Jurnal Pendidikan Progresif
e-ISSN: 2550-1313 | p-ISSN: 2087-9849
URL: https://jpp.fkip.unila.ac.id/index.php/jpp
Jounal's DOI: http://doi.org/10.23960/jpp

Vol. 16, No. 1, 2026
Article ID: 1512
Pages: 454-472

Restructuring Conceptual Understanding: The Efficacy of Representation-Based Remedial Learning on Algebraic Misconceptions

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Received: 30 December 2025 *Accepted: 23 February 2026* *Published: 02 April 2026*

Abstract: Misconceptions remain a major problem in mathematics learning at the junior high school level, particularly in algebraic expressions, which require conceptual understanding and the ability to translate various mathematical representations. This study aims to assess improvements in students' conceptual understanding and analyze changes in the types of misconceptions following the implementation of mathematical representation-based remedial learning. This study used a mixed methods approach with an explanatory sequential design. The subjects comprised 33 eighth-grade students at a public junior high school in Banda Aceh City, Indonesia, selected using purposive sampling. Quantitative data were collected using a three-tier diagnostic test before and after the intervention. In contrast, qualitative data were obtained through semi-structured interviews to deepen and contextualize the quantitative findings. Quantitative analysis was conducted using nonparametric statistics, while qualitative data were analyzed through the stages of data reduction, data presentation, and systematic conclusion drawing. The results of the analysis showed a statistically significant increase in students' conceptual understanding, with normalized gain values in the moderate category. Qualitative findings showed a decrease in misconceptions regarding interpreting algebraic symbols and translating problem language into mathematical models, as well as a shift in the structure of students' understanding when interpreting relationships among representations. However, misconceptions stemming from weaknesses in prerequisite concepts, particularly integer operations, tended to persist after the intervention. Furthermore, the increase in correct answers accompanied by low confidence levels suggests that some students' understanding remains traditional and not yet fully stable. Overall, the results of this study indicate that remedial learning based on mathematical representations is associated with improved conceptual understanding and shifts in certain patterns of misconceptions, and provide practical implications for developing learning strategies that are more adaptive to students' conceptual characteristics.

Keywords: algebraic expressions, conceptual understanding, misconceptions, remedial teaching, mathematical representation.

Article's DOI: https://doi.org/10.23960/jpp.v16i1.pp454-472

INTRODUCTION

Mathematics learning at the junior high school (SMP) level still faces various challenges, one of which is the high level of misconceptions among students. Misconceptions are conceptual understandings that do not align with accepted scientific knowledge (Üce & Ceyhan, 2019). This phenomenon is widely reported in various studies on mathematics learning, particularly when students transition from concrete to abstract understanding. Previous studies have shown that misconceptions can arise from incorrect prior knowledge, ineffective learning processes, and errors in interpreting mathematical symbols and representations (Prediger et al., 2019; Al Rababaha et al., 2020).

Misconceptions in algebra learning are persistent and can persist if not addressed appropriately, potentially hindering students' understanding of advanced mathematical concepts. When erroneous knowledge is formed early, students tend to retain that knowledge structure, leading to a continuous series of misconceptions that affect their ability to understand advanced mathematical concepts (Adýgüzel et al., 2018; Ndemo, O., & Ndemo, Z., 2018). In algebraic expressions, misconceptions often arise due to their abstract nature and their role as a prerequisite for more advanced topics such as functions and quadratic equations. Therefore, conceptual errors in this material can have long-term impacts on students' mathematical development (Fitria et al., 2023; Otero et al., 2025).

Conceptually, misconceptions are not simply understood as procedural errors, but rather as alternative knowledge structures that are stably formed in students' cognition. Some researchers view misconceptions as epistemological obstacles, namely conceptual barriers that prevent students from building correct scientific understanding (Adýgüzel et al., 2018). In the context of algebra, misconceptions are often difficult to identify because students can produce procedurally correct answers, but with incorrect conceptual reasoning. This condition causes misconceptions to remain latent and continue to be used by students when learning subsequent mathematical concepts.

Research on algebraic misconceptions shows that students' errors often stem from a superficial understanding of symbols, erroneous generalizations, and an inability to connect symbolic representations to their underlying mathematical meaning (Ndemo & Ndemo, 2018; Fitria et al., 2023). Therefore, efforts to correct misconceptions require a learning approach that not only emphasizes procedures but also facilitates a deep restructuring of students' conceptual understanding.

Various studies have identified that misconceptions in mathematics are closely related to a weak understanding of symbols, errors in communicating representations, and students' difficulties in connecting various forms of mathematical representation (Kaput, 1998; Jitendra et al., 2022). Mathematical representations play a crucial role in helping students understand abstract concepts because visual, symbolic, and verbal representations serve as bridges between concrete experiences and higher-level conceptual understanding (Ainsworth, 2021).

A strong theoretical basis for the importance of representation in learning can be traced through the dual coding theory (Clark & Paivio, 1987). This theory states that information is processed through two interrelated cognitive systems: the verbal system and the nonverbal (visual) system. When information is presented through both systems in an integrated manner, the meaning-making process becomes more effective and lasting. In mathematics learning, integrating visual and verbal representations helps students build meaningful connections between mathematical symbols and the concepts they represent, thereby reducing the likelihood of misconceptions.

Recent research shows that students' ability to connect different forms of representation is an important indicator of deep conceptual understanding (Jupri et al., 2020; Chrisnawati et al., 2024; Ario et al., 2025). Students who can flexibly shift between visual, symbolic, and verbal representations tend to have more stable conceptual understanding than those who rely solely on symbolic representations. In the context of algebra learning, the use of multiple representations serves not only as a visual aid also as a cognitive tool for constructing meaning and correcting erroneous knowledge structures.

