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Profile Of Critical Thinking Errors Of Junior High School Students Based On Facione's Theory In Solving Problems On SLETV Material

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Abstract. *This study aims to describe the profile of mathematical critical thinking errors among junior high school students, based on the components of Facione's Theory (Interpretation, Analysis, Evaluation, and Inference), in the context of solving Systems of Linear Equations in Two Variables (SLETV) problems. Specifically, this study cross-mapped Facione's cognitive failures with observed procedural errors, analysing them using the Newman Error Analysis framework (Reading, Understanding, Transformation, Process Skills, and Final Answer Writing). This study uses a qualitative method. This study found that students' critical thinking skills were generally low, with 42.05% in the low category. The highest cognitive failure point was located in the Analysis, Evaluation, and Inference domain. Triangulation analysis showed that weaknesses in Facione's Analysis Skills were the leading cause of the high frequency of Newman Transformation Errors, reflecting students' inability to model contextual problems as mathematical models. This study provides a more precise diagnostic basis for designing targeted learning interventions to optimise students' higher-order cognitive skills.*

Keywords: *critical thinking, indicators Facione, procedural errors, SLETV.*

INTRODUCTION

Mathematics is a fundamental subject at the junior high school level, aimed at developing students' critical, logical, and systematic thinking skills for addressing real-world problems (Afriansyah et al., 2021; Prajono et al., 2022). Beyond its computational function, mathematics serves as a cognitive tool for structuring reasoning and fostering analytical, evaluative, and reflective capacities (Mahmudah, 2018). Consequently, mathematics education holds a strategic role in enhancing students' critical thinking abilities (Khair, 2021; Sehrawat, 2024). (2025) conceptualise mathematical critical thinking as the capacity to identify underlying assumptions, determine the core of a problem, evaluate the implications of selected solutions, recognise potential bias from multiple perspectives, apply relevant concepts and principles, and critically assess arguments during problem-solving. Through mathematics learning, students are therefore trained to systematically analyse problems, generate alternative solution strategies, and draw logically sound conclusions (Solihah & Rejeki, 2020).

Mathematics is widely regarded as the queen of the sciences. It provides a foundational basis for developing students' logical, critical, systematic, analytical, and creative thinking abilities ('Mathematics, the Queen of Sciences', 2022; Munawwarah et al., 2020; Situngkir & Dewi, 2022). These higher-order thinking abilities constitute essential components of 21st-century skills, commonly summarised as the 4Cs: critical thinking, creative thinking, communication, and collaboration (Makmuri et al., 2021; Pasaribu et al., 2023; Putri et al., 2022). Consequently, the development of critical thinking skills must be systematically fostered and continuously strengthened across all levels of education.

Although critical thinking is widely recognised as an essential competence, empirical evidence indicates that the critical thinking abilities of junior high school (JHS) students remain at a relatively low level (Ibrahim et al., 2021; Muslimahayati et al., 2020; Nashrullah et al., 2023; Pasaribu et al., 2023). Preliminary diagnoses suggest that this limitation is not solely attributable to insufficient content knowledge but also to structural weaknesses in students' cognitive processes (Darmawan et al., 2018; Sidik et al., 2018).

In particular, studies examining JHS students' critical thinking skills consistently report that evaluation and analysis are the least developed sub-skills (Arini et al., 2023; Ronny et al., 2022). This finding is significant, as it implies that while students may be capable of identifying problems, they frequently struggle with higher-order cognitive stages that require judgment, logical justification, and reflective reasoning in proposing solutions. Deficiencies in evaluation and analysis are therefore closely associated with students' limited reasoning ability and creativity in solving real-world problems and translating them into appropriate mathematical models (Munawwarah et al., 2020).

Based on these considerations, this study was designed to comprehensively and systematically examine the cognitive failure points of JHS students, as conceptualised in Facione's framework, and how these failures manifest as observable errors within Newman's error typology during mathematical critical problem-solving. The conceptual framework of this study integrates two principal perspectives: Facione's theory of critical thinking and student error analysis. Facione (1990) characterises critical thinking as comprising six core cognitive skills: interpretation, analysis, evaluation, inference, explanation, and self-regulation. However, within the context of mathematical critical thinking, this study focuses on four key components: interpretation, analysis, evaluation, and inference (Monrat et al., 2022; Ramadhani et al., 2020; Shufaha & Agoestanto, 2023). Accordingly, the research instrument was developed to assess students' competencies across these four Facione indicators.

