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Students' Misconceptions in Simplifying Algebraic Expressions Based on Assimilation and Accommodation Frameworks

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Abstract

This study adopts a qualitative approach with a descriptive research design. The subjects of this study consist of six students from class X of a high school during the second semester of the 2023/2024 school year. The data analysis process includes three stages: data reduction, data presentation, and drawing conclusions. The validity of the findings was ensured through triangulation, which involved comparing data from students' work, interview results, and observation results. The findings revealed that students exhibited seven types of misconceptions leading to errors in simplifying algebraic expressions: (1) conjunction error, (2) exponent error, (3) reversal error, (4) difficulties with variables, (5) substitution error, (6) equation formation errors, and (7) a commutative-like terms error. These misconceptions were attributed to inappropriate assimilation and a lack of accommodation.

Keywords: *misconceptions; algebraic expressions; assimilation and accommodation*

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INTRODUCTION

Mathematics provides critical, logical, analytical, creative, and systematic thinking skills (Nurwahida & Munir, 2022). In line with this statement, Thanheiser (2023) explains that mathematics encompasses a collection of knowledge or abstract ideas, the organization of ideas into systems or structures, a set of methods for reaching conclusions, a lens or language to understand the world, and part of a person's identity. However, students often consider mathematics to be a complex, abstract, difficult, and computationally charged subject (Khofifah et al., 2021).

One of the mathematical topics perceived as difficult due to its abstract nature is algebra. This aligns with Marpa (2019), who explained that students often find mathematics complex because they struggle to relate it to daily life. Students face challenges in solving algebraic problems due to the gap between arithmetic and algebra, often becoming confused by the use of variables (Herscovics & Linchevscki, 1994). When attempting to solve real-world problems, students also have difficulty translating these problems into mathematical models (Namkung & Bricko, 2021). The abstract nature of algebra further complicates students' ability to solve mathematical problems (Marpa, 2019). This is consistent with the explanation that the main challenge in learning algebra lies in transitioning from working with concrete numbers to engaging in abstract thinking, where variables or letters represent unknown values and express systematic relationships (Chan et al., 2022).

Yi Wei (2020) explained that algebraic expressions are macro concepts in school mathematics that significantly influence the development of other micro mathematical concepts, such as functions, quadratic functions, arithmetic sequences, and others. However, in reality, high school students still experience errors and lack fluency when using symbols in algebra, particularly when simplifying algebraic expressions that involve variables, coefficients, and constants. At the same time, the *Kurikulum Merdeka* in Indonesia incorporates algebra concepts into high school materials, such as limits, derivatives, integrals, and other topics. This is supported by research from Maharani et al., (2019), which found that high school students commonly make errors when simplifying algebraic fractions, particularly in the order of operations, denominator equalization, algebraic operations, and factoring. Continuing this statement, Osei and Agyei (2024) noted that students still face difficulties in solving algebraic problems involving more than one variable, parentheses containing multiple terms, algebraic exponents, algebraic fractional forms, and the incorrect application of algebraic operations.

Based on the issues presented, the causes of algebraic errors need to be studied so that teachers can address these challenges, especially in the early grades of high school, to prevent errors from becoming persistent. In line with this, Yi Wei (2020) explained that if common errors are not addressed through intervention, they will hinder students' abilities, even in performing simple calculations. One of the causes of persistent errors is students' difficulty in understanding the concepts presented. When students struggle to learn mathematical concepts, it often leads to misunderstandings (Hakim et al., 2022; Septian & Soeleman, 2022).

A misunderstanding of a concept is referred to as a misconception. Saaroh et al. (2021) explained that errors and misconceptions often occur when students work on interconnected mathematical problems. Similarly, Nurussama and Hermanto (2022) stated that a misconception arises from confusion in linking existing concepts when solving problems. Misconceptions can also result from misunderstandings caused by incorrect information or flawed reasoning (Khusna & Rosyadi, 2021). Sari & Afriansyah (2020) further explained that a misconception is a conceptual framework error that students believe to be correct, which leads to consistent and repeated errors. Abbas (2019) emphasized that misconceptions frequently occur during the teaching and learning process.

Based on the explanations of several experts, misconceptions in mathematics can be defined as inappropriate ideas that stem from errors in thought and understanding related to mathematical concepts. These misconceptions may occur when students inappropriately apply or generalize prior knowledge and reasoning to new ideas or contexts (Im & Jitendra, 2020). Such errors in applying knowledge and reasoning can occur during the cognitive thinking process.

