Students Misconception on Algebraic Form Using The Certainty of Response Index at Junior High School in Tana Toraja District

Awi Dassa[1], Fathul Akbar[2], Said Fachry Assagaf[3], Nurdin Arsyad[4]

[1,2,3,4] State University of Makassar, Makassar, South Sulawesi, Indonesia
awi.dassa@unm.ac.id

Abstract. Misconceptions in algebraic forms are issues that arise when individuals misunderstand the concept, leading to beliefs that differ from those accepted by experts. Identifying misconceptions in algebraic forms is crucial, as contextual knowledge plays a significant role in comprehending algebraic materials. This study aims to explore the misconceptions of junior high school students in Tana Toraja district when solving algebraic problems using the Certainty of Response Index (CRI). The research, which is quantitative and employs survey methods, involved a population of eighth-grade junior high school students in the Tana Toraja district. There are 82 junior high schools in Tana Toraja Regency with a total of 13,529 students. A sample of 101 students was selected using proportional cluster random sampling. Data was collected through a written test combined with the CRI scale and analyzed descriptively, with results presented in diagrams and tables. The analysis using the CRI method revealed several misconceptions, specifically in the following areas: (1) Identifying elements of algebraic forms; (2) Grouping like and unlike terms; (3) Performing addition and subtraction operations in algebra; (4) Executing multiplication and division in algebraic forms; (5) Solving mixed algebraic operations; (6) Simplifying algebraic fractions; (7) Conducting operations with algebraic fractions; and (8) Making substitutions in algebraic problems.

Keywords: Misconceptions; Algebraic Forms; Concepts; Understanding.

1 Introduction

Conceptual understanding is a skill acquired when an individual recalls, comprehends, and grasps a subject deeply [1]. In mathematics education, achieving conceptual understanding is essential. A person who develops a strong grasp of mathematical concepts can effectively apply them in solving both simple and complex mathematical problems [2].

An individual who values and applies mathematical concepts demonstrates a high level of conceptual understanding [3]. Such understanding significantly enhances students' learning quality, as they become capable of tackling a wide range of concept-related problems [4]. When learning is built on understanding, future challenges can be

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approached more effectively [5]. Algebraic forms are one of the mathematical topics where conceptual understanding is particularly essential.

Algebra is a fundamental area of mathematics, with applications across geometry, trigonometry, calculus, statistics, matrices, vectors, topology, and differential equations, making it core knowledge within the field [6]. Algebra challenges and enhances students' thinking skills by requiring extensive abstract reasoning[7]. Common difficulties in learning algebra include interpreting variables and assigning different values to them, challenges frequently faced by students [8].

A misconception occurs when a concept held by an individual is inconsistent with the one accepted by experts [9].Unlike a simple lack of understanding, which can be remedied through further study, misconceptions create barriers to learning new knowledge, often without the learner realizing it [10]. Misconceptions present a significant challenge for teachers, as nearly any concept, including algebra, can be misunderstood despite thorough instruction [11]. Therefore, employing appropriate teaching methods for algebra is essential to address these issues effectively.

Student misconceptions can be identified using several methods, one of which is the Certainty of Response Index (CRI). The CRI method assesses misconceptions based on students' confidence in their answers [12] and was initially introduced by Hasan et al. (1999). Research has shown that CRI is an effective tool for pinpointing areas where students misunderstand a concept.

Using the CRI method allows researchers to quantify students' understanding of fraction concepts [13]. Their findings revealed a high rate of misconceptions among students. The study also identified various causes behind these misconceptions. However, the conclusions were drawn from a sample of only 21 first-generation students.

From the description above, it is clear that the CRI method can categorize students' levels of conceptual understanding. Previous studies on misconceptions used relatively small populations, often limited to a single school. This has led the author to pursue research on misconceptions with a broader population. Thus, this study investigates students' misconceptions in algebraic forms using the Certainty of Response Index (CRI) among junior high school students in the Tana Toraja district.

This research aims to address the question: "How are the misconceptions of junior high school students in Tana Toraja district in solving algebra problems using the Certainty of Response Index (CRI)?" This study focuses on students' conceptual understanding of algebra, a fundamental area in mathematics with broad applications across various fields. Many students experience misconceptions in understanding algebra, particularly in the use of variables and other abstract concepts, which can hinder further learning. By employing the CRI method, this research aims to identify the types of misconceptions encountered by junior high school students in the Tana Toraja district, offering a broader and deeper perspective compared to previous studies limited to smaller populations.