Similar findings have been reported in various other mathematics learning contexts, where student misconceptions require restructuring of conceptual understanding through learning approaches that emphasize meaningful conceptual interpretation (Powell & Fuchs, 2015). Learning that integrates concrete, visual, and symbolic representations is effective in helping students develop a gradual, continuous understanding of algebraic concepts (Prosser & Bismarck, 2023).

In addition to the representational approach, remedial learning is a widely used strategy to correct students' misconceptions by adapting learning methods to their conceptual needs (Winarso et al., 2023; Mutodi et al., 2023). Remedial learning provides students with opportunities to rebuild conceptual understanding through more structured, directed activities that strengthen foundational concepts (Alsrairi & Amjad, 2025). However, students who participate in remedial learning generally experience ongoing difficulties in understanding abstract mathematical concepts, thus requiring a more meaningful and integrated learning approach (Munusamy et al., 2025).

Although numerous studies have examined students' misconceptions in algebra learning and the effectiveness of using mathematical representations, most still treat these two aspects separately. Systematic reviews show that research on algebraic misconceptions generally focuses on identifying the types of errors and sources of student misconceptions. In contrast, research on mathematical representations focuses more on their impact on improving learning outcomes or representational abilities without explicitly integrating them into a systematic remedial learning framework (Jitendra et al., 2022; Otero et al., 2025).

Thus, research specifically integrating remedial learning with the use of mathematical representation as a primary strategy to correct students' misconceptions in algebraic expressions at the junior high school level is still relatively limited. This situation indicates a research gap that is important to bridge, given that the characteristics of students' algebra difficulties require a learning approach that is both corrective and conceptual.

Based on the research gap, this study aims to analyze improvements in students' conceptual understanding and to describe changes in the types of misconceptions after participating in mathematical representation-based remedial learning on algebraic expressions. Specifically, this study is directed to answer the following research questions: (1) Is there an increase in students' conceptual understanding after mathematical representation-based remedial learning on algebraic expressions in junior high school? Furthermore, (2) How are the changes in the types of students' misconceptions after implementing mathematical representation-based remedial learning? To answer these questions, this study used an approach that sequentially combines quantitative and qualitative analyses to obtain a comprehensive understanding of changes in conceptual understanding and misconceptions.

METHOD

Participants

The participants in this study were 33 students from class VIII-2 at SMP Negeri 6, Banda Aceh City, selected through purposive sampling. The sample selection was based on several inclusion criteria, namely: (1) students have obtained algebraic form material according to the applicable curriculum, (2) students show variations in the level of understanding of concepts and types of misconceptions in the material, and (3) students who fully participated in the learning process during the research period. The exclusion criteria in this study were students who did not participate in the entire remedial learning series or complete the pretest or posttest.

Class VIII-2 was selected because it exhibits heterogeneous mathematical conceptual abilities. This heterogeneity was identified based on the distribution of initial diagnostic test scores, which showed a fairly wide range (0–75) and variations in students' conceptual understanding levels, ranging from low to high. Furthermore, initial analysis of the three-level diagnostic test also revealed diverse types of misconceptions for each indicator of algebraic expressions. These findings indicate that this class is representative for examining the dynamics of misconception improvement through mathematical representation-based remedial learning.

For data triangulation, six students were selected as interview subjects based on variations in misconception types, error patterns, and levels of confidence identified through pretest and posttest diagnostic results. This study was conducted over four weeks during the odd semester of the 2024/2025 academic year and obtained informed consent from the school and participants.

Research Design and Procedures

This study used a mixed-methods approach with an explanatory sequential design, in which the quantitative phase was implemented first, followed by a qualitative phase to deepen and explain the quantitative results (Creswell, 2018). The quantitative phase aimed to identify improvements in students' conceptual understanding and changes in misconceptions after participating in mathematical representation-based remedial learning. The qualitative phase further explored students' thinking processes and the dynamics of misconceptions.

The quantitative phase used a one-group pretest–posttest design to compare students' conceptual understanding before and after the remedial learning intervention. The intervention was implemented through three core meetings, each lasting 2 x 40 minutes. The remedial learning was designed to integrate visual, symbolic, and verbal representations as the primary strategy for correcting student misconceptions.

This design allowed researchers to identify changes in scores and patterns of misconceptions after the intervention, but did not involve a control group. Therefore, the findings of this study should be interpreted as an indication of improvement after the implementation of remedial learning, rather than as strong causal evidence compared to other learning approaches.

The research procedure includes four stages, (1) Preparation, in the form of needs analysis, sample determination, instrument preparation, and instrument validation, and learning tools, (2) Implementation of the quantitative stage, in the form of administering a pretest, implementing remedial learning based on mathematical representation, and administering a posttest, (3) Implementation of the qualitative stage, in the form of in-depth interviews with selected students based on the results of the quantitative stage; and (4) Integration and reporting, namely combining quantitative and qualitative findings through technical triangulation. The flow of research implementation and the sequential relationship between quantitative and qualitative are visualized in the research flow diagram in Figure 1 as follows.

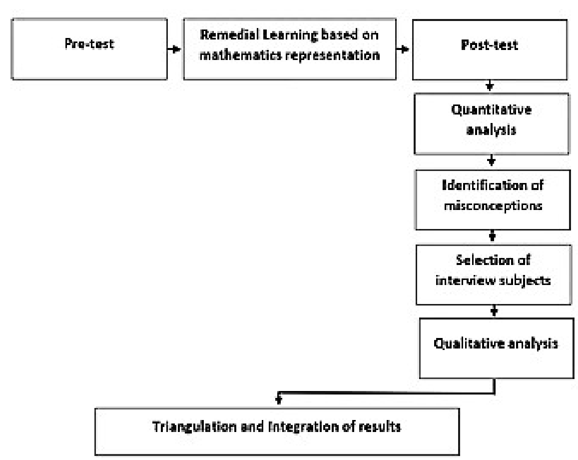


Figure 1. Research procedures

Instruments

The quantitative instrument used in this study was a three-tier diagnostic test developed to measure conceptual understanding and identify students' misconceptions in algebraic expressions. This test consists of three components: (1) answer choices, (2) reasons underlying these choices, and (3) students' level of confidence in their answers (confident/ unconfident). These three components were used to classify students' responses: misconceptions, lucky guesses (correct answers with low confidence), and no misconceptions (correct answers with high confidence). A confidence-level analysis was conducted to assess the stability of students' conceptual understanding before and after the intervention. Test indicators were arranged based on aspects of mathematical representation, including symbolic, visual, and verbal representations in algebraic expressions.

