Failures of Mathematical Creative Thinking in Solving Three-Variable Linear Equation Systems Viewed from Self-Regulation

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ABSTRACT

This study aims to analyze the failure of students' mathematical creative thinking abilities in solving systems of linear equations in three variables (SPLTV) problems based on their level of *self-regulation*. Mathematical creative thinking is an essential higher-order skill, yet many students struggle to generate ideas, apply flexible strategies, and elaborate solutions when solving complex problems. This research employed a qualitative descriptive approach involving students categorized into high, medium, and low *self-regulation* levels. Data were collected through creative thinking tests, self-regulation questionnaires, and semi-structured interviews. The analysis focused on identifying patterns of failure across indicators of creative thinking, including *fluency*, *flexibility*, *originality*, and *elaboration*. The results indicate that students with low *self-regulation* tend to fail at planning problem-solving strategies, monitoring solution steps, and evaluating results, leading to incomplete or incorrect solutions. Students with moderate *self-regulation* partially fulfill creative thinking indicators, while those with high self-regulation demonstrate better control of their thinking processes, though some difficulties remain in originality and elaboration. These findings highlight the critical role of *self-regulation* in supporting students' mathematical creative thinking and provide implications for designing instructional interventions to reduce learning failure in SPLTV topics.

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1. INTRODUCTION

Mathematics is a fundamental discipline taught continuously from elementary school to higher education [1]. Its role is not limited to mastering numerical concepts and algorithms, but also serves as a medium for developing logical, systematic, analytical, and critical thinking skills [2]. In the context of 21st-century learning, mathematics plays a strategic role in fostering higher-order thinking skills, including analyzing, evaluating, and creating[3]. These skills are essential for students to adapt to the complexity of modern life problems that require reflective and independent thinking[4].

One important cognitive aspect that supports higher-order thinking is the ability for mathematical creative thinking. Mathematical creative thinking refers to the ability to generate ideas freely, explore various solution strategies, and construct new ideas during problem solving [5]. Creative thinking is a mental activity that enables individuals to produce original ideas or multiple solutions based on prior knowledge, experience, and conceptual understanding [6]. In mathematics learning, creative thinking is not only about producing new ideas but also about developing competencies that enable students to solve problems independently and flexibly [7].

According to Torrance, mathematical creative thinking consists of four main components: (a) *fluency*, the ability to generate many ideas; (b) *flexibility*, the ability to produce diverse strategies or approaches; (c) *originality*, the ability to generate unique or uncommon solutions; and (d) *elaboration*, the ability to explain, detail, and generalize ideas [8]. These components are essential in mathematics learning, as they enable students to process information meaningfully and approach problems innovatively rather than procedurally [9]. Creative thinking has also been recognized as a key attribute required for success in the modern workforce, emphasizing its importance beyond academic achievement [10].

However, empirical evidence indicates that many students still experience difficulties in applying creative mathematical thinking when solving problems. Several studies have reported that students often fail to meet one or more indicators of creative thinking, particularly fluency, flexibility, originality, and elaboration [11],[12]. This condition reflects obstacles in students' creative thinking processes, leading to failures in mathematical creative thinking. Failure in this context can be understood as a condition in which students are unable to achieve expected learning objectives due to difficulties in the learning process [13]. Specifically, failure in mathematical creative thinking occurs when students do not meet the essential indicators of creativity in problem-solving [14].

One mathematical topic that strongly demands creative thinking is systems of linear equations in three variables (SPLTV). Solving SPLTV problems requires not only procedural skills but also the ability to interpret information, select appropriate strategies, and evaluate solutions critically [15]. Previous research shows that algebraic problem solving, particularly SPLTV, poses significant cognitive challenges for students due to its abstract structure and multi-step reasoning demands [16]. Nevertheless, classroom observations reveal that many students experience difficulties and failures in solving SPLTV problems wholly and accurately [17]. These failures are often caused by misunderstandings of the problem, inappropriate strategy selection, and a lack of evaluation of the obtained solutions [18].

