EMTEKA: Jurnal Pendidikan Matematika
Volume 7, No. 2, 2026. 981-993
DOI: https://doi.org/10.24127/emteka.v7i2.12750

e-ISSN 2746-5594
p-ISSN 2746-5608

STUDENTS' PROBLEM-SOLVING ABILITY IN THREE-VARIABLE LINEAR SYSTEMS BASED ON POLYA AND COGNITIVE STYLES

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Received 2 July 2026; Received in revised form 15 July 2026; Accepted 27 September 2026

ABSTRACT
Mathematical problem-solving ability is an essential competency in mathematics learning and may be influenced by students' cognitive characteristics. This study aims to describe students' mathematical problem-solving ability in solving Systems of Three-Variable Linear Equations (SPLTV) based on Polya's problem-solving stages: understanding the problem, devising a plan, carrying out the plan, and looking back, viewed from Field-Independent (FI) and Field-Dependent (FD) cognitive styles. The study employed a qualitative approach with a descriptive design. The participants were five students purposively selected, consisting of two FI students and three FD students. The Group Embedded Figures Test (GEFT) was used to identify students' cognitive styles, while a mathematical problem-solving test was administered to assess initial ability and select representative participants. Data were collected through written problem-solving tests, semi-structured interviews, and documentation. Data credibility was established through time triangulation, while data were analyzed using the Miles and Huberman interactive model, involving data reduction, data display, and conclusion drawing. The findings indicate that FI students tended to successfully complete all four Polya stages systematically. FD students demonstrated more varied abilities; some experienced difficulties in constructing mathematical models, carrying out solution procedures, and checking their answers. However, one FD student successfully completed all Polya stages, supported by regular practice, independent and collaborative learning, and persistence. These findings suggest that cognitive style is associated with students' problem-solving profiles but is not the sole factor influencing their performance.
Keywords: cognitive style; mathematical problem-solving ability; Polya's problem-solving stages

ABSTRAK
Kemampuan pemecahan masalah matematis merupakan kompetensi penting dalam pembelajaran matematika dan dapat dipengaruhi oleh karakteristik kognitif siswa. Penelitian ini bertujuan mendeskripsikan kemampuan pemecahan masalah matematis siswa dalam menyelesaikan Sistem Persamaan Linear Tiga Variabel (SPLTV) berdasarkan tahapan Polya, yaitu memahami masalah, menyusun rencana, melaksanakan rencana, dan memeriksa kembali, ditinjau dari gaya kognitif Field-Independent (FI) dan Field-Dependent (FD). Penelitian menggunakan pendekatan kualitatif dengan desain deskriptif. Subjek penelitian terdiri atas lima siswa yang dipilih secara purposif, yaitu dua siswa FI dan tiga siswa FD. Group Embedded Figures Test (GEFT) digunakan untuk mengidentifikasi gaya kognitif, sedangkan tes pemecahan masalah digunakan untuk mengidentifikasi kemampuan awal dan menentukan subjek penelitian. Data dikumpulkan melalui tes tertulis, wawancara semi-terstruktur, dan dokumentasi. Kredibilitas data diuji melalui triangulasi waktu, sedangkan analisis data menggunakan model interaktif Miles dan Huberman melalui reduksi data, penyajian data, dan penarikan kesimpulan. Hasil penelitian menunjukkan bahwa siswa FI cenderung mampu memenuhi keempat tahapan Polya secara sistematis. Siswa FD menunjukkan kemampuan yang lebih beragam; sebagian mengalami kesulitan dalam membangun model matematika, melaksanakan prosedur, dan memeriksa kembali jawaban. Namun, satu siswa FD mampu memenuhi seluruh tahapan Polya karena

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p-ISSN 2746-5608

didukung kebiasaan berlatih, belajar mandiri maupun bersama teman, dan kegigihan. Temuan menunjukkan bahwa gaya kognitif berkaitan dengan profil kemampuan pemecahan masalah, tetapi bukan satu-satunya faktor yang memengaruhi performa siswa.
***Kata kunci**: gaya kognitif; kemampuan pemecahan masalah matematis; tahapan pemecahan masalah Polya;*