The test instrument was developed and pilot-tested on students outside the primary research subject. The empirical validity of the test items was tested using the Pearson product-moment correlation, which indicated that all test items had moderate to high validity. The internal consistency of the instrument was assessed using Cronbach's alpha, yielding a value of 0.751, indicating adequate reliability. Furthermore, the instrument underwent expert validation by two Mathematics Education lecturers and two junior high school mathematics teachers to ensure content and construct validity, as well as language clarity.

The qualitative instrument, a semi-structured interview guide, was used to explore students' thought processes, sources of misconceptions, and mechanisms for improving conceptual understanding after remedial learning. The interview guide was validated by an educational evaluation expert to ensure its substance aligned with the research objectives.

In addition to data collection instruments, learning tools in the form of teaching modules and Student Worksheets (LKPD) were also validated by experts. This validation aimed to ensure the tools' suitability for the syntax of problem-based learning (PBL) as a framework for learning activities, and to ensure that all learning activities consistently emphasized the use of mathematical representations (visual, symbolic, and verbal) as a core strategy for correcting misconceptions.

Data Analysis

Data analysis was conducted in several stages, namely quantitative and qualitative analyses. Quantitative data were analyzed to determine the increase in students' conceptual understanding after participating in remedial learning based on mathematical representation. Quantitative analysis included descriptive statistics, including mean, minimum, maximum, and standard deviation, for the pretest and posttest. Then, the normalized gain (N-gain) score was calculated by adapting Hake's formula to interpret the level of improvement in students' conceptual understanding (Meltzer, 2002). The N-gain categories shown in Table 1 as follows.

Table 1. N-Gain interpretation categories

Normalized N-Gain Score	Category
$g > 0.70$	High
$0.30 \leq g \leq 0.70$	Moderate
$g < 0.30$	Low

Next, the N-gain data were tested for normality using the Kolmogorov-Smirnov test with a significance level of 0.05. If the data were normally distributed, the analysis was continued with a paired t-test. If the data were not normally distributed, a nonparametric statistical test was used. Furthermore, the results of a three-level diagnostic test were also analyzed to identify changes in the types of student misconceptions before and after remedial learning.

Qualitative data from interviews were analyzed through data reduction, data presentation, and conclusion drawing. This analysis aimed to deepen and explain the quantitative findings, particularly regarding the dynamics of changes in students' misconceptions regarding algebraic expressions. The integration of quantitative and qualitative results was achieved through technical triangulation, comparing diagnostic test results and interview data to gain a comprehensive understanding of the effectiveness of mathematical representation-based remedial learning.

■ RESULT AND DISCUSSION

Is There an Improvement in Students' Conceptual Understanding after Mathematical Representation-Based Remedial Learning?

The improvement in students' conceptual understanding was analyzed by comparing pretest and posttest scores following the implementation of mathematical representation-based remedial learning. Descriptively, the average posttest score (M = 56.97) was higher than the average pretest score (M = 24.85). Furthermore, the average normalized gain (N-gain) was 0.4298, which falls within the moderate category. This finding indicates an improvement in conceptual understanding, although the increase has not yet reached the high category.

The next statistical test was an N-gain normality test of students' conceptual understanding. The hypothesis test decision used a significance level of 0.05, namely, accepting H0 if the p-valuee" 0.05. The results of the N-gain normality test for students' conceptual understanding are shown in Table 2 below.

Based on Table 2, the Kolmogorov-Smirnov test yields a significance value of 0.007,

Table 2. Normality test of students' conceptual understanding gain

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
N-Gain Tes	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
	0.182	33	0.007	0.884	33	0.002

while the Shapiro-Wilk test yields a significance value of 0.002. Given the relatively small sample size of this study (N=33), the Shapiro-Wilk test is prioritized as the basis for assessing normality. Thus, the N-gain data is declared not normally distributed.

Based on these results, the difference between pretest and posttest scores was tested using the nonparametric Wilcoxon signed-rank test with a significance level of 0.05. Reject H0 if the significance is <0.05. The results of the Wilcoxon N-gain test are presented in Table 3 below.

Table 3. Test of improvement in normalized gain of students' conceptual understanding

	Posttest – Pretest
Z	-4.721[b]
Asymp. Sig. (2-tailed)	.000

Based on the results in Table 3, the Wilcoxon test results show a significance value of 0.000, which is less than 0.05, so H0 is rejected. This finding indicates that remedial learning based on mathematical representation significantly improves students' conceptual understanding.

To clarify the pattern of improvement at the individual level, the pretest and posttest scores are visualized as a scatter plot with a diagonal reference line in Figure 2 below.

Points above the diagonal line indicate an increase in student scores (posttest > pretest), while points directly on the line indicate no change in scores. The visualization results show that almost all students increased their scores, with only a few remaining stable and no students decreasing their scores.

