Linear: Journal of Mathematics Education
Volume 7, No. 1, June 2026
p-ISSN: 2722-6913 e-ISSN: 2722-760X
https://doi.org/10.32332/edfptp64

Error analysis of vocational students in solving linear equation problems

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Received: 13 October 2025 | Revised: 24 November 2025 | Accepted: 2 December June 2025 | Published Online: 3 December 2025

Abstract

Difficulties in understanding algebraic concepts often lead vocational high school students to make systematic errors in solving linear-equation problems. This study analyzes the types and causes of students' errors in solving One-Variable Linear Equations (PLSV) and Two-Variable Linear Equation Systems (SPLDV). A qualitative descriptive design was used with purposive sampling involving 25 tenth-grade Fashion Design students at SMKN 6 Palembang who had completed introductory algebra units. Instruments consisted of six problem-solving items on PLSV and SPLDV; their content validity was established through expert review and pilot testing, followed by item refinement. Data were analyzed using Miles and Huberman's interactive model with a predefined coding scheme developed from literature-based error categories. The analysis included error identification, code assignment, category confirmation through coder agreement checks, data display, and conclusion drawing. Five dominant error types emerged: (1) equation-manipulation errors rooted in procedural "transposing" without conceptual grounding, (2) misapplication of the distributive property and negative signs, (3) modeling errors when translating word problems, (4) integer-operation errors, and (5) failure to connect results to context. The findings show intertwined conceptual and procedural difficulties. Practical implications include structured learning sequences in which teachers first build conceptual schemas through visual representations, then guide students in modeling real-world scenarios using modeling templates, and finally implement reflective routines such as error-analysis sheets and justification prompts to consolidate understanding and reduce algebraic errors.

Keywords: Linear Equation Problems; Students' Errors; Vocational Students

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INTRODUCTION

Mathematics occupies an essential place in the curriculum of Vocational High Schools (SMK) because it supports students' adaptability in both everyday life and the workplace. Mathematics education is also expected to foster students' development in line with advances in science, technology, and the arts (Asfyra et al., 2020). Among the areas of mathematics, algebra plays a central role in shaping students' logical reasoning, analytical ability, and problem-solving skills. Prior work shows that algebraic understanding is closely tied to everyday decision-making (Baidoo & Ali, 2023; Juraev, 2024). Topics such as One-Variable Linear Equations (PLSV) and Two-Variable Linear Equation Systems (SPLDV) demand both computational fluency and the capacity to represent real-world situations symbolically (Halomoan et al., 2025; Jupri & Drijvers, 2016; Kieran, 2011). Recent research indicates that many students continue to rely on memorised algorithms rather than deriving solutions from understanding the meaning of the equal sign and equation structure (Chirove & Ogbonnaya, 2021).

Several studies conducted in vocational school settings have reported persistent challenges related to PLSV and SPLDV. Lusiana et al. (2023) and Ismiasih (2024) found that SMK students often struggle with conceptual and procedural elements of algebra, particularly when manipulating equations and applying algebraic rules. Similarly, Baweleng et al. (2023) and Saragi & Ikashaum (2024) observed that students face substantial difficulties in solving SPLDV word problems, including errors in translating verbal statements into algebraic expressions, misinterpreting symbols, and carrying out integer operations. Further evidence from Fitria & Rismawati (2024) indicates that students' errors tend to cluster around recurring patterns such as misidentification of variables, misapplication of procedures, and inconsistencies in symbolic representation, yet many studies stop at describing errors without systematically linking them to their underlying conceptual or procedural causes. Research specifically addressing algebraic errors in the SMK context also remains relatively limited, and few studies offer diagnostic criteria or coding indicators that can be applied consistently.

To address these gaps, the present study applies an integrated diagnostic framework that classifies and interprets students' PLSV and SPLDV errors using a theory-informed and replicable coding scheme. This approach makes it possible to connect observable mistakes to the reasoning processes behind them and to produce instructional recommendations that can be readily implemented in SMK classrooms. The novelty of this study lies in its systematic linkage between conceptual and procedural error patterns through a validated coding framework adapted to vocational education. It also provides actionable instructional implications that can support the design of more targeted and effective algebra learning in SMK.