Previous studies on error analysis in solving critical thinking problems have been conducted in the context of plane geometry by Darmawan et al. (2018) and Sidik et al. (2018), and in the context of higher-order thinking skills (HOTS) problems by Mahmudah (2018). However, these analyses were primarily grounded in Newman's problem-solving framework without integrating specific critical thinking indicators. The present study differs by employing a cross-mapping approach that systematically relates Newman's categories of procedural errors to Facione's cognitive domains of critical thinking. In contrast, Ronny et al. (2022) examined essential thinking errors without explicitly linking them to critical thinking indicators. Through this integrative framework, researchers can not only identify procedural errors but also precisely determine whether they arise from deficiencies in the analysis or inference skills required by the task. Consequently, this approach yields a more comprehensive and fine-grained profile of students' errors, providing a critical foundation for designing targeted and effective instructional interventions to enhance students' critical thinking skills.

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The instructional content examined in this study is Systems of Linear Equations in Two Variables (SLETV), a topic that inherently requires critical thinking because students must comprehend problem contexts, translate verbal information into appropriate mathematical models, and determine solutions using suitable methods. SLETV is a central component of the junior high school curriculum due to its broad applicability in everyday situations, such as price comparison, financial planning, and contextual analysis. Engaging with SLETV problems directly involves critical thinking processes, including analysing information, evaluating relationships among variables, assessing solution procedures, and formulating logical conclusions (Mahmudah, 2018; Sidik et al., 2018). Therefore, mastery of SLETV extends beyond computational proficiency to encompass the development of reasoning and evaluative skills that are fundamental to students' mathematical critical thinking.

RESEARCH METHOD

This research was conducted at one of Jakarta's public junior high schools in August 2025 using a qualitative method approach. The purpose of the research is to describe the errors of grade IX students in solving mathematical contextual problems on SLETV material, based on the components of Facione Theory (focusing on Interpretation, Analysis, Evaluation, and Inference), using Newman's analysis procedure. The research sample involved 30 grade IX students. The research data were obtained from students' answers, which represented various forms of error in solving mathematical contextual problems. The research instrument consisted of one essay question in the form of a contextual problem, designed to reveal students' mathematical critical thinking and student errors according to the stages in Newman's procedure: reading, understanding, transforming, using process skills, and writing the final answer. The indicators and rubrics used to measure critical thinking skills are shown in Tables 1 and 2.

Table 1. Mathematical Critical Thinking Indicators

Indicator	Description
Interpretation	Students can accurately comprehend the intent and meaning of the questions and clearly identify the relevant information provided.
Analysis	Students can determine the core problem to be solved by recognising and analysing the relationships among relevant information.
Evaluation	Students can develop appropriate problem-solving strategies and correctly apply relevant mathematical concepts during the solution process.
Inference	Students can solve problems systematically using the available information and formulate logical conclusions in accordance with the questions posed.

(Facione, 2015; Ramadhani et al., 2020)

Table 2. Scoring of Student Answers

No	Indicators of mathematical critical thinking	Information	Score
1	Interpretation	No response is provided, or the answer does not correspond to the question.	0
		Only partial information is written, or the underlying concept is misinterpreted.	1
		Most of the essential information has been identified, though several inaccuracies remain.	2
		All essential information is identified correctly, with only minor inaccuracies	3
		All relevant information is identified and recorded accurately and comprehensively.	4
3	Analysis	No formula is selected, and no solution plan is demonstrated.	0
		The solution steps are illogical, with incorrect connections between data and formulas	1
		An attempt is made to relate the data to an appropriate formula, but the connection is not correctly established	2
		The solution steps are generally logical, with only minor computational errors	3
		The solution steps are fully logical, systematic, and entirely correct.	4
3	Evalution	No calculation process or verification effort is demonstrated.	0
		The obtained results do not correspond to the question, and no verification is conducted.	1
		An attempt is made to verify the results, but logical errors remain.	2
		The results are appropriately verified, although minor errors remain.	3

No	Indicators of mathematical critical thinking	Information	Score
		The results are carefully verified, and all calculations are confirmed to be correct	4
4	Inference	No conclusion is provided, or no response is written.	0
		The conclusion does not align with the results or is incorrect.	1
		A conclusion is presented, but it is incomplete or unclear.	2
		The conclusion is correct, but the explanation is brief or insufficient.	3
		The conclusion is complete, transparent, and entirely consistent with the calculation results.	4

(Facione, 2015; Karim & Normaya, 2015; Nadiah et al., 2022)

Data analysis follows the Miles, Huberman, and Saldana model through stages of reduction, presentation, withdrawal, and conclusion (Zulkipli & Saidah, 2024). This process includes identifying procedural errors, assessing cognitive skills, and mapping across Facione–Newman to reveal the connection between cognitive failure and procedural errors in solving mathematical problems and thinking critically.

