2020) research on the identification of misconceptions that occur in participants of the Chemistry Mathematics course during online learning at the Chemistry Education Study Program, University of Bengkulu, in the 2020/2021 academic year. The results of the study showed that online learning impacted misconceptions in participants of the Chemistry Mathematics course, with a range of 0-50%, and the highest misconception identification results were found in the application of inverse trigonometric functions (50%). In comparison, 0% of misconceptions were obtained regarding essential algebraic functions and changing rational equations into partial fractions. Specifically in mathematics material, especially in fraction material, identification of misconceptions using diagnostic tests has been carried out quite a lot by previous researchers, including using essay questions, interviews, CRI, three-tier, and so on (Alkhateeb, 2020; Dash, 2020; Jarrah et al., 2022).

This study differs from previous studies in several key aspects. Previous studies, such as Maison et al. (2019), Elvia et al. (2020) and Inggit et al. (2021), focused on misconceptions in physics and chemistry, such as fluid statics, work and energy, and chemical mathematics, while this study targets explicitly misconceptions in fractions in mathematics. This study develops a valid and reliable five-tier diagnostic test for fractions, while previous studies have not applied the five-tier instrument to this topic. In addition, previous studies were generally conducted at the high school or college level and focused on topics other than mathematics. In contrast, this study focused on junior high school students with fundamental mathematics material. Using a five-tier diagnostic test on fractions provides a new contribution to identifying misconceptions in mathematics learning, which has not been widely explored before, thus filling the gap in research related to identifying misconceptions in this material.

This study has a significant gap compared to previous studies, which generally focus on identifying misconceptions in physics and chemistry (such as fluid statics, work and energy, and chemical mathematics) using five-tier diagnostic instruments. However, misconceptions about fraction material in mathematics, essential basic concepts for mastering advanced concepts, have not been widely studied using five-tier diagnostic tests, especially among junior high school students. The urgency of this study lies in the importance of overcoming misconceptions about fractions, which are often fundamental and ongoing and can hinder students' understanding at higher levels of education. The problem-solving plan in this study is to develop a more comprehensive and structured five-tier diagnostic instrument to identify misconceptions in more depth. This instrument cannot only detect misconceptions but also identify their causes so that teachers and researchers can be more precise in designing interventions. This five-tier diagnostic test involves five levels: answer choices, level of confidence in the answer, reasons, confidence in the reasons, and sources of students' answers.

The purpose of this study is to develop a valid and reliable five-tier diagnostic test instrument to identify misconceptions about fractions among junior high school students. Thus, this study is expected to provide an effective tool for detecting and overcoming misconceptions about fractions and to serve as a reference for teachers in improving students' understanding of mathematical concepts.

RESEARCH METHOD

The design of this study is a research and development involving qualitative and quantitative processes to produce a five-tier diagnostic test instrument that can be used to identify students' misconceptions of the concept of fractions. The development model is the 4D model, which consists of 4 main stages: Define, Design, Develop, and Disseminate (Setiawan & Faoziyah, 2020)In this model, researchers develop a misconception instrument until it is of good quality. After the product is declared valid and reliable, the instrument is implemented to identify students' misconceptions about fractions. Research respondents are needed to test the instrument's feasibility and obtain data on students' misconceptions of fractions. For this first purpose, 68 SMPN 22 Jambi City students from several different classes are willing to participate in the instrument trial stage. Furthermore, after obtaining a valid and reliable instrument, this instrument was implemented for 30 SMPN 24 Jambi City students.

This study collected two types of data: qualitative data at the stage of developing a five-tier diagnostic test involving experts as validators and quantitative data during the instrument trial and during implementation in actual classes. Qualitative data was collected using open tests, student interviews, and validation sheets filled out by experts during the five-tier diagnostic test development process. Quantitative data was collected using a five-tier diagnostic test during the trial and implementation (in different schools).

The trial data were analyzed using SPSS 22 statistical software, which can provide construct validity results using factor analysis and reliability using Cronbach's alpha. In factor analysis, several assumptions and initial requirements must be met, including the Kaiser Meyer Olkin (KMO) and Measure Sampling Adequacy (MSA) values must be > 0.5 (Sanida & Prasetyawati, 2023). Then, for reliability with Cronbach's alpha, it is said to be reliable if the alpha value is > 0.60 (Slamet & Wahyuningsih, 2022).