Theoretically, these results support the view that mathematical representations, whether visual,

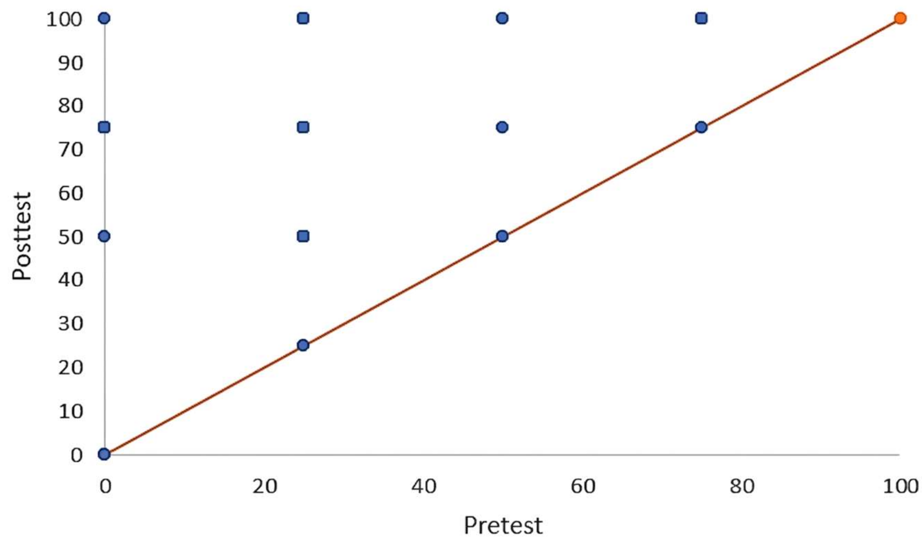


Figure 2. Scatter plot comparing pretest and posttest scores with a diagonal reference line

symbolic, or verbal, act as a bridge between concrete experiences and abstract concepts, thus helping students build more meaningful conceptual understanding. In algebra, students often process symbols mechanically without understanding their meaning (Tsamir, 2001). Remedial learning that emphasizes the use of representations provides students with opportunities to reconstruct the meaning of algebraic symbols through interconnected representations. This finding aligns with the view that mathematical representations can bridge the gap between concrete experiences and abstract symbols, thereby helping students build a deeper, more meaningful understanding of concepts (Rau & Matthews, 2017). Furthermore, mathematical representations have been identified as an effective strategy for strengthening conceptual understanding, as visual representations linked to symbols encourage more exploratory, reflective thinking when solving algebraic problems (Bicer, 2021; Stemele & Asvat, 2024). In the context of remedial learning, the use of mathematical representations also encourages the formation of cognitive connections among the various forms of representation students use to understand algebraic concepts.

Although the improvement was statistically significant, the moderate N-gain value requires critical analysis. This moderate increase indicates that the intervention's effectiveness was not evenly distributed across all aspects of conceptual understanding. Findings from the three-tier diagnostic test indicated that some misconceptions persisted, particularly those related to prerequisite concepts. Furthermore, the increase in the lucky guess category on the posttest indicates that some students were beginning to arrive at the correct answer. However, their conceptual beliefs were not yet fully stable. Conceptual understanding in mathematics is closely related to individual mathematical abilities, which influence how students construct meaning around abstract concepts, including symbolic algebraic material (Reinhold et al., 2020). This suggests that improvements in scores do not always align with the stability of conceptual understanding among all students.

Factors such as students' prior knowledge, persistent tendencies toward misconceptions, and symbol-oriented learning habits can influence the magnitude of improvement in conceptual understanding over a relatively short period.

Previous research has shown that junior high school students' conceptual understanding of algebra in Indonesia is generally at an intermediate level and still face various epistemological obstacles in constructing complete concepts (Nansiana et al., 2024). Furthermore, specially designed remedial learning has been shown to help students improve their previously erroneous understanding of mathematical concepts, although the resulting improvement is not always in the high category. Therefore, in this study, remedial learning based on mathematical representations has been shown to significantly improve students' understanding of algebraic concepts. However, the extent of improvement remains influenced by the characteristics of students' misconceptions and the strength of the underlying prerequisite concepts.

Further review of the three-level diagnostic test results reveals that the increase in conceptual understanding scores is related to a reduction in misconceptions directly related to translation and the use of mathematical representations, particularly in categories JM1, JM2, and JM3. The decrease in these three categories indicates that students are beginning to distinguish between like and unlike terms, interpret everyday language more accurately into symbolic form, and avoid combining symbolic and interpretative errors in a single response. This conceptual shift directly contributes to the increase in posttest scores, as most of the items require an understanding of algebraic rules and the ability to translate between representations consistently. Thus, the increase in N-gain reflects not only procedural changes but also improvements in conceptual structures previously distorted by misconceptions.

However, the unchanged or relatively stagnant misconceptions in the JM4 category explain why the N-gain score falls within the moderate category. Misconceptions about prerequisite concepts, particularly integer operations, limit some students' ability to correctly simplify algebraic expressions, even when they have received assistance with visual and symbolic representations. This suggests that the effectiveness of mathematical representation-based remedial learning is strongly influenced by students' initial conceptual readiness. When weaknesses in basic concepts have not been fully reconstructed, the resulting improvement in understanding tends to be partial and quantitatively suboptimal. Thus, these findings clarify that improvements in conceptual understanding scores need to be understood contextually, namely as the result of effective interventions on the representational aspect, but still influenced by the strength of the underlying prerequisite concepts.

Although the pattern of improvement is visually clear and statistically significant, the one-group pretest–posttest design did not include a comparison control group and therefore does not allow for strong causal inferences. Therefore, the results of this study are interpreted as indicating improvement following the implementation of mathematical representation-based remedial learning and require further testing through a comparative design in future research.

How do students' misconceptions change after implementing mathematical representation-based remedial learning?

Changes in students' misconceptions about algebraic expressions after participating in mathematical representation-based remedial learning were analyzed from student responses to the pretest and posttest using a three-level diagnostic test, and supported by in-depth interview data. Misconceptions identified in this study include errors in operating unlike terms (JM1), errors in translating everyday language into mathematical sentences (JM2), a combination of JM1 and JM2 errors (JM3), errors in prerequisite concepts (JM4), and errors in applying distribution properties (JM5). In addition, the lucky guess (TB) and no-misconception (TM) categories were analyzed to provide a more comprehensive picture of student response patterns.

