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# Academia Open



*By Universitas Muhammadiyah Sidoarjo*

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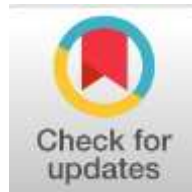
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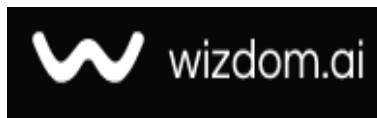
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# Diagnostic Four-Tier Test Instrument for Elementary Fraction Misconceptions: Instrumen Tes Diagnostik Four-Tier untuk Miskonsepsi Pecahan Sekolah Dasar

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## Abstract

**General Background:** Misconceptions are a primary factor contributing to students' low conceptual understanding of mathematics, particularly in fraction topics at the elementary school level. **Specific Background:** Observations and interviews at SDN 001 Nunukan revealed that fourth-grade students experience significant misconceptions when comparing, ordering, and representing fractions, which remain undetected by current assessment practices. **Knowledge Gap:** Existing assessments primarily focus on binary correctness and fail to provide a comprehensive analysis of students' underlying reasoning and confidence levels. **Aims:** This study aimed to develop a four-tier diagnostic test instrument to identify these specific misconceptions in grade IV students. **Results:** The developed instrument achieved high validity (Aiken's  $V = 0.833$ ) and very high reliability ( $KR_{20} = 0.846$ ), with practicality scores of 88.25% from students and 78.12% from teachers. Effectiveness testing revealed that more than half of the students held misconceptions regarding several fraction concepts, effectively mapping their understanding into four categories: conceptual understanding, partial understanding, lack of understanding, and misconceptions. **Novelty:** This research produced a specialized diagnostic tool capable of identifying multi-dimensional errors, including conceptual, procedural, and representational misconceptions. **Implications:** The instrument serves as a critical diagnostic tool for educators to design targeted remedial interventions and instructional strategies tailored to individual learning needs, thereby improving mathematics learning quality.

## Highlights

- ♦ The four-tier test structure successfully distinguishes between true conceptual knowledge and guessed responses by integrating confidence levels.
- ♦ Assessment items demonstrated high internal consistency and reliability, confirming the instrument's stability as a repeated diagnostic measure.
- ♦ Data analysis reveals that misconceptions regarding fraction representation and comparison remain prevalent among primary-level learners.

## Keywords

Four-Tier Diagnostic Test; Misconceptions; Fractions; Elementary School; Instrument Development

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## INTRODUCTION

Mathematics is one of the subjects taught at the elementary school level. Mathematics is a field of study that students learn continuously, from elementary school to higher education [1]. In mathematics learning, conceptual understanding is the most fundamental aspect and serves as the primary objective that students are expected to achieve [2]. Mathematical conceptual understanding enables students to comprehend the relationships among concepts and apply them flexibly, accurately, effectively, and appropriately in solving problems [3]. Conceptual understanding should be developed from the elementary school level, as this period represents a crucial stage of students' physical and cognitive development, during which they are highly receptive to acquiring new knowledge [4]. Conceptual understanding serves as the foundation for learning mathematics; therefore, students need to possess a strong understanding of mathematical concepts in order to solve various mathematical problems effectively [5]. Consequently, mathematics instruction in elementary schools should emphasize the development of conceptual understanding rather than merely focusing on the memorization of formulas or procedures.

Low learning achievement remains a common problem in mathematics education [6]. One of the efforts made by teachers to address this issue is modifying instructional methods, utilizing learning media, or implementing different learning models. These efforts can improve learning outcomes if the interventions are aligned with the specific difficulties experienced by students. However, when the interventions are not appropriate, such changes may not significantly improve students' learning outcomes. This finding is consistent with the study of [7], which emphasizes that addressing students' learning difficulties requires teachers to possess the ability to conduct initial identification and diagnosis of the problems experienced by learners. Therefore, before determining the appropriate instructional approaches, strategies, and methods, teachers need to analyze the underlying causes of students' learning difficulties. Such analysis is essential to ensure that the interventions provided are tailored to students' needs and their level of conceptual understanding [8].