METHODS

This study followed the general stages of descriptive qualitative research as described by Miles et al. (2016) and Sugiyono (2017), which consisted of three phases: preparation, implementation, and data analysis. The data were analyzed descriptively following the qualitative analysis procedure that includes data reduction, data display, and conclusion drawing as adapted from the Miles and Huberman model.

The research instrument consisted of six constructed-response items, three PLSV and three SPLDV questions, designed based on the learning indicators of the SMK mathematics curriculum, including variable representation, algebraic manipulation, modelling of verbal problems, the use of elimination or substitution methods, and verification of solutions within context. Item development began with the identification of core competencies and common algebraic difficulties reported among vocational high school students. To ensure instrument quality, all test items were reviewed and validated by one mathematics education lecturer and one senior SMK mathematics teacher, who evaluated content accuracy, conceptual appropriateness, clarity of wording, and alignment with the curriculum; their feedback was used to revise the structure and wording of the items.

During the implementation phase, students completed the six items individually within a specified time limit, and their written responses were collected and supplemented with brief interviews conducted with selected students to clarify the reasoning behind specific errors. Data analysis followed Miles and Huberman's interactive model, which includes data reduction, data display, and conclusion drawing. A predefined coding scheme, developed from the instrument indicators and algebraic error categories found in the literature, was applied to identify patterns of errors such as incorrect algebraic operations, misunderstandings of negative signs, misrepresentation of verbal problems, and failure to validate solutions. These patterns were then interpreted to determine whether each error reflected conceptual misunderstanding or procedural weakness.

This research was conducted at a vocational school in Palembang, involving 25 tenth-grade students majoring in Fashion Design. The subjects were selected purposively because this group of students had previously learned PLSV and SPLDV materials, making them suitable to provide relevant insights into the conceptual difficulties and errors occurring in real classroom settings.

RESULTS AND DISCUSSION

The findings presented below are organized based on the results of the qualitative data analysis using Miles and Huberman's model, which includes data reduction, data display, and conclusion drawing. At the preparation stage, the researcher designed six questions related to PLSV and SPLDV. These questions were then tested on the students. The following presents the students' work results in solving the given problems.

Tentukan nilai x dari persamaan berikut! $2x - 5 = x + 4$	Translation Determine the value of x from the following equation! $2x - 5 = x + 4$

Figure 1. Problem 1

In this problem, students were asked to determine the value of *x* in a PLSV by recalling the concept of an equation as a step toward finding the value of *x*.

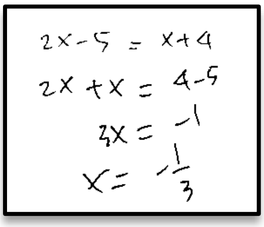


Figure 2. Students' answer for problem 1

Figure 2 shows the student's answer to the problem presented in Figure 1. From the answer, it can be seen that the student has not yet understood the concept of equality in an equation. The student merely moved the variable *x* from the right-hand side to the left-hand side without applying the correct operation. This is supported by the following interview excerpt:

R : Please explain how you solved problem number 1.
S : I moved the value of x, Ma'am, to the left side.
R : So, according to you, to find the solution of a one-variable linear equation, x must be moved to the left-hand side, right?
S : Yes, Ma'am. Because if we want to find the value of x, we have to move it to the left first, then subtract.

From that conversation transcript, it is evident that the student only knows how to solve a one-variable equation by moving the variable *x* without considering its positive or negative sign. As a result, the obtained answer is incorrect. The student's misunderstanding is related to the method of solving one-variable equations. It appears that the student merely remembers that to solve an equation, the variable *x* must be moved from one side to the other without paying attention to the positive or negative sign. This can lead to errors in the final result.