After the diagnostic test is declared valid and reliable with the provisions that have been applied, the instrument is implemented. Based on the results of applying this five-level misconception diagnostic test, from level 1 to level 4, students' conceptual understanding can be known. Then, from level 5, the causes of misconceptions experienced by students can be identified. From these data, students' answers are sorted for each question item to determine the conceptual understanding and causes of misconceptions each student possesses. The variation of students' answers consists of five categories: students understand the concept (scientific conception), lack of knowledge, false positive, false negative, and misconception. Table 1 presents the categories of students' answers to the five-level misconception diagnostic test.

Table 1. Five-tier test answer variations

Tier 1	***Tier 2***	***Tier 3***	***Tier 4***	***Tier* 5**	***Decision***	
B	Y	B	Y	Books	Conceptual understanding comes from books	PK-B
				Internet	Conceptual understanding comes from the internet	PK-I
				Teachers	Conceptual understanding comes from teachers	PK-G
				Personal Thoughts	Conceptual understanding comes from personal thoughts	PK-P
				Friends	Conceptual understanding comes from friends	PK-T
				Others	Conceptual understanding comes from others	PK-O
B B	Y TY	B B	TY Y	Books	Lack of knowledge comes from books	KP-B
B B	TY Y	B S	TY TY	Internet	Lack of knowledge comes from the internet	KP-I
B B	TY TY	S S	Y TY	Teachers	Lack of knowledge comes from teachers.	KP-G
S S	Y TY	B B	TY Y	Personal Thoughts	Lack of knowledge comes from personal thoughts.	KP-P

Tier 1	*Tier* 2	*Tier* 3	*Tier* 4	*Tier* 5	**Decision**	
S S	TY Y	B S	TY TY	Friends	Lack of knowledge comes from friends.	KP-T
S S	TY TY	S S	Y TY	Others	Lack of knowledge comes from others	KP-O
B	Y	S	Y	Books	False Positive comes from books	FP-B
				Internet	False Positive comes from the internet	FP-I
				Teachers	False Positive comes from teachers	FP-G
				Personal Thoughts	False Positive comes from personal thoughts	FP-P
				Friends	False Positive comes from friends	FP-T
				Others	False Positive comes from others	FP-O
S	Y	B	Y	Books	False Negative comes from books	FN-B
				Internet	False Negative comes from the internet	FN-I
				Teachers	False Negative comes from teachers	FN-G
				Personal Thoughts	False Negative comes from personal thoughts	FN-P
				Friends	False Negative comes from friends	FN-T
				Others	False Negative comes from others	FN-O
S	Y	S	Y	Books	Misconceptions come from books	M-B
				Internet	Misconceptions come from the internet	M-I
				Teachers	Misconceptions come from teachers	M-G
				Personal Thoughts	Misconceptions come from personal thoughts	M-P
				Friends	Misconceptions come from friends	M-T
				Others	Misconceptions come from others	M-O

The category of conception level used is based on the combination of four-tier answers in the study. To analyze the combination of students' answers on the five-tier diagnostic test instrument, the various categories of conception levels are then regrouped into several categories based on students' learning resources (Gurel et al., 2015). After the combination of students' answers is categorized, the percentage of the category of students' understanding level is calculated. The percentage of each category is calculated using the following equation.

$$P = \frac{f}{N} \times 100\% \qquad ...(1)$$

Description:
P = percentage number
f = frequency whose percentage value is being searched
N = Number of Cases (Total frequency/number of individuals)

RESULTS AND DISCUSSION

The following are the development stages using the 4D model:

Define

At the definition stage in this study, a needs analysis was carried out, starting from literature studies, observations, and interviews. Based on the results of literature studies (Ulfa et al., 2021), it was found that the problem often found in mathematics learning is misconceptions, one of which is in the material of fractions. Then, in March, at Junior high school 22 Jambi City, observations and interviews were conducted with mathematics teachers and grade VII students. The questions asked in the interview with a teacher were about how teachers can determine students' conceptual understanding of fraction material and how teachers process data by assessing students' level of understanding. Then, the interviews conducted with students referred to questions related to the concept of fractions. The results of this needs analysis are used as a reference in creating a five-tier diagnostic test instrument to support teachers in assessing students' level of conceptual understanding of the concept of fractions. This is also supported by previous research, which shows that students' conceptual understanding abilities in basic fraction concepts are still low (Amankwaah et al., 2024; Hidayat, K. R, C., & Ale, 2024).