The thinking process is a mental activity involving reasoning, problem-solving, decision-making, critical thinking, and reflective or analytical thinking (Faizah et al., 2022). It can also be viewed as a cognitive activity. Piaget's theory describes *assimilation* and *accommodation* as two cognitive processes through which individuals adapt to their environment. Hanfstingl et al. (2021) reviewed 473 research articles on assimilation and accommodation over 20 years (1998–2018), finding that these concepts have broad interpretations but remain consistent with Piaget's theory. Piaget argued that individuals must adapt to their environment through these processes, which involve changes to cognitive structures (Netti et al., 2016).

Assimilation occurs when individuals integrate new information into their existing cognitive structures. In contrast, accommodation occurs when individuals adjust their cognitive structures to incorporate new information. During assimilation, new stimuli are interpreted based on an existing schema or cognitive structure. Accommodation, however, requires changes to internal cognitive structures to integrate new knowledge. Both processes work to achieve *cognitive equilibrium*, a state in which individuals feel that their cognitive schema is sufficient to understand their environment. When there is a mismatch between the existing schema and new information, individuals experience tension or *disequilibrium*, which prompts accommodation to restore balance. These processes are essential for cognitive development and learning, as they facilitate adaptation to new ideas and contexts (Huda et al., 2018).

Research by Moru and Mathunya (2022) revealed errors and misconceptions among 8th-grade students in Lesotho when simplifying algebraic expressions. The errors and misconceptions identified in their study include conjoin errors, exponent errors, reversal errors, difficulties with variables, substitution errors, equation formation errors, commutative-like term errors, and imposed radical sign errors, all analyzed through a constructivist lens. Similarly, AL-Rababaha et al. (2022) investigated misconceptions among grade X students in the United Arab Emirates when solving algebraic problems. Their research highlighted conceptual errors in algebraic expressions, linear equations, polynomials, exponents, radical expressions, functions, and graphs. They also found that students often cling to previous misconceptions, believing their reasoning is correct, which negatively impacts their learning outcomes and achievement in algebra.

Based on the explanation above, the difference between this study and previous studies lies in its focus. In Indonesia, research analyzing misconceptions that cause errors in simplifying algebraic expressions based on the framework of assimilation and accommodation remains limited, particularly for high school grade X students. Most existing studies focus on errors among junior high school students. For example, Lestari and Fiangga (2021) analyzed errors in simplifying fractional materials, while Dinnullah et al. (2019) studied students' mistakes in solving Pythagorean theorem word problems. Therefore, this study aims to describe and analyze misconceptions in simplifying algebraic expressions among high school students, specifically within the framework of assimilation and accommodation.

RESEARCH METHODOLOGY

The type of research used is descriptive research with a qualitative approach. This study aims to analyze and describe misconceptions that occur in simplifying algebraic expression problems among high school grade X students based on the framework of assimilation and accommodation. The subjects of this study are six grade X high school students in the 2nd semester of the 2023/2024 school year, selected purposively based on frequent errors observed when simplifying algebraic expressions, which are likely caused by misconceptions.

The researcher employs several instruments to collect data, including themselves as the main instrument, as well as tests in the form of test questions, interview protocols, and documentation as supporting instruments. The test questions are designed to identify students' errors in solving algebraic expression problems, particularly those stemming from misconceptions. Students are tasked with answering five branched questions that were reviewed and approved by the supervisor.

The interviews aim to uncover additional misconceptions that contribute to students' errors in simplifying algebraic expressions, including those that may differ from those found by Moru and Mathunya (2022). The interviews are conducted after the students complete the test and serve as supplementary information. They are carried out in a semi-structured format to allow for flexibility in exploring the students' understanding.

Documentation involves collecting and analyzing the students' test results and interview responses. The test questions used in this study can be seen in Table 1, and the indicators applied for analysis are presented in Table 2.

Table 1. Test Questions Simplify Algebraic Expressions

No	Test Questions
1.	Simplify the following algebraic expressions a. $7x + 10y - 11x$ b. $4xy(-3x - 6y)$
2,	State the following statement in the algbraic expression and make it easy a. $3y$ less than 5 b. Determine the circumference of the triangle with its sides $3a, 4b, dan\ 5c$, with each side in cm
3.	Simplify the following algebraic expressions a. $7nm + 7 - 9mn - 7 + 5n$ b. $(x - 4)^2 + (4x + 2)(x - 4)$
4	Simplify if possible the following algebraic expressions: a. $2x^2 + 4y^2 + 8$ b. $\frac{y^4}{2} - \frac{2y^4}{3} + \frac{5y^3}{6}$
5	Simplify the following algebraic expressions: a. $\frac{17x^2y^3 - 11x^2y^3}{13x^2y^3}$ b. $\frac{x^2+3x}{x^2-x+12}$

An in-depth analysis was conducted to identify the misconceptions that caused students' errors in simplifying algebraic expressions and to understand their cognitive thinking processes, including assimilation and accommodation, based on test results,

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written responses, and interview data. The technical analysis in this study was carried out in three stages: data reduction, data presentation, and conclusion drawing.