Students who solve one-variable linear equations solely by using the "transposing" method without considering sign changes demonstrate a misconception in equation manipulation. In this case, the student understands the procedure mechanistically but fails to recognize that the "transposing" rule is actually an application of the inverse operation property on both sides of the equation. Consequently, when terms are moved, the signs are often ignored, resulting in incorrect answers.

According to the classification of algebraic misconceptions, this error falls under equation formation/manipulation error, as the student fails to apply the principle of algebraic equality conceptually and instead relies on an incomplete, procedural shortcut (Irawati et al., 2018; Moru & Mathunya, 2022)

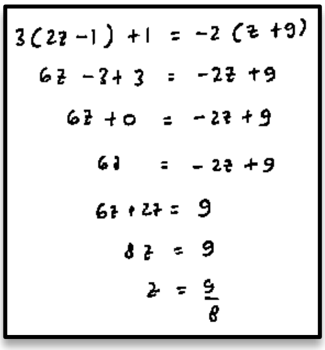
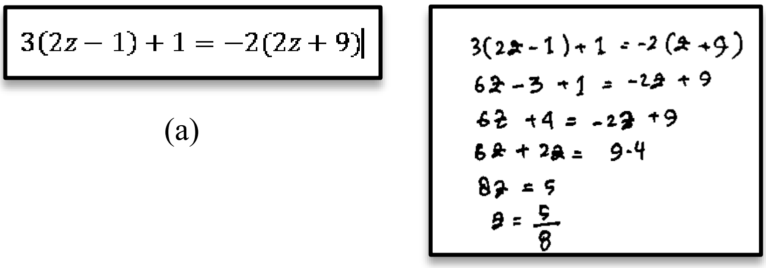


Figure 3. Problem 2

In this problem, students were asked to determine the value of *z* in a One-Variable Linear Equation (PLSV) with a different type of problem.



(a) (b)

Figure 4. Students answer for problem 2

Figures 4(a) and 4(b) show students' answers to the problem presented in Figure 3. Calculation errors are evident, where in Figure 4(a), the student correctly multiplied the numbers inside the parentheses, but also multiplied by the number outside the parentheses. This error occurred because the student misapplied the multiplication rule.

The student's error, correctly multiplying the numbers inside the parentheses, but then also multiplying again by the number outside represents a misconception of the distributive property known as invalid distribution or overgeneralization. This error arises because the student applies the distributive rule excessively without understanding the structural meaning of the algebraic expression. Various studies report that one of the persistent sources of students' algebraic errors is the over-generalisation of rules students apply to commonly encountered procedures outside their valid contexts due to a superficial understanding of the underlying concepts (J. Booth et al., 2017; Mathaba et al., 2024). Futhermore, J. L. Booth et al. (2014) emphasized that this type of misconception is persistent, as students often repeat the same mistakes even after being taught the correct procedure. Supporting evidence from the Indonesian context includes Herutomo et al. (2014), who found that students frequently misapplied the distributive property and showed weak structural understanding of algebraic expressions and Fitria & Rismawati (2024), who reported similar misconceptions in algebra topics. Therefore, this case can be categorized as a conceptual misconception that requires learning interventions focused on structural understanding rather than merely procedural practice.

Meanwhile, in Figure 4(b), the student's error in solving the equation $3(2z - 1) + 1 = -2(2z + 9)$ indicates a misconception in applying the distributive property and handling negative signs. The student correctly expanded $3(2z - 1)$ to $6z - 3$, but made an error when multiplying $-2(2z + 9)$, writing it as $-2z + 9$ (instead of the correct $-2z - 18$). This mistake aligns with the findings of Mathaba et al. (2024), who reveal that many students transitioning from arithmetic to algebra demonstrate only uni- or multi-structural understanding and therefore tend to apply arithmetical rules in algebraic contexts without proper conceptual grounding. In addition, according to Moru & Mathunya (2022), this error can be classified as an Equation Formation Error, because the student transformed an algebraic expression into an equation using incorrect steps, and also as a Difficulty with variables, since arithmetic rules interfere with the understanding of algebraic principles. Therefore, learning should place greater emphasis on understanding the concept of negative signs and the distributive property to minimize similar misconceptions.