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Introduction

Mathematical problem-solving is an important skill in mathematics education because it encourages students to think critically, creatively, and analytically. Mathematical problem-solving is defined as the activity of finding solutions to encountered problems (Fitriyana & Sutima, 2022). In the problem-solving process, students go through four stages: understanding the problem, devising a plan, carrying out the plan, and looking back (Polya, 1987). Through these stages, students do not rely solely on memorization; they also develop reasoning when solving problems related to real-life situations. Students are expected to recognize mathematical relationships in various contexts, including everyday life (Linuhung et al., 2025). Mathematical problem solving is an essential component of mathematics learning because students are required not only to obtain an answer but also to understand problems, develop appropriate strategies, and justify their solutions. Previous research has demonstrated that problem-solving-oriented learning can engage students in identifying problems, seeking relevant information, testing possible solutions, and drawing conclusions (Vahlia & Agustina, 2016).

Mathematical problem solving remains a concern in mathematics education. This is evident from PISA (2022). The urgency of improving mathematical problem-solving ability is reflected in the PISA 2022 results. Indonesia obtained a mean mathematics score of 366, which was substantially below the OECD average of 472. Only 18% of Indonesian students attained at least Level 2 proficiency in mathematics, compared with 69% on average across OECD countries. Moreover, almost no Indonesian students reached Levels 5 and 6, which require students to model complex situations mathematically and evaluate problem-solving strategies. Additionally, historically, TIMSS (2015) reported that Indonesia's mean mathematics score was 397, below the international benchmark of 500. These data indicate that mathematical abilities, particularly the problem-solving skills of students in Indonesia, are still relatively low.

A preliminary observation was conducted in 2025 in the Grade X Accounting class at SMK Muhammadiyah 2 Metro through classroom observation, an interview with the mathematics teacher, and a written mathematical problem-solving test on Three-Variable Linear Equation Systems (SPLTV). The findings indicated that students experienced difficulties in solving contextual mathematical problems across Polya's stages, including understanding the problem, devising a plan, carrying out the plan, and looking back. Problem-solving activities can also stimulate students' higher-order cognitive processes, particularly when learners are encouraged to generate, organize, and evaluate ideas during the solution process. Oktaviana et al. (2017) reported a significant difference in students' mathematical

e-ISSN 2746-5594
p-ISSN 2746-5608

learning creativity between students taught through a Creative Problem Solving model and those taught conventionally. Consistent with Vahlia et al., (2022), students tended to make errors in organizing information and checking their solutions, indicating a need to strengthen their mathematical problem-solving ability. These difficulties may be associated with cognitive style. According to Witkin et al. (1977), Field-Independent (FI) individuals tend to separate relevant information from complex contexts and process it analytically, whereas Field-Dependent (FD) individuals tend to perceive information more globally and rely more on contextual or external cues. These styles represent different tendencies in information processing and may be relevant to students' mathematical problem-solving processes.

One of the factors that influence mathematical problem-solving is cognitive style. Cognitive Style relates to how learners receive, process, and use information in solving problems (Aulia & Subekti, 2025; Yusrina et al., 2025). Students may employ different approaches when solving mathematical problems because individual learning characteristics influence how they receive, organize, and process information. Ningrum et al. (2025) found that students with visual, auditory, and kinesthetic learning styles demonstrated different ways of understanding and solving problems in two-variable linear equation systems. Differences in cognitive style also affect the problem-solving strategies used by learners (Bambang et al., 2021; Utami, et al., 2025). Therefore, understanding cognitive styles can help educators design learning that aligns with the characteristics of learners to enhance mathematical problem-solving ability (Almubarak et al., 2025; Ratnaningsih et al., 2020).