Data reduction was performed by reviewing and analyzing students' responses to the test questions related to simplifying algebraic expressions. In the data presentation stage, the identified misconceptions were classified and described based on the test results and interview responses. During the conclusion-drawing stage, the results of the test and interview data were compared to determine the cognitive thinking processes of assimilation and accommodation that occurred among the students.

Table 2. Indicators of Misconceptions that Cause Errors (Moru & Mathunya, 2022)

No.	Errors Caused by Misconception	Indicators
1	*Cojoin Error*	Students can work but experience misconceptions in addition and subtraction of similar terms and non-similar terms
2	*Exponent Error*	Students can work but experience misconceptions between the algebraic, exponential addition rule and the exponential multiplication rule
3	*Reversal Error*	Students can work but experience misconceptions when translating everyday language into mathematical form.
4	*Difficulties With Variable*	Students can work but experience misconceptions about the interference of arithmetic rules with algebraic expression rules
5	*Substitution Error*	Students can work but have a misconception about the use of variables (students have a misconception that a variable has the same value as the alphabetical order)
6	*Equation Formation Error*	Students can work on but have misconceptions about algebraic expression equations (Students change expressions algebra becomes an algebraic equation and simplifies it)
7	*Commutative Like-term Error*	Students can work but experience misconceptions in terms similar to the variables that arise in the same order
8	*Imposed Radical Sign Error*	Students can work but have misconceptions in applying square roots that are not part of the expression algebra

RESULTS AND DISCUSSION

This study involved six grade X high school students as research subjects. The students were given a test consisting of five branched questions on simplifying algebraic expressions, with each question designed to identify misconceptions based on the theory presented by Moru and Mathunya (2022). The students' responses were then analyzed using misconception indicators outlined by Moru and Mathunya (2022). During the analysis, the researcher identified seven types of errors caused by misconceptions. The specific types of misconceptions that led to students' recurring errors are presented in Table 3. The following is an analysis of misconceptions that lead to recurring errors and the cognitive processes of assimilation and accommodation.

Table 3. Misconceptions Experienced by Students

No	Misconceptions	Student					
1	*Cojoin Error*						S6
2	*Exponent Error*	S1			S4	S5	
3	*Reversal Error*		S2	S3			S6
4	*Difficulties With Variabel*	S1			S4	S5	
5	*Substitution Error*	S1		S3	S4	S5	
6	*Equation Formation Error*	S1			S4	S5	
7	*Commutative Like-terms Error*	S1				S5	
8	*Imposed Radical Sign Error*						

Subject Description:

S1 = First Student S4 = Fourth Student
S2 = Second Student S5 = Fifth Student
S3 = Third Student S6 = Sixth Student

Misconceptions Causing Conjoin Errors

The *conjoin error* observed stems from students' misconceptions when interpreting algebraic problems. This error occurs when students unnecessarily combine operations like addition and subtraction involving different terms. An example can be seen in one of the students' answers (Figure 1).

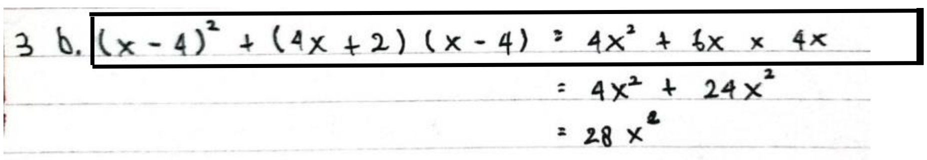

Figure 1. **Answer of a Student with Conjoin Errors (S6)**

Based on Figure 1, it is evident that S6 made a conjoin error in question 3b, starting from the expression $(x-4)^2 + (4x+2)(x-4)$. From the results of the interview session, it was found that the reason for the mistake of S6 answering the question was "because whatever is in parentheses is considered to be all added even though it is subtraction, multiplication, therefore $(x-4)^2$ The result is considered $4x$". This error occurs due to a lack of understanding of the concept of similar and non-similar terms, resulting in students' misconceptions in simplifying algebraic expressions and *conjoin errors*. *Conjoin errors* are errors that occur as a result of unnecessarily adding or subtracting different terms. Judging from assimilation and accommodation, S6 assimilated factoring algebraic expressions into a scheme of addition of numbers and terms that were not similar.