The findings of this study are expected to assist teachers in recognizing students' misconception patterns and developing more effective teaching strategies. Additionally, this research can serve as a reference for other researchers exploring similar topics, especially in applying the CRI method to understand mathematical misconceptions in larger populations.

2 Literature Review

Misconception are defined as difficulties in acquiring new knowledge due to a strongly held cognitive structure that diverges from the accepted understanding within a particular field [10]. Generally, misconceptions can be categorized into three types: generalization misconceptions, notation misconceptions, and application of rules misconceptions [14], [15]. These categories can be further divided into six specific types: translation misconceptions, sign misconceptions, calculation misconceptions, statistical misconceptions, conceptual misconceptions, and strategy misconceptions [16]–[18]. Misconceptions have a significant impact on students' learning processes, as they often indicate a failure to connect new concepts with previously learned material [19].

One method that can be used to identify misconceptions is the Certainty of Response Index (CRI). CRI considers the respondent's confidence in their answers as the basis for using this method. CRI was first introduced by Hasan, Bagayoko, & Kelley [10], who used a confidence scale for each question in multiple-choice tests to reveal three categories of concept understanding [12]. In choosing the level of confidence and the laws and methods used to obtain answers on a CRI scale test, respondents are actually guided to self-assess [10]

The CRI method is widely applied across various fields, including science, mathematics, and engineering. One significant topic within this context is algebraic forms, which are taught in the 7th grade of junior high school under the "*Kurikulum Merdeka*" Algebraic forms are divided into four key subtopics: (1) Elements of algebra, (2) Arithmetic operations involving algebraic forms and algebraic fractions, (3) Constructing algebraic forms, and (4) Properties of operations on algebraic forms [20]. The study of algebraic forms begins with the introduction of mathematical statements that can be converted into algebraic expressions [21]. These expressions are then related to the elements of algebraic forms, such as variables, constants, coefficients, and terms, to create algebraic equations. These equations can subsequently be used to solve various problems involving addition, subtraction, multiplication, and division operations, with substitution employed to determine the value of a variable.

3 Research Methods

This research employs a quantitative approach using survey methods. The primary data collection technique utilized in this study is testing, aimed at gathering information about misconceptions held by junior high school students in the Tana Toraja district concerning algebraic forms. The study's population comprises junior high school students in the Tana Toraja district for the 2022/2023 academic year. There are 82 junior high schools in Tana Toraja Regency with a total of 13,529 students [22]. A sample of 101 students was selected from five junior high schools using the proportional cluster random sampling method, which included two schools from cluster A, two schools from cluster B, and one school from cluster C. The data analysis technique applied in this research is descriptive statistics, which focuses solely on describing the collected data. The results of the descriptive statistical analysis are presented through diagrams and tables, and the findings can be summarized using the following CRI table.

Table 1. Relationship between Answers and Average CRI.

Respondent Answer Criteria	Low CRI (<2,5)	High CRI (>2,5)
Correct answer	Don't understand the concept (lucky guess)	Understand the concept
Wrong answer	Don't understand the concept	Misconceptions

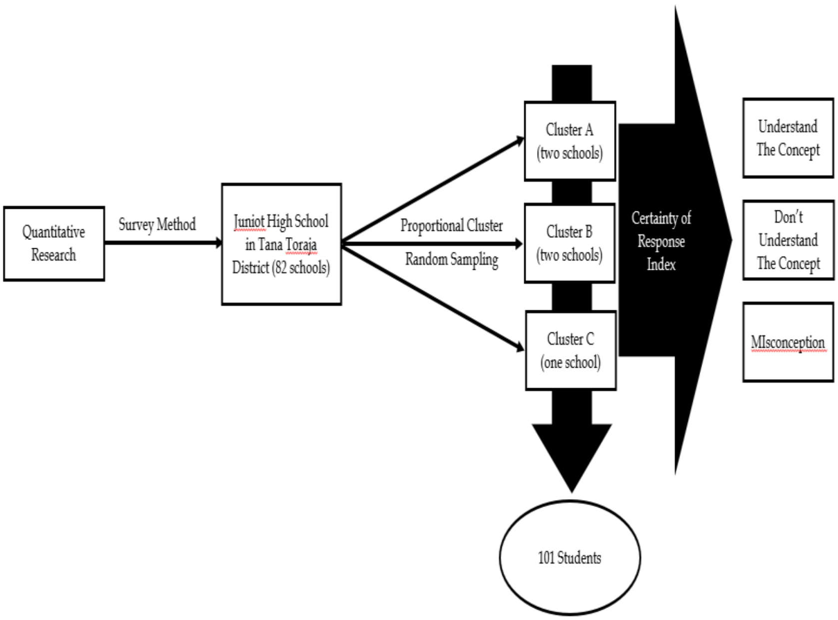

Fig. 1. A flow diagram illustrating the research methods employed in this study.