Changes in the proportion of students in each misconception category before and after the intervention are presented in Figure 3 below.

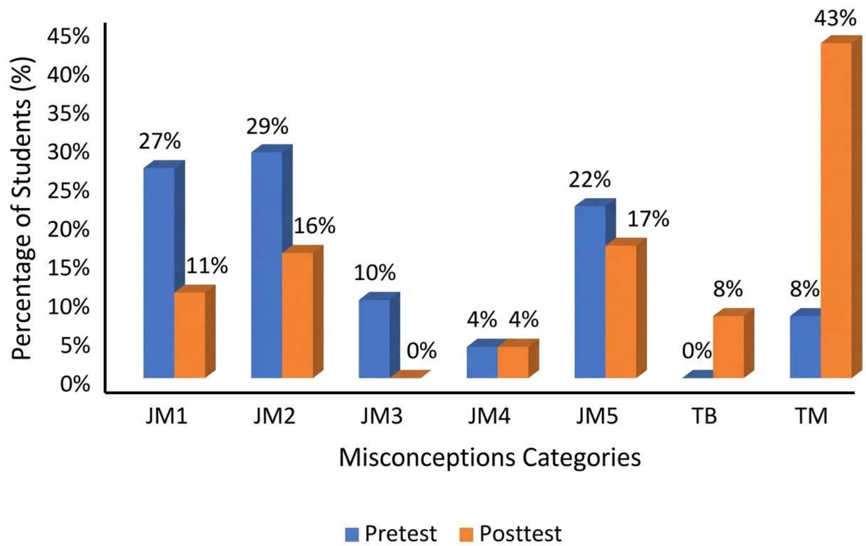


Figure 3. Average percentage of students who experienced and did not experience misconceptions during the pretest and posttest

The figure shows that, in general, the percentage of students experiencing misconceptions decreased across almost all categories, except JM4, which remained stagnant. The largest decrease occurred in JM1, followed by JM2 and JM5, while the TM category experienced the most significant increase. Quantitatively, the average decrease in the percentage of misconceptions was calculated by summing the pretest–posttest differences across the five main misconception categories (JM1–JM5), then dividing by 5. Based on this calculation, an average decrease of 8.8% was observed, reflecting a general conceptual shift among students after participating in remedial learning based on mathematical representation.

To understand the dynamics of these changes in greater depth, individual analyses were conducted for six students selected as interview subjects, as presented in Table 4 below.

Table 4. Changes in students' misconceptions among interview participants

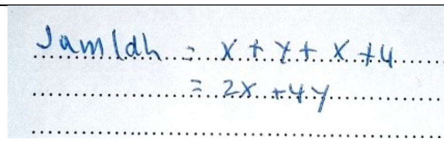
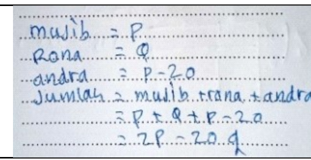
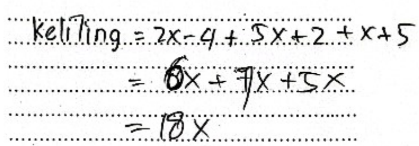
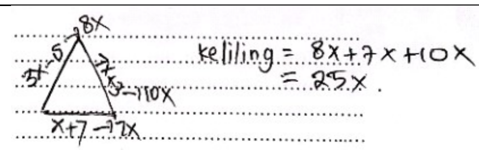
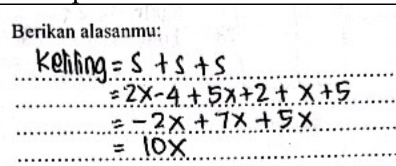
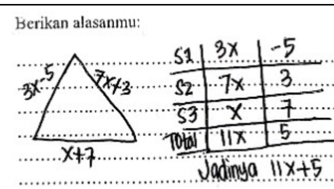
Student Code	Types of Misconceptions Experienced		Misconceptions That Changed
	Pretestt	Posttest	
P1	JM1, JM2, JM5	JM1, JM2, JM5	No change
P5	JM1, JM2, JM5	JM1, JM2, JM5	No change
P13	JM1, JM2, JM5	JM2	JM1, JM5
P16	JM2, JM3, JM4, JM5	JM1, JM2, JM4, JM5	JM3
P27	JM2, JM3, JM4, JM5	JM4, JM5	JM2, JM3
P30	JM1, JM2, JM3	Tidak ada	JM1, JM2, JM3

Table 4 shows that changes in misconceptions were not uniform. Student P30 showed the most significant improvement, with all misconceptions disappearing on the posttest, whereas students P1 and P5 showed no change. Other students (P13, P16, and P27) experienced partial changes, indicating that the intervention's effectiveness was influenced by the characteristics of their misconceptions.

Misconception JM1 was still observed among several students on the posttest, especially P1, P5, P16, and P27. Examples of student responses are shown in Table 5.

Table 5 shows that students consider unlike terms to be operable. Student P1 answered that p+q+p-20 is equal to 2p-20q. He said, "Because there the p has been added because both have p. Then the q is also added with -20 to get -20q." Meanwhile, student P5 answered that 3x-5 equals 8x and x+7 equals 7x. In this case, student P5 has understood the meaning of like terms even though he still uses everyday language. He said that "Like terms are terms that both have the same letter". Student P5 demonstrated verbal understanding of the term "like terms" but was unable to apply it to the problem, even though it had been covered in remedial learning materials.

Table 5. Several displays of answers from students who experienced a misconception JM1

Student Code	Student Responses	
	Pretest	Postest
P1		
	The student simplified $x + y + x + 4$ as $2x + 4y$, incorrectly combining the constant 4 with the variable y.	The student simplified $p + q + p - 20$ as $2p - 20q$ because the student added terms that contain the same letters and also combined q with -20.
P5		
	The student calculated the perimeter by adding $2x - 4 + 5x + 2 + x + 5$ and simplified it as $10x$.	The student calculated the perimeter as $8x + 7x + 10x$ and simplified it as $25x$.
P30		
	The student determined the perimeter as $2x - 4 + 5x + 2 + x + 5$ and simplified it as $10x$.	The student represented the side lengths as $3x - 5, 7x + 2$, and $x + 7$, then calculated the perimeter as $11x + 5$.