Design

At the design stage, a question grid was prepared based on the needs analysis in the previous stage. Several indicators were obtained that would be used as a reference in the development of this instrument, including understanding the concept of fractions as part of a whole (part to whole), comparing and ordering fractional numbers, and fractional arithmetic operations (Addition, subtraction, multiplication, division). This is also supported by several relevant works of literature which state that misconceptions that often occur in the concept of fractions are conceptual and procedural errors, namely when comparing, ordering, and performing fractional number calculation operations (Alkhateeb, 2020; Dash, 2020; Jarrah et al., 2022). Based on the question grid, 13 questions were obtained. At this stage, the design of the five-tier diagnostic test instrument was also designed, as can be seen in Figure 1.

1.1 (The first tier consists of multiple-choice questions)
   a. ....
   b. ....
   c. ....

1.2 (The second tier is the level of student confidence in choosing the first tier)
   a. Sure
   b. Not sure

1.3 (The third tier contains a choice of reasons for answering the first tier)
   a. ....
   b. ....
   c. ....

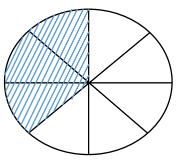
1.4 (The fourth tier is the level of student confidence in choosing the reasons in the third tier)
   a. Sure
   b. Not sure

1.5 (The fifth tier is a choice of information sources in answering)
   a. ....
   b. ....
   c. ....

Figure 1. Five-tier diagnostic test instrument design

Develop

The development of this five-tier diagnostic test instrument began with an open test. This open test is an essay question that has been made based on the previous grid. This test was administered to 28 Junior high school 22 Kota Jambi class VII B students. In this test, students were free to answer the questions in their way. Multiple-choice options will be based on the student's answers for answer choices (tier-1) or reason choices (tier-3). Interviews were also conducted with students to obtain more in-depth answers. The questions asked were related to the answers that the students had made. Then, based on the results of the open test analysis, a five-tier diagnostic test instrument was prepared. The prototype of the five-tier diagnostic test instrument that has been made is as figure 2.

Item 1	
1.1	Determine the fractional value of the shaded part of the total area in the following image.  a. $\frac{5}{3}$ b. $\frac{3}{8}$ c. $\frac{3}{5}$ d. Other
1.2	Are you sure about your answer? a. Sure. b. Not sure
1.3	The reason you chose the answer at tier 1.1 is … a. The unshaded part is the numerator, and the shaded part is the denominator. b. The shaded part is the numerator, and the whole part is the denominator. c. The shaded part is the numerator, and the unshaded part is the denominator. d. Other…………………………………………………………
1.4	Are you sure about your reasons? a. Sure. b. Not sure
1.5	The source of information you use to answer is … a. Book d. Personal thoughts

	b. Internet c. Teacher	e. Friend f. Other …

Figure 2. Sample item of a five-tier diagnostic test instrument

In Figure 2, the form of the five-tier diagnostic test instrument can be seen. Before being tested, this instrument was first validated by a team of experts and practitioners. The team of experts consisted of two Universitas Jambi Mathematics Education lecturers and a practitioner expert, namely one of the mathematics teachers at Junior high school 22 Kota Jambi. The form of the validation instrument used to assess the product is a question sheet consisting of aspects of instructions, aspects of test coverage, and aspects of language. Based on the validation instrument, there are several comments and suggestions from the validator in Bahasa Indonesia, as can be seen in the following Table 2.