Cognitive styles are commonly discussed as Field-Independent (FI) and Field-Dependent (FD) tendencies. Students with FI tendencies may be more likely to analyze information independently, whereas those with FD tendencies may rely more on contextual or social cues when processing information (Pradiarti, 2022). However, these tendencies should not be interpreted as fixed categories because students within the same cognitive-style group may demonstrate different mathematical problem-solving performances. Therefore, cognitive style may be associated with students' problem-solving processes but is not the sole determinant of their ability.

Previous studies have examined mathematical problem-solving based on Polya's stages, cognitive styles, and Three-Variable Linear Equation Systems in various contexts. Hasdi et al. (2024) examined problem-solving among students with Field-Independent and Field-Dependent cognitive styles, while Jannah et al. (2024) analyzed students' errors across Polya's stages. In Three-Variable Linear Equation Systems. However, a detailed qualitative description of vocational-school students' performance at all four Polya stages in contextual Three-Variable Linear Equation Systems problems based on Field-Independent and Field-Dependent cognitive-style tendencies remains limited. Therefore, this study describes these problem-solving profiles.

Research Methods

This study employed a qualitative descriptive design at SMK Muhammadiyah 2 Metro, Indonesia, from May to June 2026. The initial participants consisted of 18

e-ISSN 2746-5594
p-ISSN 2746-5608

tenth-grade Accounting students who completed the Group Embedded Figures Test (GEFT) and a mathematical problem-solving test involving contextual Systems of Three-Variable Linear Equations (SPLTV) problems. Based on the GEFT scores, students who obtained scores of 10–18 were classified as having a Field-Independent (FI) cognitive style, whereas those who obtained scores of 0–9 were classified as having a Field-Dependent (FD) cognitive style. The results showed that 7 students were classified as FI and 11 as FD.

Five students were purposively selected based on the representation of cognitive styles, the completeness of their written responses, variations in their problem-solving profiles across Polya's four stages, and their willingness to participate in interviews. The selected subjects consisted of two FI students and three FD students. The research instruments included the GEFT, a mathematical problem-solving test, and semi-structured interview guidelines. Data were analyzed using the Miles and Huberman model, which involved data reduction, data display, and conclusion drawing. Data credibility was established through time triangulation.

Results and Discussion

The research findings were obtained through the analysis of the Group Embedded Figures Test (GEFT), mathematical problem-solving tests, and interviews with the research subjects. The first stage of the study involved administering the GEFT to all students in Class X AKL. This test aimed to categorize students according to their Field Independent (FI) and Field Dependent (FD) cognitive styles. The data are presented in the form of a pie chart in Figure 1.

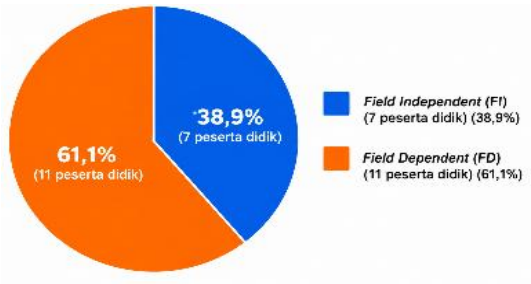


Figure 1. Percentage of Students Based on Cognitive Style.

Based on Figure 1, the majority of students in Class X AKL had a Field Dependent (FD) cognitive style, accounting for 61.1%, while 38.9% were classified as Field Independent (FI). A total of 7 students were classified as FI and 11 as FD. In the next stage, the Mathematical Problem-Solving Ability (KPM) test was administered, and the students' responses were used to select the research subjects. Five research subjects were selected, consisting of 2 students with a Field Independent (FI) cognitive style and 3 students with a Field Dependent (FD) cognitive style. Their mathematical problem-solving performance was then analyzed based on the extent to which they fulfilled the stages of Polya's problem-

e-ISSN 2746-5594
p-ISSN 2746-5608

solving process. The classification of cognitive styles based on the scores obtained is presented in Table 1.

Table 1. GEFT Test Results and Selected Participant Codes

No	Participant Code	GEFT Score	Cognitive Style
1	ZPA	17	FI
2	TS	15	FI
3	AR	4	FD
4	EMA	5	FD
5	RFA	5	FD

The mathematical problem-solving abilities of students with each cognitive style are described below.