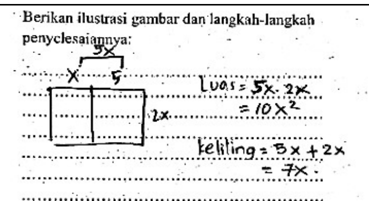
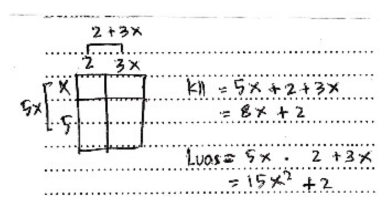
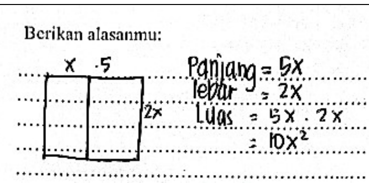
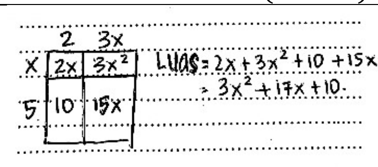
In contrast to P1 and P5, student P30 showed significant improvement after undergoing remedial learning based on mathematical representation. During the pretest, he also simplified algebraic operations by adding adjacent terms. However, during the posttest, he showed improvement and was able to apply mathematical representations in his answers. He said, "I used to think that if numbers and letters could just be combined. However, when it was explained using a table, I started to think that the correct way to add them is according to the same variables; if the table is different, they cannot be added." This statement shows that remedial learning based on mathematical representation was successful in helping some students develop a stronger conceptual understanding. Students not only know the addition procedure but also understand the reasoning behind the procedure.

Students who still showed misconceptions about JM2 on the post-test included P1, P5, P13, and P16. The following displays the answers of several students who have and have not shown improvement after this remedial learning.

Table 6 shows that students misinterpret everyday language as mathematical sentences. Student P13 was unable to interpret visual information into mathematical sentences, so he made a mistake in determining the appropriate length and width. He said that, "The width of the shape is 5x because there are the number 5 and the letter x on the same side. So, combined, the result is 5x." This quote makes it clear that P13 experienced persistent misconceptions in the JM2 category. Based on the interview results, it was found that student P13's lack of conceptual understanding was due not only to a lack of conceptual understanding but also to a lack of habit of thoroughly reading visual information.

Meanwhile, P27 and P30 showed significant conceptual understanding after remedial learning. During the pretest, one of the sides was considered 5x when it should have been

Table 6. Sample student responses showing the JM2 misconception

Student Code	Student Responses	
	Pretest	Postest
P13		
	The student represented the rectangle with sides $5x$ and $2x$, calculated the area as $5x\ \times 2x$, and determined the perimeter as $5x + 2x = 7x$.	The student represented the sides as $5x, 2 + 3x$, and x, calculated the perimeter as $5x + 2 + 3x = 8x + 2$, and determined the area as $5x\ (2 + 3x)$.
P30		
	The student represented the length as $5x$ and the width as $2x$, then calculated the area as $5x \times 2x = 10x^2$.	The student divided the rectangle into several parts labeled $2x, 3x^2, 10$, and $15x$, then calculated the total area as $3x^2 + 17x + 10$.

5+x. However, during the posttest, he used the plane figure to find its area and assumed that if there were a line, then cutting it arbitrarily with different sizes would add the size instead of multiplying it. He said, "I already understand that x and 5 cannot be 5x, but x+5, then to find the area, I used a table." Although remedial learning has touched on relevant aspects of representation, some students still need additional reflective practice, especially in translating visual representations into symbolic ones that are meaningful and consistent.

No students still demonstrated misconceptions of JM3 during the post-test. The following shows the answers of several students who did and did not improve after this remedial learning.

Table 7. Sample student responses showing the JM3 misconception

Student Code	Student Responses	
	Pretest	Postest
P16	Dara = x Zahra = y Anggi = 4x Jumlah = x + y + 4x = xy + 4x	Mujib = p Rona = q Andra = p - 20 Jumlah = p + q + p - 20 = 2p - 20q
	The student represented Dara as x, Zahra as y, and Anggi as $4x$, then simplified $x + y + 4x$ as $xy + 4x$.	The student represented Mujib as p, Rona as q, and Andra as $p - 20$, then simplified $p + q + p - 20$ as $2p - 20q$.

Table 7 shows that students assume that unlike terms can be operated on and misinterpret everyday language as mathematical sentences. Students P16 and P27 showed a shift in the type of misconception. In the post-test, student P16 no longer showed the misconception all at once in a single problem, but still showed misconceptions in other problems of separate types, namely JM1 and JM2. In the pre-test, student P16 interpreted "4 is more than Dara" as 4x and assumed that x + y + 4x is the same as xy + 4x. However, in the post-test, he simplified the form q-20 as -20q even though he was able to transform everyday language into mathematical sentences. Student P16 said, "During the remedial yesterday, it was explained using pictures and example sentences, so I understood the meaning of the story problem. However, while working on the problem, I was confused about how to simplify p + p + q - 20. I thought q - 20 had to be added, and I was sure because the answer was in the answer choices."