Based on observations and interviews conducted in Grade IV at SDN 001 Nunukan, it was found that some students still experienced misconceptions regarding fractions, particularly in comparing and ordering fractions. Students tended to apply whole-number reasoning, assuming that fractions with smaller denominators have smaller values. In addition, teachers had not systematically identified students' misconceptions, and assessment practices were still focused primarily on whether answers were correct or incorrect. As a result, students' misconceptions were not optimally detected and were likely to persist throughout the learning process.

To address this issue, the researcher developed a four-tier diagnostic test instrument to identify students' misconceptions. A four-tier test is a multiple-choice diagnostic assessment that integrates several supporting components, enabling it to effectively detect students' misconceptions [9]. The four-tier diagnostic test was selected because it provides a more comprehensive analysis of students' understanding through four levels: the answer choice, the confidence level in the selected answer, the reason for the answer, and the confidence level in the chosen reason. Nur & Siahaan, (2023) conducted a review to examine the effectiveness of four-tier tests in identifying misconceptions [10]. Based on their analysis of both national and international studies, they concluded that the four-tier diagnostic test is an effective instrument for detecting students' misconceptions. This effectiveness stems from its structure, which not only distinguishes between true and false, but also identifies students' reasoning patterns and cognitive self confidence as indicators of conceptual understanding. This instrument provides diagnostic information for teachers to design more appropriate and effective learning interventions.

## METHOD

This study employed a Research and Development (R&D) approach aimed at developing a four-tier diagnostic test instrument to identify students' misconceptions regarding fractions in Grade IV elementary school. The research was conducted at SDN 001 Nunukan during the second semester of the 2025/2026 academic year, involving one Grade IV teacher and 22 students as participants. The development uses the 4D model of Thiagarajen et al. (1974): define, design, develop, and disseminate. The define stage includes analysis of needs, student characteristics, fraction material, and misconceptions; design involves preparing the design and items for a four level diagnostic test; develop involves validation by material, language, and evaluation experts, then revisions are made based on input. Finally, the disseminate stage involved distributing the validated instrument to elementary school teachers for use in identifying students' misconceptions.

The data in this study were analyzed using both qualitative and quantitative descriptive techniques. Content validity analysis was conducted descriptively to determine the validity level of the developed four-tier diagnostic test instrument. The content validity of the instrument was assessed using Aiken's V index. The evaluation process employed a Likert scale, with the scoring criteria presented in the following table.

**Table 1.** Criteria for Instrument Item Assessment by Validators (Retnawati, 2018)

Rentang Nilai	Kategori
1	Very Invalid
2	Invalid
3	Valid
4	Very Valid

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The content validity results were calculated using Aiken's V formula (Aiken, 1985), as follows:

$$V = \frac{\sum S}{n(C-1)}$$

V : Aiken's validity index

S : score assigned by a rater minus the lowest possible score

r : score assigned by the rater

lo : lowest rating score (1)

C : highest rating score (4)

n : number of raters

An Aiken's V index of less than 0.40 indicates low validity, a value between 0.40 and 0.80 indicates moderate validity, and a value greater than 0.80 indicates high validity [11].

Instrument reliability was analyzed using the KR-20 coefficient. The practicality of the instrument was determined based on the percentage scores obtained from teacher and student response questionnaires, which were subsequently converted into practicality categories. The practicality of the four-tier diagnostic test instrument was determined by analyzing teachers' and students' questionnaire responses. The obtained scores were converted into percentages using the following formula:

$$P = f/N \times 100\%$$

P = Percentage score of the questionnaire results

f = Total score obtained

N = Maximum possible score

The effectiveness data were obtained from students' responses to the eight four-tier diagnostic test items administered during the study. Instrument effectiveness was determined through the analysis of students' response patterns and the identification of misconceptions. The classification of students' responses was based on the conceptual understanding categories developed by (Kaniawati et al., (2019), as presented below [12].