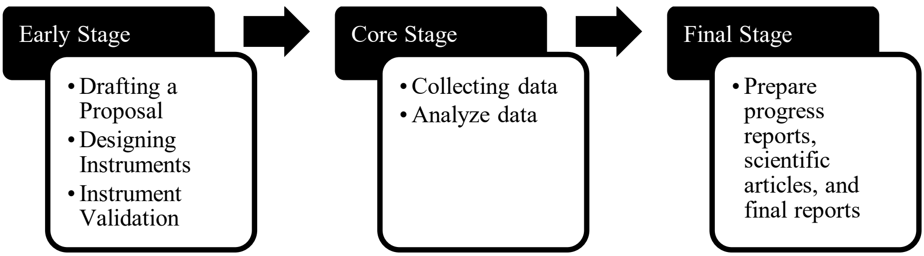

Fig. 2. A flow diagram illustrating the research methods employed in this study.

4 Result and Discussion

The analysis results from this research indicate that students in the Tana Toraja district experience misconceptions. Utilizing the CRI test, various misconceptions related to algebraic forms were identified. The collected data is then presented in graphical format.

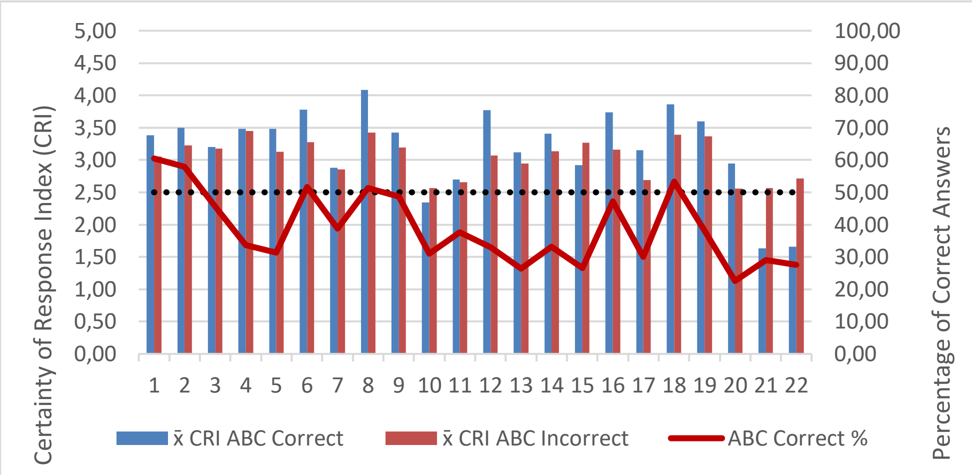

Fig. 3. Graph of Student Understanding in Tana Toraja District Using the CRI Method.

Figure 3 illustrates the results of the analysis of student understanding based on the CRI test. The graph displays the average values for correct and incorrect CRI responses, as well as the percentage of correct answers among students. From this graph, it is evident that only five questions have a correct response percentage exceeding 50%, indicating that students' understanding of algebraic forms remains low. The average CRI in the graph shows that students grasp the concepts in questions #1, #2, #6, #8, and #18, where the correct response percentage is above 50% and the average correct CRI exceeds 2.5. For all other questions, students demonstrated misconceptions, as indicated by a correct response percentage below 50% and an average incorrect CRI greater than 2.5.

The low level of understanding of algebraic forms is closely linked to the presence of misconceptions. In this research, eight key indicators have been identified to assess whether students are experiencing misconceptions. Each indicator includes a table detailing the average correct CRI, average incorrect CRI, and the percentage of correct responses from students. If the majority of students demonstrate an understanding of the concept, the column is marked in blue; conversely, if the majority have misconceptions, the column is marked in red. Additionally, examples of student work that were identified as having misconceptions through the CRI method are provided. Below are some misconceptions associated with the eight indicators.

4.1 Misconceptions in Identifying Elements of Algebraic Forms

To assess the level of understanding of the concepts within this indicator, three questions were utilized. These questions pertain to the definition of one of the elements of algebraic forms, the application of these elements, and the transformation of real-life problems into algebraic forms. The students' responses were subsequently analyzed using the CRI method to determine an average CRI, as presented in Table 2.