The test score for students' mathematical critical thinking ability was determined based on the percentage of the obtained score using the following formula (Sudijono, 2018) :

$$Score = \frac{Obtained\ Score}{Maximum\ Score} x100$$

Students' mathematical critical thinking abilities are categorised according to the following criteria:

Table 3. Mathematical Critical Thinking Ability Category

Score (%)	**Category**
81.25 < X ≤ 100	Very High
71.50 < X ≤ 81.25	High
62.50 < X ≤ 71.50	Currently
43.75 < X ≤ 62.50	Low
0 < X ≤ 43.75	Very Low

(Aiyub et al., 2021)

RESULT AND DISCUSSION

1. Profile of students' critical thinking skills based on Facione

Based on the written test results, the average level of critical thinking ability of students on the SLETV material is presented in Table 4.

Table 4. Student Critical Thinking Ability Level

Indicator	Average Achievement of Each Indicator
Interpretation	62.50%
Analysis	29.69%
Evaluation	29.69%
Inference	25%
Average level of independence	42.05%

A detailed analysis indicates that student performance was highest on the Interpretation indicator, with an achievement rate of 62.50%. Interpretation reflects students’ ability to comprehend the information and contextual elements embedded in word problems (Facione, 2015). Although this indicator exceeds the overall average, it remains in the low category. The most pronounced cognitive deficiencies are evident in the higher-order thinking indicators, namely analysis (29.69%), Evaluation (29.69%), and Inference (25%). The substantial decline in achievement from Interpretation to Analysis and Evaluation suggests a gap between students’ initial comprehension of problem information and their ability to process information, solve problems, and critically evaluate solution strategies. Analysis skills require students to identify logical relationships among variables, whereas evaluation involves assessing the relevance and validity of the applied strategies (Wang & Abdullah, 2024). The markedly low performance across Analysis, Evaluation, and Inference indicates that students’ cognitive weaknesses are concentrated at stages demanding higher-level reasoning, logical justification, and reflective thinking, which are essential for effectively solving SLETV

2. Analysis of Student Error Frequency Based on Newman's Typology

To analyse the procedural aspects of Facione's cognitive weaknesses, students' answers were evaluated using Newman's five stages. The frequency and distribution of errors committed by the 30 study participants are summarised in Table 5.

Table 5: Frequency and Distribution of Student Errors Based 0n Newman's Typology (N=30)

Newman's Stages Error	Number of students making Errors (n)	Percentage (%)	Description
Reading Error	3	10%	Failure to comply with problem instructions
Misunderstanding	10	33,33%	inability to identify given and required information
Transformation Error	24	80.00%	errors in mathematical modeling
Proccess Skills Errors	19	63.33%	computational inaccuracies
Final Answer Writing Error	24	80.00%	Failure to interpret results within the problem context.

The findings from Newman's error analysis indicate that Transformation Errors constitute the most prevalent type of student error, accounting for 80.00%, followed by Process Skill Errors at 63.33%. Transformation errors arise when students are unable to convert verbal statements in word problems into appropriate mathematical representations, specifically systems of linear equations in two variables (Darmawan et al., 2018). Conceptually, the transformation stage serves as a critical link between problem comprehension in verbal form and the execution of solution procedures (Wulandari, 2023). The high incidence of errors at this stage demonstrates a clear correspondence between procedural failures identified through Newman's framework and the previously observed low performance in Facione's Analysis skills.

3. Cognitive Cross-Mapping: Integrating Facione and Newman

The subsequent stage of analysis employed a cross-mapping approach to identify the cognitive origins of procedural errors. Table 6 illustrates the conceptual framework for associating Facione's cognitive domains with Newman's error stages in the context of solving SLETV.

Table 6. Conceptual Cross-Mapping of Facione's Cognitive Domains and Newman's Error Stages in Solving SLETV.