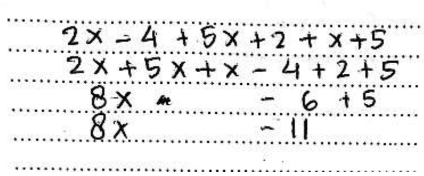
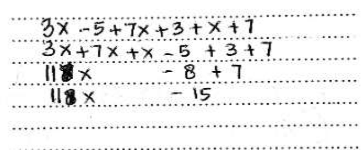
Overall, no further students experienced misconception JM3 at the posttest stage. The complete disappearance of this misconception indicates that the remedial learning implemented was specifically effective in targeting dual misconceptions, namely a combination of symbolic errors and verbal misinterpretations. This success is inseparable from the characteristics of the intervention, which explicitly emphasizes the sequential relationship between verbal, visual, and symbolic representations.

In remedial learning, students are first guided to understand the problem context verbally, then visualize it through images or tables, before finally formalizing this understanding in symbolic form. This tiered approach allows students to build consistent meaning relationships between representations, thereby preventing multiple understandings, which is the main characteristic of JM3 misconceptions. Unlike other misconceptions that persist due to weak prerequisite concepts or procedural habits, JM3 misconceptions are relatively more responsive to interventions that directly target the process of meaning translation between representations.

Students who still demonstrated misconception JM4 during the post-test included P16 and P27. The following shows the answers of several students who did and did not improve after this remedial learning.

Table 8 shows that students added integers incorrectly and produced mathematically illogical forms during the pretest and posttest. Student P27 showed a persistent misconception of type JM4. During the interview, the student indicated that he did not use the concept of like terms correctly and made mistakes in integer operations, which were part of the prerequisite material. Student P27 said, "I added them all up, ma'am, 3x + 7x + x produces 11x, then -5 + 3 + 7 = -8 + 7 = -15. The result -8 was obtained because 3 + 5 is 8, and there is a negative sign in front of 5, so the final result is -8." This shows that students have not internalized the understanding of integers as an important prerequisite in simplifying algebraic expressions.

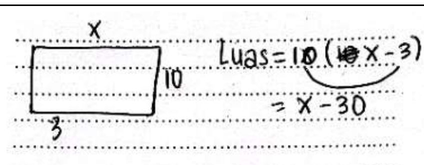
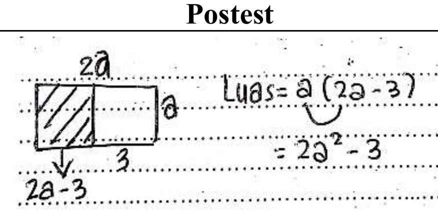
Table 8. Sample student responses showing the JM4 misconception

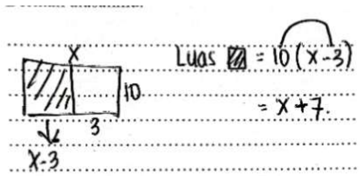
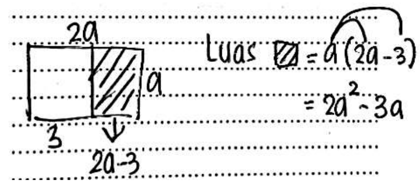
Student Code	Student Responses	
	Pretest	**Postest**
P27		
	The student simplified 2⁇- 4 + 5⁇+ 2 + ⁇+ 5 by grouping the variable terms and constants, resulting in 8⁇+ 11.	The student simplified 3⁇- 5 + 7⁇+ 3 + ⁇+ 7 by grouping the variable terms and constants, resulting in 11⁇- 15.

Meanwhile, the other four students did not show JM4's misconceptions in the pretest or posttest. During an interview with student P13, he stated that he still remembered the material on integers. In the interview, he said, "I remember that minus is like debt and positive is like money. So it's better to understand, ma'am, how to find the remaining money or the remaining debt." This statement indicates that understanding the prerequisite concepts underlying algebraic operations began to be embedded through remedial learning that emphasized symbolic representation and reasoning. Findings from the diagnostic test showed no change; findings from the three-level diagnostic test showed an increase in individual understanding among certain students.

Students who still showed misconception JM5 in the post-test stage included P1, P5, P16, and P27. The following displays the answers of several students who have and have not shown improvement after this remedial learning.

Table 9. Sample student responses showing the JM5 misconception

Student Code	Student Responses	
	Pretest	**Postest**
P16		

	The student represented the rectangle with sides 10 and ⁇- 3 , then calculated the area as 10(⁇- 3) and simplified it as ⁇- 30.	The student represented the rectangle with sides ⁇ and (2⁇- 3), then calculated the area as ⁇(2⁇- 3) and simplified it as 2⁇^{2} - 3.
P13		
	The student represented the rectangle with sides 10 and (⁇- 3), then calculated the area as 10(⁇- 3) and simplified it as ⁇+ 7.	The student represented the rectangle with sides ⁇ and (2⁇- 3), then calculated the area as ⁇(2⁇- 3) and simplified it as 2⁇^{2} - 3⁇.

In Table 9, it appears that student P16 only multiplied 10×(-3) to equal -30 but did not multiply 10×(x). Similarly, student P13 subtracted only 10 and -3, resulting in 7. In this case, students P13 and P16 both experienced misconceptions in applying the distributive law. During the pretest, student P16 showed that he multiplied a×(2a) but did not multiply a×(-3) again. He said, "There is an a in front of it, ma'am, so the only thing that is multiplied is the one with the letter a as well." This shows that students do not yet understand the distributive law. The terms inside the parentheses are only multiplied by the terms outside the parentheses that have the same letter.

This is different from student P13, who previously experienced misconception JM5 in the pretest but was able to solve the problem correctly and provide the correct reasoning during the posttest. Table 10 shows that the student has a much better understanding of the distributive law. He said, "I like distributive multiplication like this now, ma'am. I like to use arrows like this so I don't forget to multiply." This statement indicates that the student is beginning to understand the distributive law as an operational rule that applies to all elements in parentheses.

The lucky guess (TB) category refers to students who select the correct answer and reasoning but express uncertainty about the reasoning process. In the pretest, no students fell into the TB category. However, after implementing mathematical representation-based remedial learning, the number of students categorized as TB increased in the posttest.