Table 2. Average CRI Indicator of Algebraic Form Elements.

Question Number	x̄ CRI ABC Correct	x̄ CRI ABC Incorrect	%ABC Correct
1	3,38	3,05	60,46
2	3,50	3,23	57,96
3	3,20	3,18	45,46

The analysis of these three questions reveals that students demonstrate an understanding of the concepts in questions #1 and #2, while they experience misconceptions in question #3. An example of a misconception related to question #3 is illustrated in Figure 4.

Question #3: One sheet of stamp duty is stated to be one piece. If there are 4 stamp sheets, then the algebraic form is...

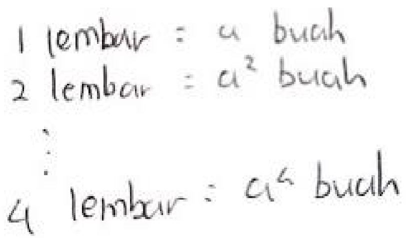

Fig. 4. Misconceptions in Question #3.

In Figure 4, students selected a^4 as the most appropriate answer. They indicated that one sheet of stamp duty is equivalent to a unit, and as the number of sheets increases, they wrote that the total becomes a^2, ultimately arriving at a^4 units for four sheets. Students expressed the belief that an increase in the number of stamp sheets leads to a higher exponent of the unit variable. However, the correct interpretation is that adding more stamp sheets should result in an increase in the coefficient of the unit variable. For example, with two stamp sheets, the total should increase to $2a$ units, meaning that with four stamp sheets, the total should actually be $4a$ units.

4.2 Misconceptions in Grouping Similar Terms and Dissimilar Terms

To assess the level of understanding of the concepts within this indicator, two questions were posed. These questions focus on identifying like terms and unlike terms in algebraic forms. The students' responses were subsequently analyzed using the CRI method to calculate an average CRI, as presented in Table 3.

Table 3. Average CRI Indicators of Similar Terms and Dissimilar Terms.

Question Number	x̄ CRI ABC Correct	x̄ CRI ABC Incorrect	%ABC Correct
4	3,48	3,45	33,65
5	3,48	3,13	31,29

According to Table 3, students exhibited misconceptions in questions #4 and #5. Figure 5 provides an example of a misconception related to question #4.

Question #4: Look at the following algebraic form!

$$\mathbf{3x^2y - 3xy^2 - 5x^2y^2 + 5xy^2}$$

From the algebraic form above, what includes similar terms is...

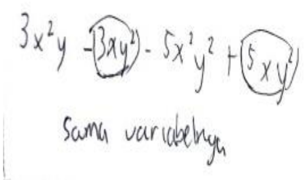

Fig. 5. Misconceptions in Question #4.

In Figure 5, students identify $3xy^2$ and $5xy^2$ as similar terms. They correctly recognize that the terms share the same variables, despite having different coefficients. While this understanding is accurate, a misunderstanding arises when students evaluate the coefficients. They often mark terms as similar without considering whether the coefficient values are positive or negative. As a result, students conclude that $3xy^2$ and $5xy^2$ are similar terms, rather than recognizing that it should be $-3xy^2$ and $5xy^2$.

4.3 Misconceptions about Algebraic Addition and Subtraction Operations

Two questions were posed to evaluate the level of understanding of the concepts in this indicator. These questions focus on the arithmetic operations of addition and subtraction in algebraic forms. The students' responses were then analyzed using the CRI method to calculate an average CRI, which is presented in Table 4.

Table 4. Average CRI Indicators for Algebraic Addition and Subtraction Operations.

Question Number	x̄ CRI ABC Correct	x̄ CRI ABC Incorrect	%ABC Correct
6	3,78	3,27	51,62
7	2,88	2,85	38,73

Table 4.3 indicates that students demonstrate an understanding of the concept in question #6, whereas they experience misconceptions in question #7. An example of a misconception related to question #7 is illustrated in Figure 6.

Question #7: In the algebraic form $4a^2 - 2a + 1$, the highest power is two. If you subtract ☐ then the highest power is one.
The correct answer to fill in the blanks in the box is...

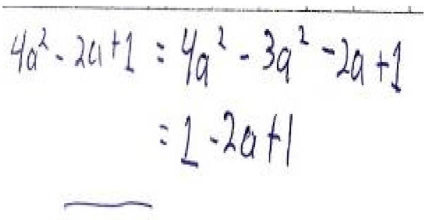

Fig. 6. Misconceptions in Question #7.