Facione Cognitive Stages	**Critical Cognitive Functions in SLETV**	**Newman's Error Categories**	**Underlying Cognitive Mechanisms of Failure**
Interpretation	Understand the data, context, and questions.	Errors in reading and understanding	Failure to identify relevant variables, data, or concepts.
Analysis	Identify logical relationships, solve problems, and build models.	Transformation error	Inability to sort out relevant variables or concepts.
Evaluation	Assess the relevance and validity of solution strategies (elimination/substitution)	Process skill error (at the beginning of the procedure)	Choosing the wrong or inefficient method, or being unable to assess the feasibility of work steps.
Inference	Draw logical conclusions, determine solutions, and interpret results.	Process Skill Error (at the end of the procedure) and Final Answer	Wrong conclusion; Failed to return the solution to the context of the problem.

Focus of Analysis 1: The Relationship between Interpretation and Reading or Understanding

Although interpretation recorded the highest score among Facione's cognitive domains (62.50%), 33.33% of students were still identified as exhibiting misunderstanding errors. As illustrated in Figure 1, these students demonstrated incomplete execution of Facione's Interpretation stage. Specifically, while they were able to represent the problem using variables x and y, they showed inconsistent interpretations of these variables. For example, in Equation (1), x was used to represent "orange ice," whereas in Equation (2), x was assigned to "a bowl of meatballs." This indicates that although students could decode the textual information in the problem, they failed to convey the task's underlying meaning or intent accurately. Such initial interpretative failures exert a substantial downstream impact on cognitive performance (Facione, 2015). When variables are incorrectly identified at the outset, all subsequent analysis and evaluation processes become fundamentally flawed.

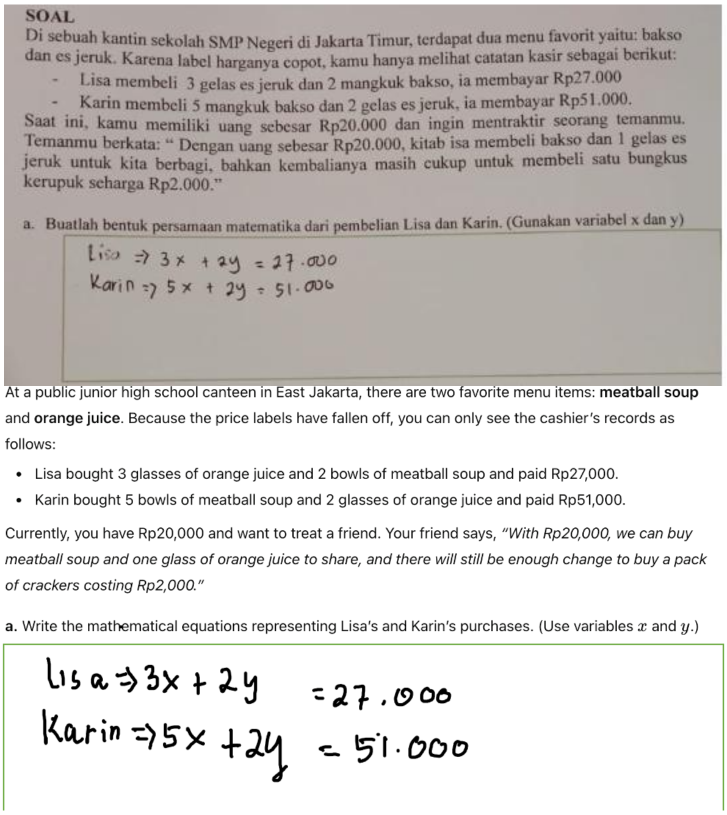
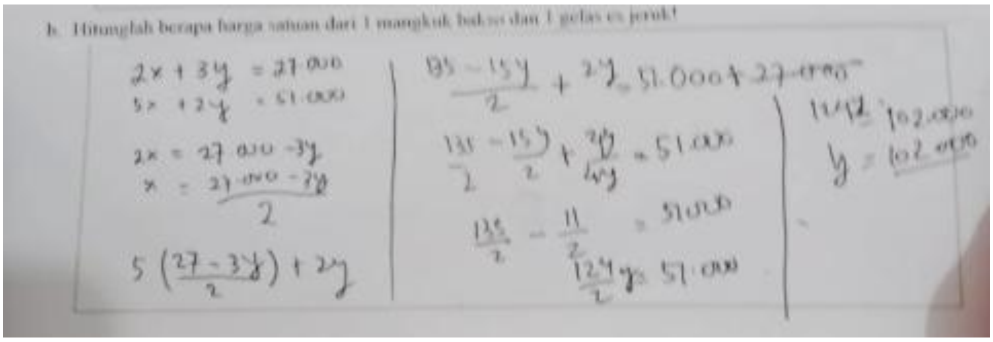


Figure 1. The student's misinterpretation of the answer to question part a.