Students' failure to solve mathematical problems is not solely due to conceptual mastery but also to their ability to regulate their own learning processes. *Self-regulation* refers to an individual's ability to plan, monitor, and evaluate learning activities independently [19]. Students with well-developed *self-regulation* tend to control their thinking processes effectively, set learning goals, and correct errors during mathematical problem solving [20]. Research has shown that self-regulation significantly influences students' problem-solving performance, persistence, and creative engagement in mathematics learning [21].

While previous studies have examined mathematical creative thinking and *self-regulation* separately [22], research that analyzes explicitly patterns of failure in mathematical creative thinking based on self-regulation levels, particularly in SPLTV problem solving, remains limited. Therefore, this study aims to analyze students' failure in mathematical creative thinking when solving SPLTV problems based on self-regulation levels. The novelty of this research lies in its focus on failure analysis rather than merely comparing levels of ability, as well as in integrating mathematical creative thinking indicators with self-regulation categories. The findings of this study are expected to provide theoretical insights and practical implications for developing more targeted instructional strategies and scaffolding to support students' mathematical creative thinking.

2. METHOD

This research employed a descriptive qualitative design to examine students' failures in mathematical creative thinking when solving systems of linear equations in three variables, from the perspective of *self-regulation*. This design was chosen to explore students' cognitive processes, strategies, and difficulties in depth, particularly in relation to fluency, flexibility, originality, and elaboration indicators of creative thinking. A qualitative approach allows for a detailed analysis of students' reasoning and error patterns that cannot be fully captured through quantitative measurements alone [23].

The research was conducted at SMA Negeri 2 Kota Jambi, beginning with the preparation of research instruments, followed by data collection and data analysis. Initially, a mathematical creative thinking test, a *self-regulation* questionnaire, and semi-structured interview guidelines were developed and reviewed by experts to ensure content validity and clarity [24]. Data collection started with administering the *self-regulation* questionnaire to students, which was used to classify them into high, medium, and low *self-regulation* categories. Subsequently, students completed the mathematical creative thinking test involving three-variable linear equation problems. Based on the test results and *self-regulation* categories, representative students from each group were selected for interviews to explore their problem-solving processes and difficulties further.

The research subjects consisted of senior high school students who had studied systems of linear equations in three variables. Subjects were selected through purposive sampling based on their level of *self-regulation*, completeness of written responses, clarity of reasoning, and willingness to participate throughout the research process [25]. Data were collected through written tests, questionnaires, and interviews to obtain comprehensive, triangulated data. The written test results were analyzed to identify failures in each indicator of mathematical creative thinking, while interview data were used to confirm and deepen the interpretation of students' written responses. The comparison between students' written answers and verbal explanations enabled the researcher to identify consistent failure patterns across different *self-regulation* levels. The differences in

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students' performance tendencies were described narratively and supported by visual representations.

The indicators analyzed in this study are based on Torrance's creative thinking indicators, as presented in Table 1 below.

Table 1. Indicators and Descriptors of Mathematical Creative Thingking Ability

No	Indicators	Descriptor
1.	*Fluency*	Students are able to generate a number of ideas or strategies to solve a problem.
2.	*Flexibility*	Students are able to produce varied and diverse ideas, approaches, or solution strategies.
3.	*Originality*	Students are able to generate new and unique expressions or solutions that are uncommon or unusual.
4.	*Elaboration*	Students are able to enrich, develop, and generalize an idea in a detailed and systematic manner.

3. RESULTS AND DISCUSSION

3.1. Results

1) Description of *Self-Regulation Questionnaire* Data Analysis

Based on the results of the *self-regulation questionnaire* analysis conducted using the Rasch model to obtain interval-level measurements independent of sample characteristics, the findings indicate that the self-regulation instrument demonstrates good person reliability and consistently distinguishes students into different levels of *self-regulation* ability. The person-measured values obtained from the Rasch analysis were subsequently used to classify students into high, medium, and low *self-regulation* categories. The classification was based on the mean and standard deviation of the person's logit scores. Students with logit values above one standard deviation from the mean were categorized as having high *self-regulation*; those with logit values around the mean were categorized as having medium self-regulation; and those with logit values below one standard deviation were categorized as having low *self-regulation*. The distribution of students' *self-regulation* categories is presented in Table 2.