Laura dan Cinta mempunyai tabungan bersama sebesar Rp 300.000,00. Jika tabungan Laura Rp 40.000,00 lebih besar dari tabungan Cinta, maka berapakah tabungan mereka masing-masing?	Translation Laura and Cinta have a joint savings account of Rp 300,000. If Laura's savings are Rp 40,000 more than Cinta's savings, how much do they each have?

Figure 5. Problem 3

In this problem, students were asked to solve a word problem involving a PLSV by first understanding the content of the problem, formulating it into an equation, and then determining the answer as requested.

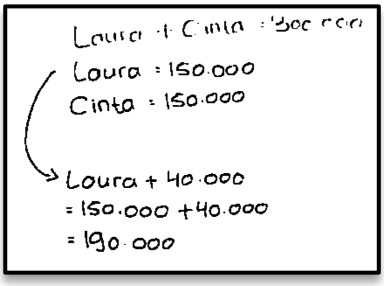


Figure 6. Student’s answer for problem 3

Figure 6 shows the student’s answer to the problem presented in Figure 5. The results indicate that the student was able to correctly understand part of the information from the problem, as evidenced by the accurate formulation of the first equation that aligns with the given statement. However, when writing the second equation, the student made an error in the mathematical modeling process. The information “Laura’s savings = Cinta’s savings + 40,000” should have been expressed as an equation, but instead, the student directly added 40,000 without first formulating it as an algebraic model.

This error falls under the category of modeling error, which occurs when students are unable to accurately translate a contextual situation into a mathematical form. Similar findings were reported by Soneira et al. (2023), who found that inaccuracies in representing problem contexts often stem from students’ limited ability to construct appropriate algebraic models due to the influence of linguistic and structural factors in problem statements. It can also be classified as a reversal error, where the student makes a mistake in converting everyday language into mathematical symbols (Moru & Mathunya, 2022).

Thus, the student’s answer shows that they are in the early stages of understanding mathematical representation but still need further practice in connecting verbal language with the correct algebraic model.

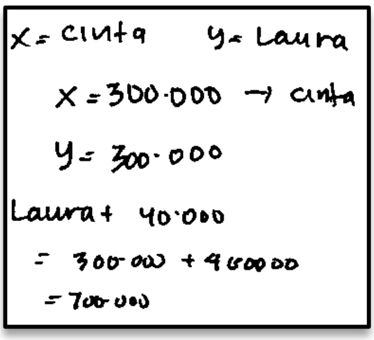


Figure 7. Another student’s answer for problem 4

Figure 7 shows another student’s response to the problem presented in Figure 5. It can be seen that the student was unable to write an equation based on the given problem or construct an appropriate mathematical model. The student misunderstood the meaning of the problem, writing that Cinta had Rp 300,000.00 and Laura also had Rp 300,000.00, whereas in fact, the correct interpretation is that their total savings together amounted to Rp 300,000.00 thus, it would be impossible for each of them to have that amount individually. This misunderstanding is supported by the following interview excerpt:

R : What do you understand from the problem?
S : That, Ma'am, Cinta has Rp 300,000.00 *and Laura has Rp300,000.00, and Laura has Rp* 40,000.00 *more.*
R : Try reading the problem again. It says, "Cinta and Laura have savings together." What does that mean?
S : Ohh, so that means it's the total savings they have together, Ma'am? So the savings should be divided equally, right, Ma'am?
R : Yes, that's right.

The conversation shows that the student did not fully understand the meaning of the problem, resulting in an error when constructing the mathematical model. The student's mistake in writing the amounts of Cinta's and Laura's savings indicates an inaccuracy in the process of mathematical modeling from the word problem. The student assumed that Cinta's savings were Rp 300,000.00 and Laura's savings were also Rp 300,000.00, whereas the correct interpretation is that their combined savings total Rp 300,000.00 with a difference of Rp 40,000.00. This demonstrates that the student has not yet mastered the process of that is, converting everyday language into a correct mathematical model.