Focus of Analysis 2: the relationship between Analysis and Transformation

The results indicate that Transformation Errors constitute the most prevalent procedural error, accounting for 80.00%. Further examination reveals that these errors stem from students' deficiencies in Facione's Analysis skills, which were observed in 29.69% of cases. Analysis skills require students to decompose problems, identify logical relationships among variables, and determine the interactions among them. For instance, as shown in Figure 2, when asked to calculate the unit price of one bowl of meatballs and one glass of iced orange juice, students exhibited substantial Transformation Errors. These errors involved incorrect substitution of variables, representing not mere minor procedural mistakes but fundamental conceptual failures in linking price and quantity information to construct valid equations. The inability to organise variables and establish algebraic relationships provides strong evidence of weaknesses in Facione's Analysis skills.



b. Determine the price of one bowl of meatball soup and one glass of orange juice.

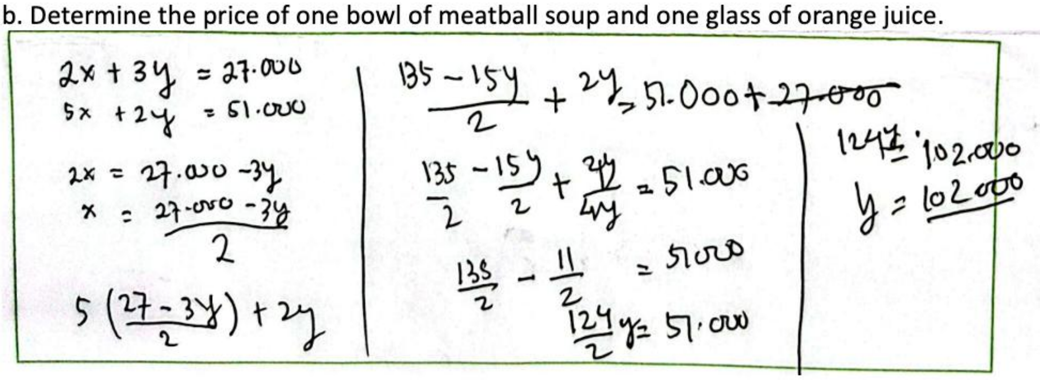


Figure 2. Student Analysis Errors in answering question part b

In the context of SLETV, the transformation process requires problem decomposition and pattern abstraction, which presents substantial cognitive challenges for students with low analytical skills (Darmawan et al., 2018). Transformation errors thus serve as a highly sensitive indicator of deficiencies in Facione's Analysis skills.

Focus of Analysis 3: The Relationship between Evaluation/Inference and Process Skills

Skill Errors (63.33%) and Final Answer Writing Errors (80.00%) reflect low achievement in Facione's Evaluation and Inference domains, which were observed at 29.69% and 25%, respectively.

1. Evaluation Failures and Mistakes in the Strategic Process: According to Facione, procedural errors arising from weak evaluation skills occur when students select inappropriate solution strategies or fail to verify the accuracy of their steps. For instance, students may attempt the elimination method but incorrectly multiply coefficients to eliminate variables or make algebraic addition or subtraction

errors that should have been checked. Low evaluation scores indicate insufficient self-monitoring and self-regulation, leading students to perform procedures mechanically without validating their correctness.

2. Inference Errors: Inference skills require students to draw logical conclusions from available information or evidence. Errors in this domain occur when students complete calculations correctly but fail to derive a valid conclusion. For example, as illustrated in Figure 3, a student successfully performed the computation but did not provide a logically consistent final answer. In a case involving the purchase of meatball bowls, the computation yielded 4.22, which cannot correspond to a fractional number of bowls; thus, the maximum number of whole bowls that can be purchased is 4. This example demonstrates that, although students may possess adequate computational skills, their ability to interpret context and draw accurate conclusions (Inference) remains underdeveloped.