Table 2 Suggestions and comments from validators and improvements from researchers

Validator	Suggestion	Revision
Expert	1. Add mixed fractions questions 2. Add and revise question instructions 3. Sort the questions according to the material's order and difficulty level. 4. The language used in the questions does not conform to Indonesian language rules. 5. Pay attention to the uniformity of alternative answers and use clear and easy-to-understand sentences. 6. Create variations of questions that can be linked to contextual problems.	1. Adding mixed fractions questions 2. Fixing the question instructions 3. Sort the questions according to the material's order and difficulty level. 4. Improve language usage according to Indonesian language rules 5. Improve alternative answers by paying attention to uniformity with other alternative answers. 6. Changing item 3 to contextual
Practitioners	1. The order of the students' reason options (tier 3) in answering questions should be the same as the order of the answer options in tier 1.	1. Match the order of the reason options (tier 3) with the answer options (tier 1)

A revision was made based on the comments and suggestions from the validator in Table 1. After the instrument was declared feasible by the validator, it could be continued to the test stage of the question feasibility. This test was conducted on 68 Junior high school 22 Kota Jambi students in grades VII G, VII H, and VII I. This test was used to determine the construct validity of each question item based on the loading value using factor analysis (Putri & Febrilia, 2024). Furthermore, the instrument's reliability was determined based on Cronbach's alpha value. The validity value of the instrument can be seen in Table 3.

Table 3. Instrument Validity

	Component			
	1	2	3	4
Item 5	.820			
Item 4	.760			
Item 7	.736			.423
Item l8	.718			
Item 6	.689			
Item 12		.911		
Item 13		.863		
Item 11		.858		
Item 1			.897	
Item 3			.879	
Item 9				.878

Item 10	.455	.681

Based on Table 3, the loading value of each question can be seen. The loading value shows the correlation between the indicator and its construct. Factor 1 consists of five questions, namely questions 4, 5, 6, 7, and 8. Factor 2 consists of three questions, namely questions 11, 12, and 13. Factor 3 consists of two questions, namely questions 1 and 3. Finally, factor 4 consists of two questions, namely questions 9 and 10. Of the 13 questions, there is 1 item that is not displayed, namely question 2; this is because the question does not meet the criteria in the previous factor analysis stage, namely the KMO and MSO values <0.50 (Putri & Febrilia, 2024). So, it is not valid for use. Then, the reliability value is obtained at 0.758. Because 0.758> 0.6, it can be concluded that the instrument developed is reliable (Slamet & Wahyuningsih, 2022).

Disseminate

From the question feasibility test results, 12 questions were obtained that were suitable for use in the application test. This application trial was conducted on 30 Junior high school 24 Kota Jambi class VII E students. The percentage of students' concepts and misconceptions regarding the concept of fractions was obtained as follows:

Percentage of Correct Answers

The data analyzed for correct answers were one-level tests (level 1), two-level tests (level 1 and level 3), and four-level tests (level 1 to level 4). The assessment method used was the same as (Gurel et al., 2015). The graph in Figure 3 shows the percentage of students who answered correctly.

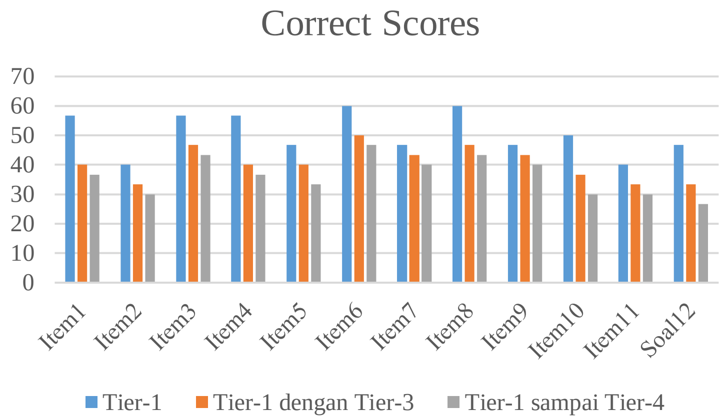


Figure 3. Percentage of student correct answers

In the graph in Figure 3, it can be seen that the highest percentage is in the “tier-1” category, then “tier-1 and tier-3”, and finally “tier-1 to tier-4”. This shows that the more tiers used, the lower the percentage of students' correct answers. However, this proves that some students still answer questions without understanding the concept thoroughly. Then the highest percentage of correct answers for “tier-1 to tier-4” is in question number 6, which is 46.7%, meaning that question number 6 is a question that is relatively easy for students to understand, while the lowest is in question number 12, which is 26.7%, meaning that the concept in this question is relatively tricky for students to understand.