According to Jupri & Drijvers (2016), students' difficulties often occur at the stage of translating contextual problems into algebraic form. Similar findings were reported by Ndemo & Ndemo (2018), who stated that students' misconceptions in algebra generally stem from a weak understanding of the basic concepts of variables and relationships, leading to modeling errors. In addition, Musyarofah et al. (2025) emphasized that students often face difficulties when translating word problems into mathematical models, particularly due to limited understanding of contextual relationships and symbolic representation, which is clearly evident in this case.

Tentukan himpunan penyelesaian yang memenuhi persamaan $x - 3y = 5$ dan $x + y = 11$!	Translation Determine the solution set that satisfies the equations $x - 3y = 5$ and $x + y = 11$!

Figure 8. Problem 4

In this problem, students were asked to determine the values of x and y SPLDV by recalling the solution concepts using the elimination method, substitution method, or a combination of both.

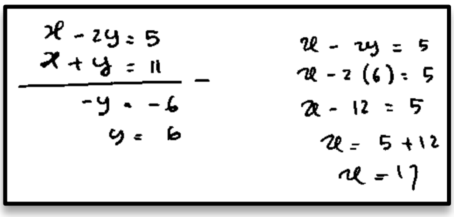


Figure 9. Student's answer for problem 4

Figure 9 shows one of the students' answers to the problem presented in Figure 8. The student attempted to solve the SPLDV using the elimination and substitution methods to find the values of x and y, but still made an error in arithmetic operations, such as writing $-2y - y = -y$, which indicates a mistake in subtracting negative numbers. This error is further supported by the following interview excerpt:

R : Can you explain what you did to find the solution to this problem?
S : This is about two variables, right, Ma'am, so I used the elimination method. I eliminated equation 1 and equation 2 by subtracting them so that x would be eliminated, and then I got the value of y. After that, I substituted the value of y to find x.

From the conversation, it can be seen that the student understood the problem and was familiar with using the elimination and substitution methods, but still made mistakes during the calculation stage. This error falls under the category of sign error, a misconception that arises from a weak understanding of integer operations involving negative numbers. According to Stemele & Asvat (2024), sign errors are among the common obstacles in algebra, because students frequently misinterpret the coefficient of a variable such as $y = -1$ and apply integer addition or subtraction improperly.

Sebuah celana harganya 4 kali harga sebuah baju. Jika Tuti membeli 1 celana dan 3 baju, ia harus membayar Rp 700.000,00. Tentukan jumlah yang harus dibayar Silvi jika ia membeli 2 celana dan 5 baju!	Translation A pair of pants costs 4 times the price of a shirt. If Tuti buys 1 pair of pants and 3 shirts, she has to pay Rp 700,000.00. Determine the amount Silvi has to pay if she buys 2 pairs of pants and 5 shirts!

Figure 10. Problem 5

In this problem, students were asked to find the solution to a word problem involving a SPLDV by recalling the concept of SPLDV, applying the solution steps using the elimination and substitution methods, and understanding the content of the problem before finding the solution.

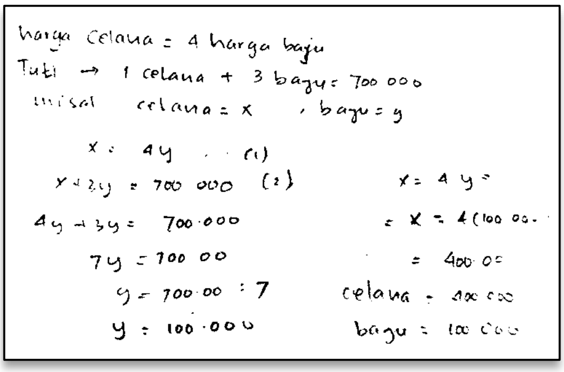


Figure 11. Student’s answer for problem 5

Figure 11 shows a student’s answer to the problem presented in Figure 10. The student was able to construct equations from the SPLDV word problem and solve them correctly. However, the solution was incomplete because the student stopped after finding the price of one shirt and one pair of pants, without continuing to calculate the price of two pairs of pants and five shirts as required by the problem. This occurred because the student did not fully write down the given and asked information, resulting in an incomplete answer.