1. Mathematical Problem-Solving Profile of Field Independent (FI) Subjects

Based on the GEFT and Mathematical Problem-Solving Ability (KPM) test results, Two FI students, ZPA and TS, were selected based on their GEFT and KPM test results because they demonstrated the most consistent problem-solving responses. Their performance across Polya's four stages is presented in Table 2.

Table 2. Mathematical Problem-Solving Data of Subjects ZPA and TS at the Four Stages of Polya's Problem-Solving Proces

Polya's Problem-Solving Stage	Subject ZTA (FI)	Subject TS (FI)	Synthesis of FI Findings
Understanding the Problem	Consistently able to identify the given information and what was being asked in Test 1 and Test 2.	Consistently able to identify the given information and what was being asked in Test 1 and Test 2.	Both FI subjects consistently understood the SPLTV problems accurately across the two data collection sessions.
Devising a Plan	Consistently determined solution strategies using the elimination and substitution methods.	Determined solution strategies using the elimination and substitution methods systematically.	Determined solution strategies using the elimination and substitution methods systematically.
Carrying Out the Plan	Able to carry out the elimination and substitution methods according to the selected strategy until obtaining the value of each variable.	Able to carry out the elimination and substitution methods according to the selected strategy until obtaining the value of each variable.	Both subjects were able to apply the strategies appropriately to obtain solutions to the SPLTV problems.
Looking Back	Checked the results by substituting the variable values into the original equations and formulating an appropriate conclusion.	Checked the results by substituting the variable values into the original equations and providing a conclusion, although minor errors were present.	Both subjects performed the checking stage. ZTA was more consistent and accurate, whereas TS fulfilled the indicators adequately but still demonstrated minor error

a. Understanding the Problem

e-ISSN 2746-5594
p-ISSN 2746-5608

At the stage of understanding the problem, Field-Independent (FI) students were able to identify relevant information, distinguish the given information from what was being asked, and understand the problem independently by reading it repeatedly. Akbar et al. (2020) reported that FI students could independently identify and record the given information and the questions in a problem. Similarly, Wati et al. (2023) found that FI students were able to understand problems and identify the given information and what was being asked. This ability reflects the characteristics of the FI cognitive style, which tends to analyze information independently, focus on essential details, and remain less influenced by irrelevant elements. R. I. Kurniawan et al. (2020) also stated that FI students could identify the given information and what was being asked effectively and independently.

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b. Devising a Plan

Field-Independent (FI) students were able to determine appropriate strategies for solving systems of linear equations in three variables (SPLTV), such as constructing mathematical models and selecting the elimination method, substitution method, or a combination of both. FI students were also able to provide reasons for choosing the strategies they used. R. L. Kurniawan et al. (2021) stated that students with an FI cognitive style were able to outline the steps or strategies for solving problems, understand the problem, translate it into a mathematical model, and determine the methods to be used. Consistent with Akbar et al. (2020), subjects with an Field-Independent (FI) cognitive style were able to translate problems into mathematical models, which were then used in the subsequent stages of problem solving. Students with an Field-Independent (FI) cognitive style were able to determine an effective plan for solving problems (Zulvia et al,. 2025)

c. Carrying Out the Plan

At the stage of carrying out the problem-solving plan, Field-Independent (FI) students were able to implement the planned strategies through systematic calculation steps. They applied each step accurately in accordance with the strategies established beforehand. Students with an Field-Independent (FI) cognitive style were able to use the predetermined steps appropriately (Zulvia et al., 2025). Students with an FI cognitive style were also able to carry out the plan effectively using correct procedures(Anggraeni et al,. 2019). Field-Independent (FI) subjects were able to apply the planned strategies systematically until they obtained the correct solutions. Although one subject made minor errors in writing or calculation, the interview results indicated that these errors were caused by a lack of carefulness or haste in writing the answers, rather than by an inability to understand the concepts. Therefore, the errors were technical in nature and did not affect the subject's overall problem-solving process

d. Looking Back

At the looking-back stage, FI students verified their answers through substitution or by checking their consistency with the original problem and formulated contextually appropriate conclusions. Subject TS correctly concluded Problems 1 and 2 but made an addition error when checking Problem 3. The subject's answer is presented in Figure 2.