Assimilation occurs when students try to solve a problem by using knowledge or understanding they already have before, even if that understanding does not entirely fit into the correct rules in the new context. In the case of the misconception of conjoin error, assimilation can be seen in how students attempt to combine different terms (e.g., terms containing subtraction and multiplication) in a way they already understood, even if this does not conform to the correct principles of algebra. Accommodation occurs when

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students adjust their understanding or cognitive structure to understand new information or concepts that contradict previous understanding. Regarding the misconception of conjoin error, accommodation means that students need to be aware of the error in how they combine different tribes and then change their understanding to conform to the correct algebraic rules. Still, it turns out that accommodation does not occur.

Misconceptions Causing Exponent Errors

The *exponent error* arises from students' misconceptions about the rules of exponential multiplication in algebra. This error was identified in S1 and S5 when solving question 1b (Figure 2).

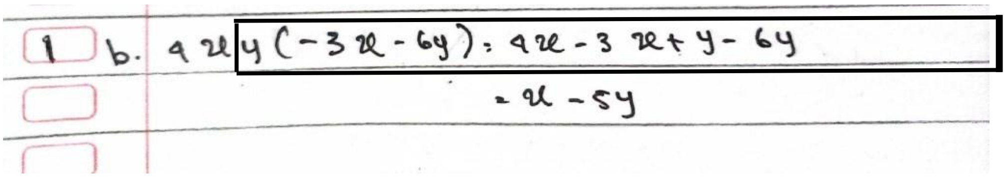

Figure 2. Answers of Students with Exponent Errors (S1, S4, S5)

From Figure 2, S1 and S5 made errors by treating $4xy$ as separable into $4x$ and y. During the interview session, it was found that S1 and S5 experienced a misconception when multiplying algebraic exponents with different variables. S1 and S5 assume that $4xy$ is not a unit and can be separated into $4x$ and y So that only y is operated without paying attention to $4x$. Subject operates y itself with the terms in parentheses without regard to the base or rank, therefore, S1 and S5 are mistaken due to the misconception of exponential multiplication. This misconception occurs because S1 and S5 do not understand the concept of multiplication in algebraic exponents, resulting in an exponent error. Judging from assimilation and accommodation, S1 and S5 assimilate algebraic expression rank multiplication into an ordinary arithmetic multiplication scheme that does not conform to it, causing errors.

Assimilation occurs when S1 and S5 try to incorporate a new concept (exponential multiplication of different variables) into their cognitive structures. They try to associate exponential multiplication in a way they are already familiar with, which is the exponential addition rule for simpler expressions, such as $am \cdot an = am+n$. They assume that the same rule applies to expressions with different variables, although this is not true. Meanwhile, accommodation occurs when S1 and S5 face incorrect results and need to improve their understanding.

After getting feedback or through further learning, they changed their cognitive structure regarding the rules of algebraic exponents to include that exponents on different variables cannot be treated in the same way as they thought. They understand that each exponent must be taken into account based on the appropriate exponential multiplication rule, and that the separation of factors present in expressions such as $4xy$ is not correct in the context of algebraic exponents.

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Misconceptions Causing Reversal Errors

A reversal error found is the student's misunderstanding in translating everyday language into mathematical algebraic expressions. Students who experience a reversal error are S2, S3, and S6. S2 and S3 students experienced a reversal error when working on question no 2a, which was the same error, while S6 also experienced an error when working on question number 2a, but with different answers. The results of the answers of S2 and S3 students can be seen in Figure 3 because the wrong answer is the same and the S6 answer can be seen in Figure 4.

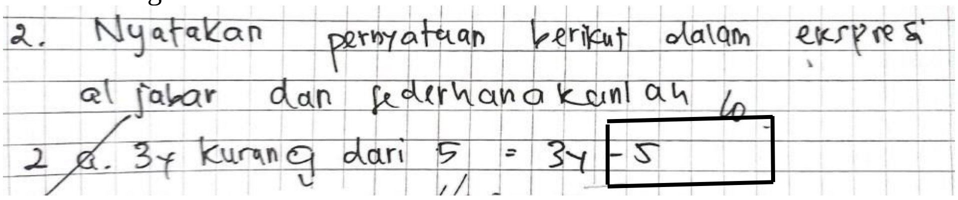

Figure 3. Answers of Students with Reversal Errors (S2 and S3)