**Tabel 2.** The classification of students responses

KONSEPSI	Kriteria Kombinasi Jawaban Siswa			
	Tier 1	Tier 2	Tier 3	Tier 4
Misconception	Incorrect	Confident	Incorect	Confident
Understand the concept	Correct	Confident	Correct	Confident
Partial Understanding of the Concept	Correct	Not confident	Correct	Not confident
	Correct	Not confident	Correct	Not confident
	Correct	Not confident	Correct	Confident
	Correct	Not confident	Incorrect	Not confident
	Incorrect	Not confident	Correct	Not confident
	Incorrect	Not confident	Correct	Confident
	Correct	Confident	Incorrect	Confident
	Incorrect	Confident	Correct	Confident
	Correct	Confident	Incorrect	Not confident
Lack of Understanding of the Concept	Incorrect	Not confident	Incorrect	Not confident
	Incorrect	Confident	Incorrect	Not confident
	Incorrect	Not confident	Incorrect	Not confident
Uncodable	Unable to answer all tiers or one or more tiers are left unanswered			

## RESULTS AND DISCUSSION

During the define stage, a needs analysis was conducted through an examination of the curriculum, the characteristics of Grade IV elementary school students, fraction concepts, and common misconceptions experienced by students. The analysis revealed the need for a diagnostic instrument that not only measures the accuracy of students' answers but also uncovers their reasoning and confidence levels. Such an instrument enables misconceptions to be identified more accurately and comprehensively.

The design stage involved developing the instrument blueprint based on the learning indicators of the fraction topic and the

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misconceptions identified during the previous stage. Subsequently, four-tier diagnostic test items were constructed, consisting of answer choices, reasons for the answers, confidence levels in the selected answers, and confidence levels in the selected reasons. In addition, scoring guidelines and criteria for interpreting students' levels of conceptual understanding were developed during this stage.

During the develop stage, content validity, reliability, practicality, and effectiveness tests were conducted.

### Content Validity of the Four-Tier Diagnostic Test Instrument

Based on the analysis, the instrument obtained an average validity score of 0.833, which falls within the high validity category. Meanwhile, the evaluation aspect achieved an average validity score of 0.789, indicating a moderate to high level of validity. These findings demonstrate that the developed instrument is suitable for use, although several revisions were made in accordance with the validators' recommendations [13].

### Reliability Testing of the Four-Tier Diagnostic Test Instrument

The reliability test aimed to assess the instrument's consistency in measuring students' misconceptionson fractions. It was analyzed using KR20 with SPSS. The results showed a KR20 value of 0.846, which is categorized as very high. This indicates that the four level diagnostic rest instrument has stronf internal consistency and produces stable and reliable data for identifying fourth grade students' misconceptions on fractions. A high reliability value indicates that each item in the instrument is well-related in measuring the same construct, namely understanding the concept of fractions. According to Arikunto, an instrument with high reliability will produce consistent data when used under relatively similar conditions. Therefore, these reliability results strengthen the instrument's suitability as a misconception diagnostic tool that can be used repeatedly in the learning process.

### Practicality Testing of the Four-Tier Diagnostic Test Instrument

Based on the practicality questionnaire completed by 23 students, a total score of 466 out of a maximum score of 528 was obtained. The analysis yielded a practicality percentage of 88.25%, which falls into the very practical category. This result indicates that the four-tier diagnostic test instrument is easy for students to understand and use [14]. A high level of practicality from a student perspective indicates that the test format, language used, and instructions are well-understood. This is important because overly complex diagnostic instruments can hinder students from accurately expressing their understanding.

Meanwhile, the practicality questionnaire completed by two classroom teachers produced a total score of 50 out of a maximum score of 64. The analysis resulted in a practicality percentage of 78.12%, which is categorized as practical. This finding suggests that the four-tier diagnostic test instrument is practical for use in identifying students' misconceptions. Positive teacher reviews indicate that the instrument is not only easy to use but also provides useful information for planning follow-up learning. This finding aligns with previous research on diagnostic instrument development, which found that practicality is a crucial factor in ensuring sustainable implementation in schools.

### Effectiveness Testing of the Four-Tier Diagnostic Test Instrument

The effectiveness data were obtained from the administration of the four-tier diagnostic test instrument on fraction concepts to Grade IV students at SDN 001 Nunukan. Based on the students' response patterns, the percentages of conceptual understanding were classified into four categories: understanding the concept, partial understanding of the concept, lack of conceptual understanding, and misconception. These percentages were calculated from the combinations of students' responses to each test item, thereby providing a detailed description of students' conceptual understanding across the learning indicators of fraction concepts [15]. The percentages of students' conceptual understanding for each test item are presented in the following table:

**Table 3.** Corrections by validator

Concept assessed	UM	M	PU	LU
Comparing fractions with different denominators	45%	40%	15%	0
Ordering fractions with different denominators	41%	55%	4%	0
Comparing fractions with different numerators	31%	45%	18%	6%
Ordering fractions with different numerators	18%	50%	14%	18%
Relating fractions to pictorial representations	19%	55%	13%	13%
Relating fractions to decimal numbers	32%	54%	0%	14%
Relating fractions to percentages	23%	54%	18%	5%
Determining equivalent fractions	32%	32%	13%	23%

UM :Understanding the Concept M : Misconception

PU: Partial Understanding of the Concept

LU: Lack of Conceptual Understanding

Based on Table 3, the misconception category remained dominant across most test items. The highest percentage of misconceptions occurred in items 2, 5, 6, and 7, with an average of 54.55%. This finding indicates that more than half of students still misunderstand the concept of fractions in these items. Conversely, the highest conceptual understanding was found in item 1, with 45% of students correctly solving the fraction, although this did not reach the total percentage of respondents. The variation in percentages across the different categories suggests that students' levels of conceptual understanding varied among the fraction indicators. These results demonstrate that the four-tier diagnostic test instrument is capable of providing a detailed assessment of students' conceptual understanding and effectively identifying misconceptions in each concept being evaluated [16].

The predominance of misconceptions indicates that the concept of fractions remains a difficult topic for elementary school students to grasp. This finding aligns with Van de Walle's statement that students often struggle to understand the numerator-denominator relationship and the relationship between fractions, decimals and percentages. The high number of misconceptions indicates students' weak ability to connect various mathematical representations. According to Piaget's constructivist theory, this occurs because students are still constructing knowledge schemas that are not fully aligned with correct scientific concepts. Therefore, teachers need to provide more meaningful learning experiences through the use of concrete models, visual media, and exploratory activities that can assist students in reconstructing their concepts.

Furthermore, the instrument's ability to identify variations in students' levels of understanding demonstrates that the four-tier test serves not only as a learning evaluation tool but also as a diagnostic tool capable of uncovering the sources of students' conceptual errors. These findings support research by Caleon and Subramaniam, which found that four-tiered instruments are more effective than conventional multiple-choice tests because they can differentiate between students who truly understand concepts, those with misconceptions, and those who simply guess. Therefore, the information obtained from this instrument can serve as a basis for teachers to design more targeted remedial learning.

Finally, the disseminate stage was carried out by distributing the developed instrument to elementary school teachers as its intended users. The dissemination process involved providing the instrument along with guidelines for its use, enabling teachers to employ it as a diagnostic tool for identifying students' misconceptions in mathematics learning, particularly on fraction concepts. The dissemination process was conducted on a limited scale at SDN 001 Nunukan, involving fourth-grade teachers as the primary users of the instrument to assess its effectiveness in the classroom.

At this stage, teachers provided general feedback based on the results of the instrument's use in class, indicating that the instrument was able to reveal variations in student understanding in greater detail through a combination of answers, reasons, and levels of confidence. These findings indicate that the four-tiered instrument is more effective than conventional tests because it can identify misconceptions in greater depth. Using the 4D model, this instrument has proven valid in uncovering patterns of conceptual errors, thus not only assessing learning outcomes but also providing a basis for teachers to design more targeted learning interventions.

## CONCLUSION

Based on the findings of this study, the four-tier diagnostic test instrument on fraction concepts for Grade IV elementary school students was successfully developed using the 4D model and was found to be valid, reliable, practical, and effective. The instrument was capable of identifying students' levels of conceptual understanding as well as various types of misconceptions, including conceptual, procedural, and representational misconceptions.

Teachers are encouraged to utilize the four-tier diagnostic test instrument to identify students' misconceptions and design more appropriate instructional interventions. Future researchers are recommended to develop similar diagnostic instruments for other subject matters or educational levels. Teachers are advised to use the results of misconception identification as a basis for developing remedial measures, selecting learning strategies, and providing more targeted guidance. Thus, the four-level diagnostic test serves not only as an evaluation but also as an effort to continuously improve the quality of mathematics learning.

This study was limited to 23 fourth-grade students and therefore cannot be generalized. Future research should involve a larger and more diverse sample and test the instrument in various contexts and materials to strengthen external validity.

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