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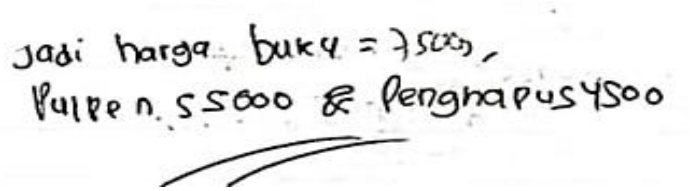


Figure 2. Subject TS's Response to Problem 3 in the Looking Back Stage

Subject TS made a calculation error. The correct price of the book should have been Rp6,500; however, the subject confirmed during the interview that the error resulted from incorrectly operating the signs of the numbers, leading to an inaccurate final answer. Thus, TS fulfilled Polya's looking-back indicator, although the final result was not entirely accurate. FI students demonstrated a reflective process by reviewing their solution steps and ensuring that their answers were consistent with the problem context (Sudarsih et al,. 2026). Akbar et al. (2020) tated that FI students were able to formulate conclusions by relating the results to the questions. This finding indicates that FI students tended to solve problems independently, systematically, and analytically, consistent with Witkin's theory that Field Independent individuals can analyze information separately and are less influenced by their surroundings.

Based on the findings, FI subjects fulfilled all four stages of Polya's problem-solving process: understanding the problem, devising a plan, carrying out the plan, and looking back. Therefore, they can be considered capable of solving mathematical problems. Anwar & Rahmawati, (2017) stated that students are considered capable of solving problems when they can apply all four stages of Polya's problem-solving process.

2. Profile of Subjects' Mathematical Problem-Solving Abilities with a Field-Dependent (FD) Cognitive Style

Based on the results of the Group Embedded Figures Test (GEFT) and the Mathematical Problem-Solving Ability (KPM) test, three students were selected as research subjects in the Field Dependent (FD) category. Two FD subjects were selected because their mathematical problem-solving test responses were the most consistent, while one FD subject was selected because they demonstrated a different problem-solving profile from the others, particularly by being able to fulfill all of Polya's stages. Therefore, the researchers were interested in including these students as research subjects, namely subjects with the initials AR, EMA, and RFA. The presentation of the test data for these subjects is shown in Table 3..

Table 3. Problem-Solving Data of Subjects AR, EMA, and RFA Across the Four Stages of Polya

Polya's Problem-Solving Stages	**Subject AR (FD)**	**Subject EMA (FD)**	**Subject RFA (FD)**
Understanding the Problem	Was consistently able to understand the problem. Subject AR was able to	EMA understood the problem by identifying the known and asked	Was consistently able to understand the problem and identify important

e-ISSN 2746-5594
p-ISSN 2746-5608

Polya's Problem-Solving Stages	Subject AR (FD)	Subject EMA (FD)	Subject RFA (FD)
	identify important information in the problem.	information and explaining its meaning despite minor errors.	information needed to solve the system of linear equations in three variables (SPLTV).
Devising a Plan	Still experienced difficulties in developing a solution plan and determining an appropriate strategy.	Did not fulfill the planning indicator. The subject made errors when formulating the equations.	RFA was able to determine a strategy for solving the SPLTV problem. Although a minor error occurred when constructing the mathematical model, RFA was able to correct it.
Carrying Out the Plan	Experienced difficulties implementing the predetermined plan and did not fully meet the implementation indicator.	Used the elimination and substitution methods to determine the values of the variables, but made algebraic operation errors, resulting in an inaccurate final answer.	RFA implemented the solution strategy in both tests, obtained the correct results, and corrected errors despite requiring more time..
Looking Back	Was not yet able to optimally check the correctness of the obtained results.	Did not perform a review of the solution. EMA only wrote the final answer without providing a conclusion corresponding to the question.	RFA reviewed the solution, evaluated the steps, and corrected errors to obtain a satisfactory answer.