Percentage of Misconceptions

Misconception data analysis was carried out the same way as for correct answers, but the scoring was adjusted to the description of the misconception obtained (Table 4). Students who answered according to the answers in the table were given a score of 1, and those who were wrong were given a score of 0. Misconception data analysis was not done by scoring each question as the correct answer. However, the scoring was adjusted to the description of the misconception (Gurel et al., 2015).

Table 4. Description of misconceptions

Code	Misconception Description	Item
M1	In fractions, the denominator is the remainder of the whole.	Item 1 (C, A, C, A)
M2	In a fraction, the numerator is the remainder of the whole.	Item 1 (A, A, A, A)
M3	The smaller the denominator, the smaller the fraction.	Item 2 (A, A, A, A)
M4	The larger the denominator, the smaller the fraction, without involving the numerator.	Item 2 (B, A, B, A)
M5	Operations on addition and subtraction of fractions are the same as integer operations.	Item 3 (A, A, A, A) Item 4 (B, A, B, A) Item 5 (A, A, A, A) Item 6 (B, A, B, A) Item 7 (A, A, A, A)
M6	Calculation operations on fractions are carried out by cross-multiplying the numerator and denominator.	Item 3 (C, A, C, A) Item 4 (A, A, A, A) Item 5 (C, A, C, A) Item 6 (C, A, C, A) Item 7 (C, A, C, A) Item 8 (B, A, B, A) Item 9 (A, A, A, A)
M7	Multiplication and division of fractions have the same procedure as adding and subtracting fractions with the same denominator.	Item 8 (C, A, C, A) Item 10 (C, A, C, A)
M8	The operation of dividing a fraction by a fraction is the same as the operation of multiplying a fraction by a fraction.	Item 10 (B, A, B, A) Item 11 (A, A, A, A) Item 12 (B, A, B, A)
M9	Dividing a fraction by a fraction is the same as multiplying a fraction by a fraction; then, the numerator and denominator are cross-multiplied.	Item 11 (B, A, B, A)

Table 4 shows that based on the analysis, nine types of misconception descriptions were obtained on the concept of fractions. Code M1 means the first type of misconception, and Code M2 means the second type of misconception, and so on. Then for item 1 (C, A, C, A) in section M1, it means that the first type of misconception is found in question 1 with the answer key (C, A, C, A) for the first to fourth levels. Then based on the analysis of the misconception description, the following percentages were obtained figure 4.

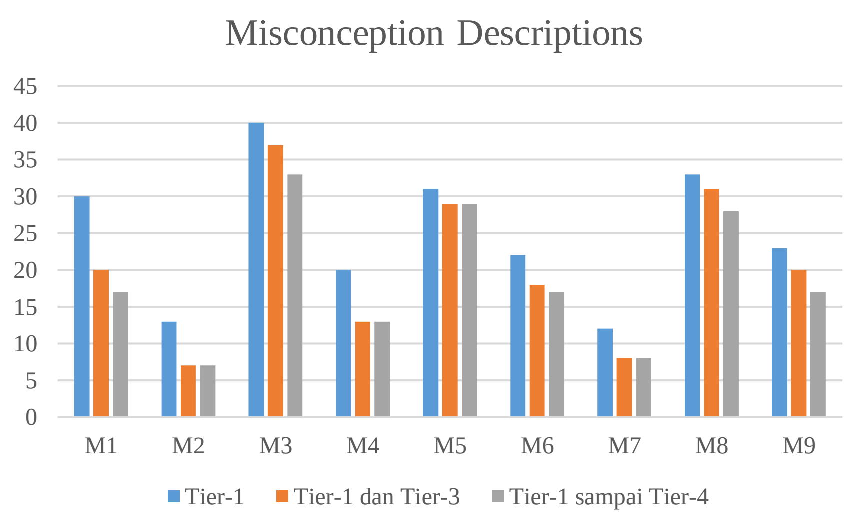


Figure 4. Percentage graph of misconception descriptions

Based on the graph in Figure 4, the highest percentage is in the one-level test (tier-1), followed by the two-level test (tier-1 and tier-3), and finally, the four-level test (tier-1 to tier-4). This means that the percentage has decreased from the one-level test (tier-1) to the four-level test (tier-1 to tier-4), although not significantly. This also shows that there is an incomplete understanding of the concept.