In solving the SPLDV word problem, the student successfully modeled the situation into mathematical equations and solved them algebraically to obtain the values of each variable the price of one shirt and one pair of pants. However, an error occurred when the student stopped at finding the variable values without proceeding to the final step, which was to calculate the total cost of two pairs of pants and five shirts as requested in the problem. This indicates that the student had difficulty understanding the context of the question or failed to interpret the problem’s instructions completely.

For instance, Soneira et al. (2023) showed that when students translate contextual problems into algebraic models, their procedural fluency often does not guarantee accurate modelling of the situation. Therefore, this student’s mistake can be categorized as a contextual modeling error, which occurs when a student successfully solves the equations but fails to connect the results back to the real-world context of the word problem.

	Translation
100 siswi perempuan dari suatu sekolah menengah kejuruan memerlukan dua warna gaun yang akan digunakan untuk acara perpisahan. Gaun berwarna biru harganya Rp 500.000,00 dan gaun berwarna pink harganya Rp 750.000,00. Jika total biaya untuk seluruh gaun adalah Rp 60.000.000,00, maka berapa banyak gaun untuk masing-masing warna yang harus disiapkan oleh pihak sekolah?	100 female students from a vocational high school need two colors of dresses to wear for their graduation ceremony. The blue dresses cost Rp 500,000.00 each, and the pink dresses cost Rp 750,000.00 each. If the total cost for all the dresses is Rp 60,000,000.00, how many dresses of each color must the school prepare?

Figure 12. Problem 6

In this problem, students are asked to solve a word problem involving SPLDV. They are required to write the mathematical model based on the problem and solve it using the SPLDV concept.

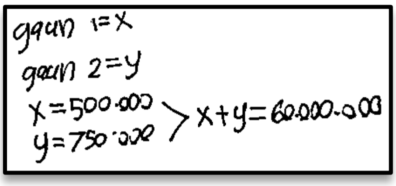


Figure 13. Student's answer for problem 6

Figure 13 shows the student's answer to the problem in Figure 12. It can be seen that the student was unable to construct a mathematical model from the given problem. This error indicates that the student has not yet mastered the process of transforming contextual information into mathematical form. The student struggled to identify relevant quantities and the relationships between variables that should be expressed as a system of two linear equations.

This finding is consistent with Wijaya & Robitzsch (2014), who found that students' difficulties in solving contextual or word problems often occur at the early stages of mathematical modelling, particularly when interpreting real-world information and translating it into appropriate symbolic representations.. In other words, the student still experienced a modeling error, where the main obstacle lies in connecting real-world situations with mathematical equations. This is further supported by the following interview excerpt:

R : In this problem, what are you asked to find?
S : We are asked to determine the number of blue dresses and pink dresses.
R : Can you write the equation based on the problem?
S : $x + y = 60{,}000{,}000$*, right, Ma'am?*
R : And what about the prices of the two dresses?
S : I can't write that, Ma'am.

This conversation snippet shows that the student was still unable to create a mathematical model from the information provided in the problem. In addition, the student could not identify and formulate the correct mathematical relationships based on the given data.

Data in this study were analyzed descriptively using the Miles and Huberman model, which includes data reduction, data display, and conclusion drawing. Students' written answers were first examined to identify and classify types of errors that appeared in solving PLSV and SPLDV problems. The analysis was then strengthened through interviews with selected students to understand their reasoning and the causes of the errors they made. The qualitative interpretation was carried out by connecting students' responses with algebraic concepts and relevant theoretical references.