a. Understanding the Problem

At the stage of understanding the problem, most Field Dependent (FD) students were able to write down the information given and what was being asked in the problem. This indicates that FD students were generally able to understand the information presented. Students tended to understand problems more easily when provided with additional explanations or guidance from others, such as peers or teachers. Students with a Field Dependent (FD) cognitive style tend to seek assistance from their peers when they experience difficulties in understanding a problem (Fitria & Sity, 2023). his finding is consistent with the characteristics of the FD cognitive style, which tends to perceive problems holistically and requires environmental support to organize the information obtained. Students with an FD cognitive style also tend to seek guidance and instructions from peers or teachers when understanding problems (Remains & Eve, 2019).

b. Devising a Plan

At the devising-a-plan stage, Field Dependent (FD) students generally experienced difficulties in independently determining appropriate solution strategies. They tended to rely on peers and previously demonstrated examples, and had difficulty constructing mathematical models and organizing suitable solution strategies. These findings are consistent with Rohmani, Rosmaiyadi, & Husna, (2020), who reported that FD students had difficulty determining appropriate plans

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and formulas, and with Anggraeni et al. (2019) who found that FD subjects were less able to organize information independently.

This tendency reflects the FD cognitive style, which is associated with reliance on external references and difficulty determining appropriate strategies independently. However, subject RFA demonstrated a different profile. RFA was able to assign variables, formulate equations, and construct a solution plan despite needing repeated attempts to find the solution. For example, RFA represented the prices of books, pens, and erasers using variables and modeled the transaction mathematically. The subject's answer is presented in Figure 3..

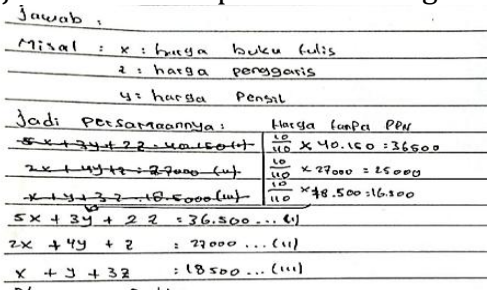


Figure 3. Subject RFA's Answer at the Devising a Plan Stage

The subject explained that the elimination and substitution methods were learned through school activities and repeated practice. In addition to trying several approaches, these experiences helped RFA construct an appropriate mathematical model based on the information provided. As shown in Figure 3, RFA assigned x, y, and z to represent the prices of a notebook, pencil, and ruler before VAT, respectively. The subject first calculated the total price before VAT as the basis for constructing the mathematical model. However, RFA forgot to replace the total price in Equations (ii) and (iii), resulting in the continued use of the price including VAT. Based on the interview, this error was caused by carelessness rather than a lack of conceptual understanding. The subject corrected the results in the subsequent stage. Therefore, RFA fulfilled Polya's indicator of devising a plan.

c. Carrying Out the Plan

At the stage of carrying out the solution plan, several FD students attempted to use the elimination and substitution methods, but their solutions were not entirely correct. Errors included incorrect mathematical models, substitution and arithmetic mistakes, and incomplete solution steps. These difficulties affected the accuracy of their final answers. Anggraeni et al. (2019) found that FD subjects had difficulty implementing solution plans correctly because they did not adequately check the information in the problem.Pradiarti & Subanji, (2022) reported that FD subjects were unable to implement solutions correctly, resulting in inaccurate final answers.

However, subject RFA was able to correctly implement the planned strategy and obtain the correct answer. Although the answer sheet contained several corrections, these corrections indicated that the subject had made calculation errors that were subsequently recognized and corrected. Thus, RFA's difficulties were related to a lack of precision rather than a lack of conceptual understanding or an inability to determine an appropriate solution strategy. The subject's answer is presented in Figure 4.