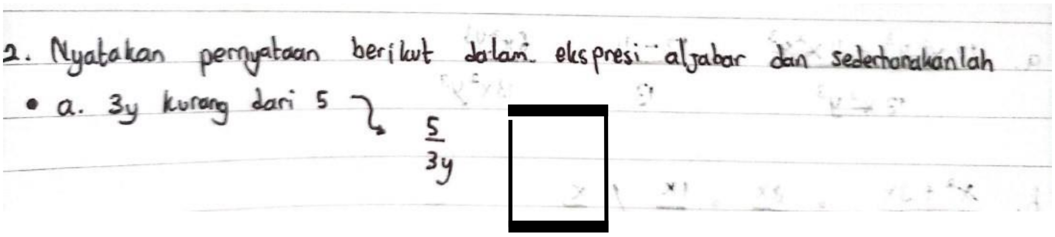

Figure 4. Answer of a Student with a Reversal Error (S6)

Based on Figure 3, it can be observed that S2 and S3 made the same type of error, a reversal error, specifically in question 2a. S2 and S3 encountered errors from the beginning of their work on the question. During the interview session, it was revealed that S1 and S5 shared a similar misconception in translating everyday language into mathematical expressions. When interviewed, S2 and S3 stated that they interpreted the phrase "less than" as subtraction, leading them to write $3y - 5$ instead of $3y < 5$. This indicates that students struggle with misconceptions related to understanding the language used, which results in errors. These mistakes may occur because students are not accustomed to translating everyday language into mathematical forms.

Based on Figure 4, it can be observed that S6 made a reversal error, but with a different answer compared to S2 and S3. The figure shows that S6 interpreted the answer in the form of a fraction. During the interview session, S6 explained that they understood the phrase "less than" to mean placing 3y below 5, resulting in a fraction as their interpretation of the phrase. The interview results indicate that S6 had a misconception in interpreting the phrase "less than," similar to S2 and S3, even though with a different interpretation. Misconceptions like this, where students misinterpret everyday language into symbols or mathematical forms, can be categorized as reversal errors.

Judging from assimilation and accommodation, S2 and S3 demonstrate assimilation in translating everyday language into mathematical symbols, specifically interpreting "less than" as "<." Meanwhile, S6 also shows assimilation but interprets everyday language by translating it into a fractional form. This indicates that the schema of the phrases or words used does not align with the cognitive abilities of S2, S3, and S6.

Assimilation occurs when S2 and S3 try to adapt everyday sentences into the framework of mathematical logic already in their cognitive structure. They try to use rules they understand (for example, the order of multiplication and addition in algebra) to translate everyday sentences but ignore differences in the context of mathematical operations. They assumed that the word sequence used in everyday language could be translated directly into a similar sequence of algebraic operations.

Accommodation occurs when students finally have to change their understanding of the sequence of operations in algebra to correct the error. For example, they need to understand that in mathematics, the sequence of operations must follow stricter rules (such as the rule of operation priority), and they need to adapt the way they process information from everyday language to fit the logic and rules in mathematical expressions. In other words, students must restructure their understanding to fit the correct structure in algebra rather than simply relying on direct translations from language to mathematical symbols.

Misconceptions Causing Difficulties with Variables

Learners' difficulties with variables are identified as students' misconceptions in simplifying expressions, where they ignore variables that are part of algebraic expressions. Students who experience these difficulties include S1, S4, and S5. These students encountered challenges with variables while working on question 4a. The answers provided by S1, S4, and S5 are shown in Figure 5.

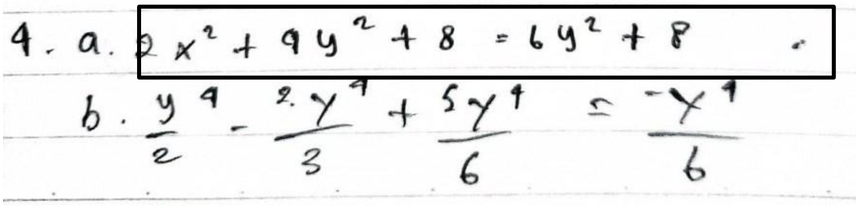

Figure 5. Answers of Students with Difficulties Involving Variables (S1, S4, S5)

Based on Figure 5, it can be observed that S1, S4, and S5 made the same error due to misconceptions about variables, resulting in the identical answer $6y^2 + 8$. During the interview session, it was found that S1, S4, and S5 shared a similar misconception: they assumed that the variable x was the same as the variable y and focused primarily on the coefficient of the variable rather than the variable itself. The interviews also revealed that students prioritized the operational rules of addition from arithmetic, ignoring elements such as variables and exponents. This indicates that students simplified the problem by focusing first on the addition of numbers, without considering the rules governing variables and their exponents. This showed that there is no restructuring process in the accommodation process.