Overall, the third misconception (M3) has the highest percentage of misconceptions, at 33%, in item 2, the smaller the value of the denominator of a fraction, the smaller the fraction. The lowest percentage of misconceptions is in misconception one (M2), at 7%, in item 1, that in the concept of fractions, the numerator is the remainder of the entire fractional part.

Apart from analyzing correct answers and misconceptions, an analysis of false positives, false negatives, and lack of knowledge was also carried out. The percentage obtained can be seen in Table 5 .

Table 5. Percentage of false positives, false negatives, and lack of knowledge

Category	Item (%)												Mean (%)
	1	2	3	4	5	6	7	8	9	10	11	12	
False Positive	16.7	3.3	6.7	16.7	6.7	10	0	10	3.3	13.3	6.7	13.3	8.9
False Negative	10	6.7	6.7	3.3	10	0	13.3	3.3	13.3	10	3.3	6.7	7.2
Lack of Knowledge	10	13.3	10	3.3	6.7	3.3	6.7	6.7	10	10	20	16.7	9.7

Based on table 3, it can be seen that the percentage of false positives is 8.9% with the highest false positives found in items 1 and 4 and the lowest false positives found in item 7. The percentage of false negatives is 7.2% with the highest false negatives found in items 7 and 9 and the lowest in item 6. Finally, the percentage of lack of knowledge was obtained at 9.7% with the highest lack of knowledge in item 12 and the lowest in items 4 and 6.

Furthermore, apart from being able to identify 5 categories of conceptions in students, this five-tier instrument can also summarize sources of information that cause misconceptions. From the percentage results at tier-5, it was found that the source of information that caused misconceptions was predominantly caused by the personal thoughts of the students themselves with a percentage of 31.9%. The percentage results from each information source used are as follows.

Table 6. Percentage of causes of misconceptions based on information sources

M	Item												%
	1	2	3	4	5	6	7	8	9	10	11	12	
MB	0	0	3.3	3.3	6.7	3.3	6.7	0	6.7	0	0	0	2.5%
MI	0	0	0	0	0	3.3	0	3.3	0	0	0	0	0.5%
MG	0	0	0	0	0	0	0	3.3	0	0	0	0	0.3%
MP	23.3	43.3	30	36.7	33.3	30	30	30	20	36.7	33.3	36.7	31.9%
MT	3.3	3.3	0	0	3.3	3.3	3.3	3.3	6.7	0	6.7	0	2.8%

Implementing a five-tier diagnostic test for fractions has broader implications for mathematics education. By shifting from traditional assessments that focus purely on correctness to diagnostic tools that explore student reasoning, educators can: (1) Improve Conceptual Understanding: By diagnosing misconceptions early, teachers can intervene before flawed understanding becomes ingrained. This supports a more robust conceptual foundation crucial for more advanced mathematical thinking. (2) Tailor Instructional Approaches: Teachers can adjust their teaching strategies based on the diagnostic insights. For instance, if a significant portion of the class shares a specific misconception, targeted remediation can be incorporated into lessons.

CONCLUSION

Developing and implementing a five-tier diagnostic test represents a significant step forward in addressing student misconceptions in mathematics, particularly concerning fractions. This instrument offers valuable insights that can transform teaching practices and improve learning outcomes based on student conceptions by providing a more nuanced view of student understanding and reasoning. As more educators adopt this approach, it can revolutionize mathematics education by fostering deeper conceptual understanding and reducing the prevalence of persistent misconceptions. The success of this diagnostic test also points to the need for similar tools in other areas of mathematics and science education, where misconceptions often hinder student progress.

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AUTHOR CONTRIBUTIONS

Conceptualization, Herliana, Maison, and Syaiful; Software, SPSS statistic 22 software; Validation, Nizlel Huda; Investigation, students, teachers, and staff of Junior high school 22 Kota Jambi, and Junior high school 24 Kota Kambi.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

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