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e-ISSN 2746-5594
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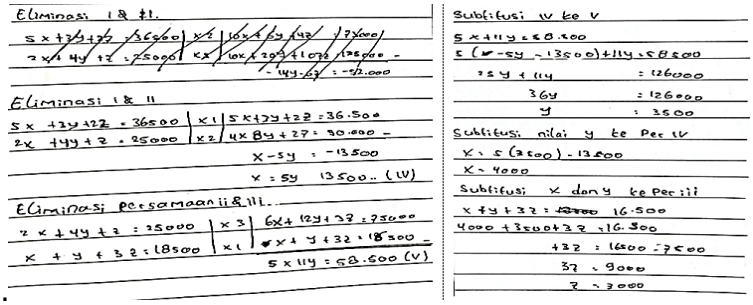


Figure 4. Subject RFA's Answer at the Carrying Out the Plan Stage

Based on the interview results, RFA explained that they rechecked and corrected the solution steps whenever the calculation results seemed incorrect. This indicates that the subject was able to carry out the solution process systematically despite requiring several corrections. RFA's problem-solving ability was supported by frequent practice, studying with peers, independent study at home, and persistence in obtaining the correct answer. These habits helped the subject understand SPLTV solution procedures and correct calculation errors during the process.

d. Looking Back

Most Field Dependent (FD) subjects had not yet checked their answers or related the variable values to the problem context. This finding is consistent with Sudarsih et al (2026) and Akbar et al. (2020) also reported that the subjects were unable to write and review their answers and failed to relate their solutions back to the concepts addressed in the questions. Based on the interview results, several subjects admitted that they assumed their answers were correct or did not check them because the allotted time was nearly over. According Polya (1987), students need to check each solution step to ensure the correctness of their answers. However, subject RFA was able to formulate a conclusion and relate the solution to the problem context by carefully reviewing the obtained variable values. The subject's answer is presented in Figure 5.

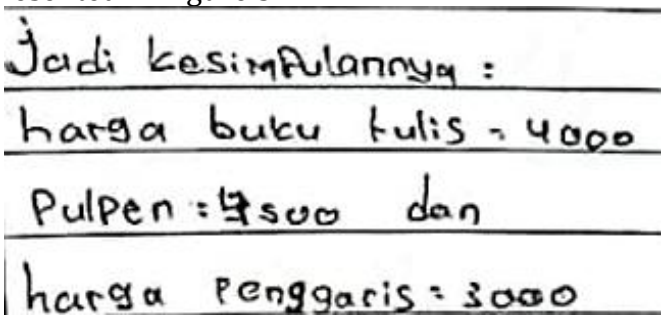


Figure 5. Subject RFA's Answer at the Looking Back Stage

Based on the interview results, RFA explained that they rewrote the obtained variable values as a conclusion and reread the calculation results to ensure that the answer was consistent with the information in the problem. This indicates that the

e-ISSN 2746-5594
p-ISSN 2746-5608

subject was able to relate the solution to the problem context. Therefore, RFA fulfilled Polya's indicator of looking back.

Conclusion and Suggestion

The findings show that FI students fulfilled all four stages of Polya's problem-solving process: understanding the problem, devising a plan, carrying out the plan, and looking back. FD students generally understood the problems but experienced difficulties in the remaining stages. However, subject RFA successfully completed all four stages. This variation indicates that cognitive style alone does not fully explain students' mathematical problem-solving profiles. Interview data also suggested that learning habits, practice intensity, carefulness, and perseverance were associated with differences in performance, although their causal effects were not established.

Teachers should consider cognitive-style characteristics when providing differentiated scaffolding rather than labeling students according to fixed abilities. Support should be tailored to students' needs, including understanding problem contexts, constructing mathematical models, selecting strategies, checking solutions, and practicing gradually. Future research may involve more diverse subjects, mathematical topics, and factors beyond cognitive style to broaden understanding of mathematical problem solving and evaluate appropriate instructional strategies.

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