These findings can be interpreted from two perspectives. On the one hand, the improvement in the TB category indicates that students are beginning to move toward correct answers and can use mathematical representations more accurately. However, this condition also indicates that students' conceptual understanding is not yet fully stable and remains in a transitional stage. In other words, remedial interventions can produce fragile knowledge, in which students have acquired the correct procedures or representations but are not yet fully confident in their underlying conceptual meaning.

Quantitatively reviewed based on the category distribution in Figure 3, the increase in conceptual understanding is also evident in the no-misconception (TM) category, which increased from 8% in the pretest to 43% in the posttest. However, the emergence of the lucky guess (TB) category at 8% in the posttest indicates that the increase in correct answers was not fully followed by a proportional increase in confidence levels. This finding indicates that although there was a shift from misconceptions to correct answers, some students were still at a stage of conceptual restructuring that was not yet fully stable.

This phenomenon was seen in P1 students who were able to solve problems with the aid of visual representations, but still expressed doubt about their answers. This suggests that while mathematical representations help reduce misconceptions, conceptual restructuring requires more time and reflective practice to solidify students' understanding and build sufficient confidence.

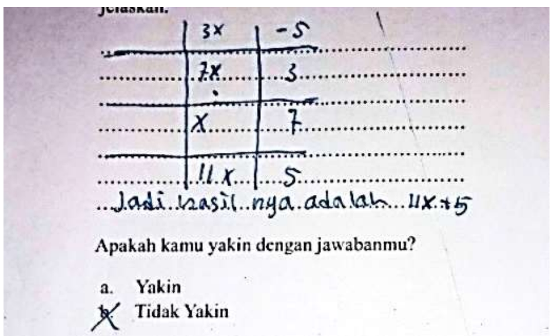


Figure 4. Student responses exhibiting TB (lucky guess)

Figure 4 shows that student P1 used a visual representation in his answer to the question, but he crossed out the uncertain part. During the interview, he stated, "I have only recently used the Gini table, so I don't know if my answer for adding these numbers (integers) is correct." Essentially, he doubted his answer, even though it was correct. This indicates that the use of mathematical representation helped students overcome their misconceptions, even though their confidence level was reduced.

The misconceptions experienced by students in algebraic expressions align with the research of Chow and Treagust (2013), which explains that misconceptions in algebra often arise when students simplify operations involving numbers and variables and operate mechanically on numbers and coefficients without understanding their symbolic meaning. Both are rooted in students' misunderstanding of the concept of like terms, such as 2x-4 equals 6x and 5x+2 equals 7x (Irawati et al, 2018). Other misconceptions are also consistent with the findings of Riccomini et al. (2015), who stated that students' misconceptions in algebra stem from errors in interpreting everyday language in mathematical sentences. Multiple misconceptions between JM1 and JM2 are categorized as JM3. This is in line with the findings of Fitria et al. (2023), which show that in one problem, student responses can represent more than one interrelated misconception.

Misconceptions related to prerequisite concepts in integers, such as -5 + 3 equals -8 or -8 + 7 equals -15. This is in line with the findings of Fitria et al. (2023), who showed that students' misconceptions on prerequisite concepts can trigger misconceptions in advanced concepts due to the interdependent relationships between concepts. The analogy of "debt-receivable" as a form of verbal representation used by students when working with integer material is consistent with the findings of Ünal et al. (2023), which show that this kind of verbal representation helps students understand the meaning of positive and negative signs in a more contextual way. With this, students consider the minus sign as debt and the positive sign as money, making it easier to analogize the final result of the problem. Meanwhile, student misconceptions that arise when the distributive law is applied incorrectly align with the findings of Al Rababaha, Yew, and Meng (2020), who report that errors in the distributive law are also student misconceptions in algebra, such as 10(x-3) equals x-30. This error indicates that students cannot multiply terms distributively, and some students only multiply terms with the same letter.

Several students who successfully corrected their misconceptions used visual representations in the form of "arrow" illustrations to help them understand that each term in parentheses must be multiplied. Furthermore, some students used plane-figure drawings to represent the algebraic multiplication of two terms. These results indicate that visual representations play a crucial role in establishing logical connections between geometric concepts and symbolic algebraic expressions. This is consistent with the findings of Jupri et al. (2020), who also emphasized that geometric visualization can serve as a concrete means to explain the distributive law more meaningfully. Students with low confidence in their answers, even though they are correct, can also experience this. This is consistent with the findings of Arslan et al. (2012), who found that student uncertainty can arise from students' new understanding of concepts. In addition to mathematical ability, students' mathematical beliefs also play a role in shaping conceptual understanding, especially when students encounter abstract mathematical concepts (Rittle-Johnson et al., 2015; Rau, 2017). The multiple representations-based learning approach has been shown to increase the depth of students' conceptual understanding by helping connect various forms of representation to interpret algebraic concepts more comprehensively (Altýnbaþ et al., 2025).

Thus, the results of this study indicate that remedial learning based on mathematical representation not only increases conceptual understanding scores but also shifts the structure of students' misconceptions conceptually. However, the extent of this shift is influenced by the strength of students' prerequisite concepts.

CONCLUSION

Remedial learning based on mathematical representations led to increased conceptual understanding and a shift in students' misconceptions about algebraic expressions. Visual, symbolic, and verbal representations helped students reconstruct conceptual meaning more systematically. However, because this study used a one-group pretest–posttest design without a control group, these findings need to be confirmed through research with a comparative design and a longer intervention duration.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the writing process of this manuscript, the author used ChatGPT to help improve the language quality, editorial clarity, and readability of the academic text. The use of ChatGPT did not include data analysis, interpretation of research results, or drawing scientific conclusions. All content produced with the help of ChatGPT has been thoroughly reviewed, edited, and verified by the author. The author is solely responsible for the accuracy, scientific integrity, and final content of the published manuscript.

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