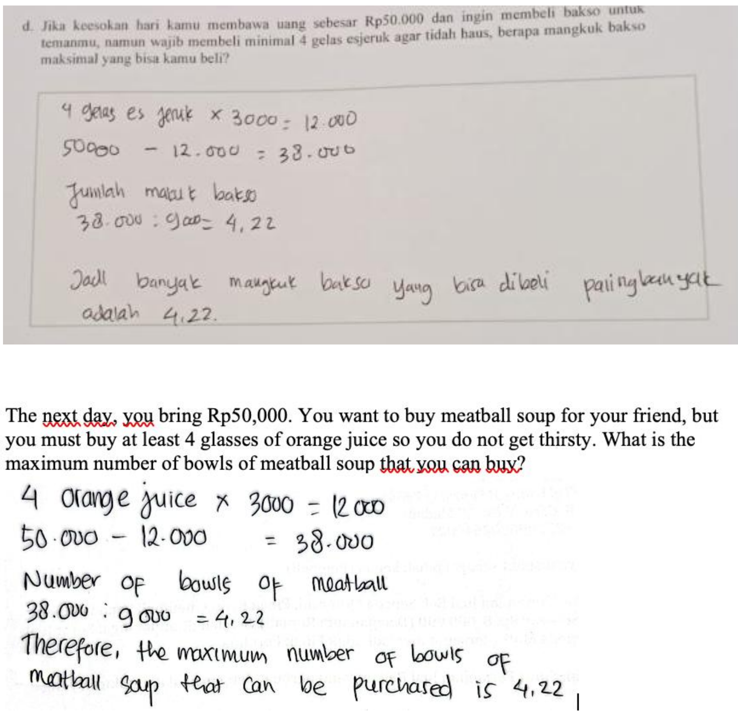


Figure 3. Student inference error in answering question Part d.

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Synthesis of Cognitive Failure Profiles

This integrated analysis provided a more comprehensive and precise characterisation of students' error profiles, summarised in Table 7.

Table 7 Synthesis of Facione's Cognitive Failure Profile Confirmed by Newman's Errors

Lowest Facione Indicator	Average achievement (%)	Newman's Most Common Triggering Mistakes	Description of Core Cognitive Failure
Analysis	29.69%	Transformation	Students' inability to identify variables and their relationships to build appropriate mathematical models.
Evaluation	29.69%	Process Skills	Inability to choose the right solution strategy or failure to assess the accuracy of the steps taken by students.
Inference	25%	Process Skills and Final Answers	Inability to carry out the final step, namely, concluding correctly.

This study confirms that the structural weaknesses of junior high school students do not lie solely in mastery of material or minor calculation errors, but also in higher-level cognitive processes.

1. Precision Diagnosis: The Facione-Newman integration provides a more precise diagnostic tool. Teachers are not only informed that students are making Transformation Errors, but also understand that these errors are rooted in Facione's cognitive analysis deficits. This more precise diagnosis is crucial because it requires targeted instructional interventions. If the problem is analysis, interventions should focus on developing problem decomposition and abstraction skills, not just computational exercises.
2. The Need for Cognitive Scaffolding: Given the low levels of Analysis and Evaluation skills, pedagogical interventions should shift from focusing solely on problem solving to strengthening reasoning. Effective interventions, such as *Level* 2 scaffolding (explaining, reviewing, and restructuring), can be implemented to help students construct modelling arguments and verify their own steps. This explicitly addresses the low Evaluation and Inference failure,

in which students tend to follow procedures without critically evaluating or verifying their steps.

CONCLUSION

Based on the foregoing analysis, it can be concluded that junior high school students' critical thinking skills in the SLETV topic remain relatively low, with an overall achievement rate of 42.05%. Among Facione's cognitive indicators, the most pronounced deficiency is observed in inference skills, which reach only 25%, followed by analysis and evaluation abilities, each accounting for 29.69%. Furthermore, the Newman Error Analysis indicates that procedural errors are predominantly concentrated at the transformation stage (80.00%) and in process skills (63.33%). The cross-mapping of cognitive indicators and error categories reveals that weak analytical abilities, as conceptualised by Facione, are strongly associated with a high frequency of transformation errors, suggesting that students experience substantial difficulty translating contextual problems into appropriate systems of linear equations. In addition, limitations in evaluation and inference skills contribute to errors in process execution and in the formulation of final answers, reflecting students' insufficient capacity to derive accurate contextual conclusions.

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