Assimilation in this case occurs when S1, S4, and S5 try to integrate rules they already know in arithmetic (e.g. the addition of ordinary numbers) into more complex concepts in algebra. They try to apply the rule of summing numbers to variables, which leads to errors in simplifying expressions. On the other hand, accommodations are

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supposed to occur when they need to change their understanding of algebraic operations. To correct this error, students need to realize that different variables (such as x and y) must be treated as separate entities and that addition operations in algebra cannot be performed on different variables without considering the basic rules of algebra. This process forces them to change their cognitive structure regarding how variables work in algebraic expressions and how more complex mathematical operations should be applied. However, in this case, the accommodation process does not occur, which is marked by the absence of a restructuring process.

Misconceptions Causing Substitution Errors

The error of substituting numeric values for letters is identified as a student's mistake caused by a misconception. In this case, students simplify expressions by ignoring the proper substitution of numbers for variables and tend to disregard the variables altogether. For example, $3a$ is assumed to mean that a has a value of 3. Consequently, when solving a problem such as $3a + 4b$, students assume $a = 3$ and $b = 4$, leading to an incorrect sum of 7, without considering the variables. Students who exhibited this type of error include S1, S3, S4, and S5. The answers provided by S1, S3, S4, and S5 are identical and are illustrated in Figure 6.

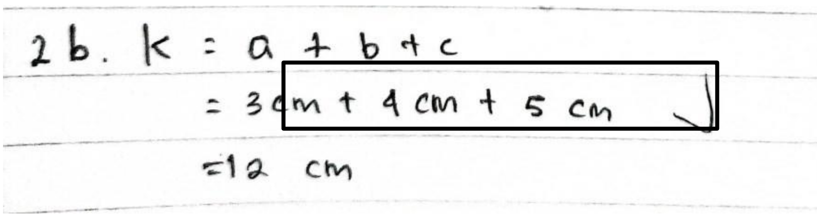

Figure 6. Answers of Students with Substitution Errors (S1, S3, S4, S5)

Based on Figure 6, it can be observed that S1, S3, S4, and S5 made the same mistake due to misconceptions about the value of variables, believing that the variables could be ignored. All four students arrived at the same incorrect answer, 12. During the interview session, it was found that S1, S3, S4, and S5 shared the same misconception. They assumed that the coefficients of the variables could be added directly without considering the variables. The correct answer to the problem should have been $3a + 4b + 5c$, as the terms cannot be combined because they involve different variables. However, the students incorrectly interpreted a as having a value of 3, b as 4, and c as 5. This assumption led them to substitute these values and calculate $3 + 4 + 5 = 12$, resulting in the incorrect answer "12 cm." They argued that assigning values to the variables completed the simplification process. From their approach to solving problem 2a, it is evident that the students had a misconception that variables represent only one specific value. This misconception led them to believe that their solution was correct and that they had fully simplified the expression.

Judging from assimilation and accommodation, S1, S3, S4 and S5 have misconceptions in the assimilation process when understanding the numbers in the variables and assuming that the values possessed by the variables must be entered so that

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the simplification is complete. This shows that there is no restrictualization process in the accommodation process.

Assimilation in this case occurs when students try to relate a numerical concept they know (the addition of numbers) to a new algebraic concept, and they assume that a variable in an algebraic expression functions like a regular number that can be directly replaced with a number that they deem appropriate. They integrate the rules of number addition into their cognitive structure, not realizing that variables have different roles in algebra and cannot be substituted arbitrarily.

The new accommodation will occur when students get feedback indicating that they cannot simplify algebraic expressions simply by arbitrarily replacing variables with numbers. To overcome these misconceptions, students need to change their thinking about algebra variables. They must learn that variables cannot be directly substituted with numbers unless there is a specified value, and that algebraic expressions retain their symbolic form until further operations or values are given. After reflection and clarification, students will accommodate their understanding by differentiating between numbers and variables in the context of algebra, which allows them to avoid the mistake of substitution of these numbers in the future. However, in this case, the accommodation process did not occur, marked by the absence of a restructuring process.

Misconceptions Causing Equation Formation Errors

The equation formation error occurs when students simplify a problem by converting it into an equation and solving it based on a variable of their choice. This error stems from a misconception. In this case, the researcher observed that the students' answers included an "=" sign placed before the "<" sign. While the students' interpretation of the question was correct, the inclusion of the "=" sign before the "<" sign was incorrect, as it could lead to additional errors. Students who exhibited equation formation errors include S1, S4, and S5. Their answers are identical and are shown in Figure 7.