The results of the analysis revealed that vocational high school students still experienced various difficulties in solving PLSV and SPLDV problems. Many students made procedural mistakes, such as manipulating equations incorrectly and relying on the “transposition” technique without understanding the meaning of equality. For instance, some students directly moved terms across the equality sign without applying inverse operations, leading to wrong results. Interviews indicated that these students tended to focus on memorized steps rather than on conceptual reasoning about how equality works in algebra.

In addition to equation manipulation errors, several students also misapplied the distributive property and mismanaged negative signs. Some students correctly multiplied terms within parentheses but also multiplied them again by the coefficient outside, producing double multiplication. Others made sign errors when subtracting or distributing negative coefficients, which changed the equation results entirely. These cases demonstrate that the understanding of basic algebraic properties among students is still limited and inconsistent. Another common difficulty involved mathematical modeling when translating word problems into equations. Many students were unable to represent verbal information into algebraic expressions correctly, especially in SPLDV problems.

The analysis also showed that several students made errors in performing integer operations, particularly when combining positive and negative numbers in equation-solving steps. These errors reflect basic arithmetic misconceptions that affect algebraic reasoning. Finally, some students stopped after obtaining numerical answers without checking whether their results matched the given context, leading to incomplete problem-solving. This shows that students tend to separate computation from contextual understanding, treating algebra merely as symbol manipulation rather than a modeling tool for real situations.

Overall, the findings indicate that students’ errors in learning PLSV and SPLDV are both conceptual and procedural. Conceptually, students struggle to understand equality, variable relationships, and symbolic representation; procedurally, they tend to rely on rote algorithms such as transposing terms and applying rules without reflection. These results suggest that learning strategies in algebra need to emphasize conceptual understanding and contextual problem modeling rather than focusing solely on computation. Teachers should design activities that integrate real-life contexts, visual models, and reflective discussions to strengthen students’ algebraic reasoning and reduce recurring errors.

The following table summarizes the difficulties students experienced in solving problems related to linear equations in one and two variables.

Table 1. Students' error in Solving SPLDV and PLSV Problems

No.	Students' Errors in Solving Linear Equation Problems
1.	Errors in manipulating equations a. Students use the "transposition method" (*transposing terms*) mechanically without understanding the concept of equality. b. This causes sign errors (positive/negative) due to a lack of understanding of the inverse operation principle.
2.	Errors in applying the distributive property a. Students show *overgeneralization* (for example, multiplying by an outer factor again even though it has already been distributed inside the parentheses). b. This indicates weak structural understanding of algebraic expressions.
3.	Errors in handling negative signs a. For instance, writing $-2(2z + 9)$ as $-2z + 9$ instead of $-2z - 18$. The negative-sign error shown in Figure 4(b) is taken directly from a scanned student answer sheet. b. This shows a *cognitive gap* between arithmetic and algebra.
4.	Errors in mathematical modeling (modeling errors) a. Students fail to convert contextual information into a system of two-variable linear equations. b. The main obstacle lies in connecting real-world situations to mathematical models.
5.	Errors in understanding the context of word problems a. Students stop after finding the values of the variables but do not continue to the final answer as requested (e.g., calculating the total price). b. This reflects weak ability to connect algebraic results to the problem context
6.	Errors in integer operations Sign errors often occur during elimination or substitution because students do not understand that variables can have negative coefficients.

CONCLUSION

The results of this study show that vocational high school students' difficulties in solving PLSV and SPLDV problems arise from both conceptual and procedural weaknesses. Students frequently demonstrated errors in manipulating equations, applying the distributive property, handling negative signs, modeling verbal problems, and connecting algebraic solutions to the real-world context of the tasks. These recurring errors indicate that students tend to rely on memorized procedures such as transposing terms without understanding the underlying principles of equality, inverse operations, algebraic structure, and contextual reasoning. The findings highlight the need for instructional approaches that explicitly strengthen conceptual understanding, support structural interpretation of algebraic expressions, and provide systematic scaffolds for translating contextual information into mathematical models.

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