In Figure 6, students select $3a^2$ as the solution to the problem. They attempt to solve $4a^2 - 3a^2$ under the assumption that the highest power, $4a^2$, can be eliminated. However, when students subtract $4a^2$ from $3a^2$, they incorrectly conclude that the result is one. In reality, this subtraction should yield a^2. Students incorrectly subtract the variables, believing that the variable itself disappears while only the coefficients change in value. A variable will only disappear when its coefficient is zero.

4.4 Misconceptions about Algebraic Multiplication and Division Operations

To assess the level of understanding of the concepts in this indicator, two questions were posed, focusing on algebraic multiplication and division. The students' responses were subsequently analyzed using the CRI method to calculate an average CRI, which is presented in Table 5.

Table 5. Average CRI Indicators for Multiplication and Division Operations in Algebraic Forms.

Question Number	x̄ CRI ABC Correct	x̄ CRI ABC Incorrect	%ABC Correct
8	4,09	3,43	51,33
9	3,43	3,19	48,68

Table 5 reveals that students grasp the concept in question #8, while they encounter misconceptions in question #9. An example of a misconception related to question #9 is illustrated in Figure 7.

Question #9: The result of $3x^3\ y^2\ : xy$ is…

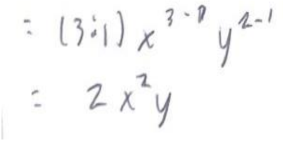

Fig. 7. Misconceptions in Question #9.

In Figure 7, students respond with $2x^2y$ as the result of performing arithmetic operations on the algebraic expression $3x^3y^2 : xy$. When dividing, students subtract the coefficients and powers of the variables. However, in algebraic division, the coefficients should be divided according to the same rules as basic arithmetic operations.

4.5 Misconceptions about Algebraic Mixed Operations

Two questions were posed to evaluate the level of understanding of the concepts in this indicator, focusing on arithmetic operations involving mixed algebraic forms. The students' responses were then analyzed using the CRI method to calculate an average CRI, which is presented in Table 6.

Table 6. Average CRI of Algebraic Mixed Operation Indicators.

Question Number	x̄ CRI ABC Correct	x̄ CRI ABC Incorrect	%ABC Correct
10	2,35	2,57	31,08
11	2,70	2,66	37,59

Table 6 indicates that students encountered misconceptions in questions #10 and #11. An example of a misconception related to question #10 is illustrated in Figure 8.

Question #10: The result of $a \times 2a^3 - 2a^6 : 2a^2$ is…

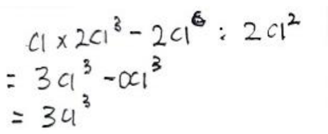

Fig. 8. Misconceptions in Question #10.

In Figure 8, students provide $3a^3$ as the result of performing operations on algebraic forms. In algebraic multiplication, students incorrectly add the coefficients and multiply the powers of the variables. In contrast, during algebraic division, they mistakenly subtract the coefficients and divide the powers of the variables. However, in algebraic multiplication, the coefficients should be multiplied while the exponents of the variables are added, and in algebraic division, the coefficients should be divided while the exponents of the variables are subtracted.

4.6 Misconceptions about Simplifying Algebraic Forms

To assess the level of understanding of the concepts in this indicator, two questions were posed, focusing on simplifying algebraic forms. The students' responses were subsequently analyzed using the CRI method to calculate an average CRI, which can be found in Table 7.

Table 7. Average CRI of Algebraic Form Simplification Indicators.

Question Number	x̄ CRI ABC Correct	x̄ CRI ABC Incorrect	%ABC Correct
12	3,77	3,07	33,06
13	3,12	2,94	26,32

Table 7 shows that students encountered misconceptions in questions #12 and #13. An example of a misconception related to question #12 is illustrated in Figure 9.

Question #12: The simple form of $\frac{4x^2}{10xy^2}$ is…

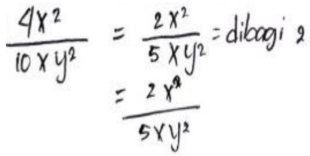

Fig. 9. Misconceptions in Question #12.

In Figure 9, students provide $\frac{2x^2}{5xy^2}$ as their answer for simplifying the algebraic expression. They simplify the algebraic fraction by dividing the coefficients in the numerator and denominator by the same number until no further division is possible. However, to correctly simplify algebraic fractions, the values of the variables in both the numerator and denominator must also be indivisible; only then can the fraction be considered simplified.