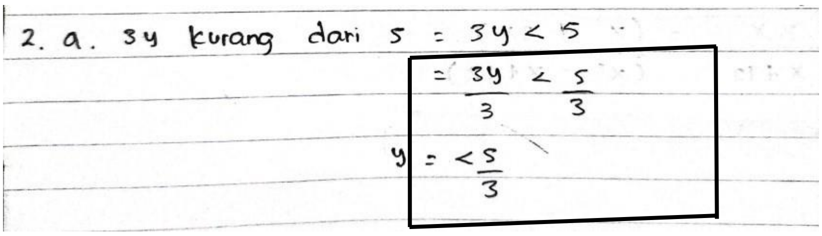

Figure 7. Answers of Students with Equation Formation Errors (S1, S4, S5)

Based on Figure 7, it can be observed that S1, S4, and S5 have the same mistake due to the misconception about dividing two expressions by giving equal to and solving according to the variables chosen by the students. S1, S3, S4, and S5 have the same answer, which is $y =< \frac{5}{3}$. When the interview session was conducted, it was found that S1, S4, and S5 experiencing the same misconception, namely assuming that the sign "=" is placed in front of "< " sign. Students assume that by giving the sign =, the student simplifies the expression and looks for the value of y. This assumption results in students immediately simplifying the question by equalizing the denominators 3y and 5 even though without equalizing the denominator, the student's answer is correct. Students make mistakes when working on number 2a caused by a misconception between equations and inequalities in algebraic expressions.

Judging from assimilation and accommodation, S1, S4 and S5 experienced disturbances when using algebraic expression equations and inequalities. This case shows that the equation solution scheme interferes with the algebraic expression inequality scheme. Students have assimilated but experienced disruptions when the accommodation process was carried out. The assimilation process is shown when students can translate everyday problem into mathematical symbols but experience misconceptions during the accommodation process. Disruptions to the accommodation process cause students to make mistakes in simplifying algebraic expressions.

Assimilation occurs when students try to apply a rule they understand in the form of linear equations or inequalities, but they use symbols "=" erroneously because it assumes that the sign "=" can be used to compare two expressions, when in this case the sign "≤" or "≥" should be used, depending on the context of the question. They integrate the rules of equation writing that they are already familiar with (e.g., a =< b) and try to apply them in the context of inequality but are unaware of the critical difference between them. New accommodations will occur when students realize that the use of the symbol = in the context of inequality is wrong and that each type of mathematical expression (equation or inequality) has different symbolic rules. However, this does not happen so it can be said that there is a disruption in the accommodation process that causes misconceptions.

Misconceptions Causing Commutative-Like Terms Errors

The *commutative-like terms error* refers to the students' mistakes caused by a misconception when simplifying problems involving similar terms. This error occurs when students fail to recognize that terms remain equivalent even if the order of variables is exchanged or reversed, such as *xy* and *yx*. Students who exhibited this commutative-like terms error were S1 and S5. The answers provided by S1 and S5 are identical and can be seen in Figure 8.

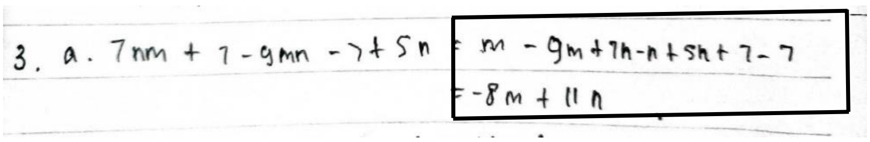

Figure 8. Answers of Students with Commutative-like Terms Errors (S1 and S5)

Based on Figure 8, it can be observed that S1 and S5 made the same error due to a misconception regarding the inability to recognize similar terms when the order of variables is reversed. This mistake and misunderstanding of similar terms can be observed in the students' answers to question no. 3a. S1 and S5 both provided the incorrect answer: -8m + 11n. During the interview session, it was revealed that S1 and S5 assumed that *mn* and *nm* were different terms and separated *m* and *n*. They believed that *mn* referred only to *m* and *nm* referred only to *n*, leading them to perform operations on *m* and *n* independently, without considering the equivalence of *mn* and *nm*. This activity highlights the students' difficulty in understanding similar terms and their lack of comprehension of the

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commutative property of multiplication. As a result, the students struggled to recognize that variables arranged differently, such as *mn* and *nm*, are equivalent.

From the perspective of assimilation and accommodation, S1 and S5 experienced challenges when applying the commutative property of algebraic multiplication. Their misconception reflects an incomplete assimilation process, where they attempted to incorporate new information into their existing cognitive framework but were unable to restructure it properly during accommodation. This disruption in the accommodation process indicates that the students do not fully understand the commutative nature of multiplication.