4.7 Misconceptions about Algebraic Fraction Operations

Four questions were designed to assess the level of understanding of concepts in this indicator, focusing on the arithmetic operations of addition, subtraction, multiplication, and division of algebraic fractions. The students' responses were analyzed using the CRI method to calculate an average CRI, which is presented in Table 8.

Table 8. Average CRI of Algebraic Fraction Calculation Operation Indicators.

Question Number	x̄ CRI ABC Correct	x̄ CRI ABC Incorrect	%ABC Correct
14	3,41	3,14	33,19
15	2,92	3,26	26,60
16	3,73	3,16	47,25
17	3,15	2,69	29,99

Table 8 indicates that students encountered misconceptions in questions #14, #15, #16, and #17. An example of a misconception related to question #14 is shown in Figure 10.

Question #14: The result of $\frac{3}{x} + \frac{y}{x}$ is…

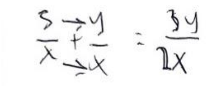

Fig. 10. Misconceptions in Question #14.

In Figure 10, students provide $\frac{3y}{2x}$ as their answer for operating on algebraic fractions. They mistakenly treat the addition of algebraic forms as if they were performing algebraic multiplication. This is evident when students write $3 + y = 3y$, despite the fact that constants and variables cannot be directly added together. In the denominator, while students correctly add the variables, they overlook that this is a fraction; when adding fractions with the same denominator, only the numerators should be combined.

4.8 Misconceptions of Substitution in Algebraic Forms

Four questions were utilized to assess the level of understanding of concepts in this indicator, focusing on the arithmetic operations of addition, subtraction, multiplication, and division of algebraic fractions. The students' responses were analyzed using the CRI method to calculate an average CRI, which is displayed in Table 9.

Table 9. Average CRI of Algebraic Substitution Indicators.

Question Number	x̄ CRI ABC Correct	x̄ CRI ABC Incorrect	%ABC Correct
18	3,86	3,39	53,25
19	3,60	3,36	38,07
20	2,94	2,56	22,55
21	1,63	2,56	29,11
22	1,65	2,71	27,55

Table 9 indicates that students demonstrated an understanding of the concept in question #18. However, they experienced misconceptions in questions #19, #20, #21, and #22. An example of a misconception from question #19 is illustrated in Figure 11.

Question #19: If $a = -2$, then the value of $3a^2$ is...

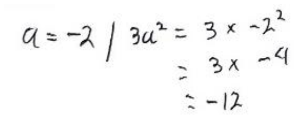

Fig. 11. Misconceptions in Question #19.

In Figure 11, students arrive at the answer of -12 when substituting values into an algebraic expression. They encounter difficulties in determining whether the result of exponentiation should be positive or negative. There are a couple of potential reasons for this misunderstanding. First, some students struggle to apply the rules of integer operations, causing them to incorrectly perceive the value of $a \times a$ as negative instead of positive. Second, some students mistakenly interpret exponentiation as $a + a$ rather than $a \times a$, leading them to calculate a^2 as $a + a = -2 + (-2) = -4$.

The analysis of data across various indicators in algebra education reveals several types of misconceptions prevalent among students, correlating with existing research. Translation misconceptions occur when students struggle to convert real-world problems into mathematical expressions [23]. Conceptual misconceptions arise in understanding the rules for grouping like and unlike terms, consistent findings [24]. Additionally, arithmetic misconceptions are evident in algebraic operations, including addition, subtraction, multiplication, and division [19], [25]. Systematic misconceptions manifest in the simplification of algebraic forms and the calculation of fractions [26], [27], respectively. Moreover, students exhibit arithmetic misconceptions during algebraic substitution due to difficulties in determining variable values [18].

5 Conclusion

This research aims to provide an overview of the misconceptions held by junior high school students in Tana Toraja district when solving algebra questions using the Certainty of Response Index (CRI). The analysis reveals that student in Tana Toraja district experience various misconceptions in understanding algebraic forms. Specifically, the research identified misconceptions in the following areas: (1) identifying the elements of algebraic forms; (2) grouping similar and dissimilar terms; (3) performing complete addition and subtraction operations in algebra; (4) executing multiplication and division operations within algebraic forms; (5) completing mixed algebraic operations; (6) simplifying algebraic fractions; (7) carrying out operations with algebraic fractions; and (8) making substitutions in algebraic problems.

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