Discussion

This study identifies seven types of misconceptions experienced by high school X grade students in simplifying algebraic expressions, which aligns with previous studies' results that show that students often have difficulty understanding abstract concepts in mathematics, especially algebra. For example, the misconception of the Conjoin Error found in S6 shows its confusion in combining terms that should not be combined, reflecting difficulties in understanding the relationships between elements in algebraic expressions. The Exponent Error misconception, which occurs in S1, S4, and S5, illustrates students' confusion in applying the correct exponential rule, a difficulty also found in research by Marpa (2019) regarding the transition from arithmetic to algebra. Misconceptions of Reversal Error, experienced by S2, S3, and S6, indicate errors in the sequence of operations or management of negative signs that should be applied correctly, as explained by Namkung & Bricko (2020) regarding the challenges of understanding the transition between concrete arithmetic concepts and more abstract algebra.

In addition, the learners' difficulties with variables, observed in S1, S4, and S5, reflect common problems students face when working with variables as symbols representing unknown numbers rather than as real numbers. Previous research by Herscovics and Linchevski (1994) also demonstrated that this difficulty arises due to a gap between understanding arithmetic and algebra. The misconception of substituting numeric values for letters, found in S1, S3, S4, and S5, highlights that students often mistakenly replace letters or variables with concrete numbers, even when variables should only be used symbolically. This error is frequently caused by students' confusion in understanding the abstract nature of variables in algebra. The misconception of equation formation error, experienced by S1, S4, and S5, reveals difficulties in forming equations that align with the given problem. Meanwhile, the commutative-like terms error, which occurs in S1 and S5, indicates mistakes in combining or composing terms with common variables or powers. These difficulties can be explained through Piaget's cognitive theory of assimilation and accommodation. Students attempt to assimilate new information into their existing cognitive structures, but due to their immature understanding of algebraic concepts, they tend to repeat errors and fail to accommodate new information by restructuring their mental schemas.

Based on the study results, it can be concluded that the misconceptions students experience when solving algebraic problems are largely influenced by their difficulty in understanding abstract concepts, such as the use of variables and algebraic operations. Therefore, a change in the approach to teaching algebra is needed, one that focuses on developing students' critical and logical thinking skills while providing a more concrete

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understanding of the application of algebraic concepts in daily life. Based on these findings, it is suggested that algebra teaching approaches emphasize a deeper understanding of variables and other abstract concepts to reduce misconceptions. The integration of Moru and Mathunya's (2022) theory in the analysis of misconceptions offers a new perspective on students' thinking errors, which can serve as a basis for developing more effective algebra teaching methods.

CONCLUSION AND SUGGESTIONS

Based on the results and discussion, it can be concluded that seven misconceptions occur among high school grade X students when simplifying algebraic expressions. This study yielded similar findings to the research conducted by Moru and Mathunya (2022). However, this study identified seven specific misconceptions that lead to errors, namely: misconceptions resulting in conjoin errors, misconceptions resulting in exponent errors, misconceptions resulting in reversal errors, misconceptions related to learners' difficulties with variables, misconceptions involving the substitution of numeric values for letters, misconceptions leading to equation formation errors, and misconceptions leading to errors with commutative-like terms.

In the case of misconceptions resulting in conjoin errors, one student (S6) experienced this issue. Misconceptions resulting in exponent errors were found in three students: S1, S4, and S5. Reversal errors occurred in three students: S2, S3, and S6. Misconceptions related to learners' difficulties with variables were observed in three students: S1, S4, and S5. Misconceptions involving substituting numeric values for letters were experienced by four students: S1, S3, S4, and S5. Equation formation errors occurred in three students: S1, S4, and S5. Lastly, misconceptions involving commutative-like terms errors were observed in two students: S1 and S5.

The results and discussion indicate that the assimilation and accommodation processes in students' cognitive thinking are evident. However, some students are unable to fully absorb new knowledge during the accommodation stage, which leads to errors caused by misconceptions when simplifying algebraic expressions. Insufficient assimilation and failure in accommodation are identified as the main causes of these misconceptions.

Based on the findings and conclusions, it is recommended that future research explores misconceptions in different mathematical topics. Additionally, future studies should consider developing more varied questions with multiple alternative answers. Research focusing on the detailed processes of assimilation and constructive accommodation would provide further insights. It is also suggested that future studies identify other types of misconceptions, such as errors caused by the imposed radical sign, to support improvements in algebra instruction for high school grade X students.

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