Table 2. Students' Self-Regulation Levels Based on Rasch Model Analysis

Level	Criteria	Logit Values	Jumlah Murid	Kode Murid
High	$>M+SD$	$LVI \geq 1.49$	5	A30, A23, A01, A15, A19
Medium	$M \pm SD$	- $0.01 \leq LVI < 1.49$	28	A21, A29, A05, A02, A09, A14, A20, A25, A34, A12, A13, A18, A22, A31, A32, A33, A36, A03, A24, A26, A27, A06, A11, A17, A07, A08, A16, A28
Low	$<M-SD$	$LVI < -0.01$	3	A10, A04, A35

Mean: 0.74, SD: 0.75, LVI (Linear Variable Interval)

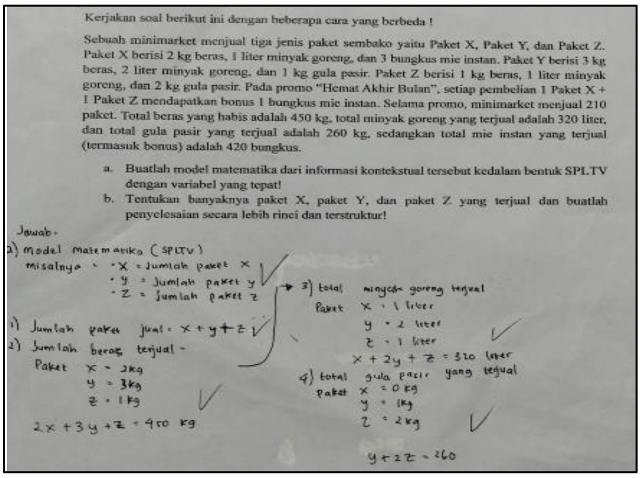
As shown in Table 2, most students fall into the medium *self-regulation* category, while a noticeable proportion of students are classified as having low self-regulation.

These results indicate that students' *self-regulation* abilities have not yet developed optimally, which may affect their success in solving problems that require mathematical creative thinking. Based on this categorization, three students were selected for further in-depth analysis: A30, representing the high self-regulation category; A12, representing the medium self-regulation category; and A04, representing the low *self-regulation* category.

2) Description of Subject Work with High *Self-Regulation* (S1)

Before working on the creative mathematical thinking test, the student with high *self-regulation* (coded as S1) was asked to read the problem carefully using the *think-aloud* technique. During this stage, S1 was able to read and interpret contextual information independently, without intensive guidance from the researcher. S1 explicitly identified the information on the types of basic-needs packages, the composition of each package, the promotional conditions, and the total quantities sold. This indicates that S1 demonstrated good planning ability (*self-planning*) at the initial stage of problem solving**.**

Based on the analyzed answer sheet, S1 began the solution by identifying the important information in the problem and defining the variables accurately. S1 assigned the variables x, y, and $z$to represent the number of packages X, Y, and Z sold. Subsequently, S1 constructed a mathematical model based on the total number of packages sold and the total amounts of rice, cooking oil, and sugar sold during the promotion. The mathematical modeling process carried out by S1 is shown in Figure 1.


Kerjakan soal berikut ini dengan beberapa cara yang berbeda !

Sebuah minimarket menjual tiga jenis paket sembako yaitu Paket X, Paket Y, dan Paket Z. Paket X berisi 2 kg beras, 1 liter minyak goreng, dan 3 bungkus mie instan. Paket Y berisi 3 kg beras, 2 liter minyak goreng, dan 1 kg gula pasir. Paket Z berisi 1 kg beras, 1 liter minyak goreng, dan 2 kg gula pasir. Pada promo "Hemat Akhir Bulan", setiap pembelian 1 Paket X + 1 Paket Z mendapatkan bonus 1 bungkus mie instan. Selama promo, minimarket menjual 210 paket. Total beras yang habis adalah 450 kg, total minyak goreng yang terjual adalah 320 liter, dan total gula pasir yang terjual adalah 260 kg, sedangkan total mie instan yang terjual (termasuk bonus) adalah 420 bungkus.

a. Buatlah model matematika dari informasi kontekstual tersebut kedalam bentuk SPLTV dengan variabel yang tepat!
b. Tentukan banyaknya paket X, paket Y, dan paket Z yang terjual dan buatlah penyelesaian secara lebih rinci dan terstruktur!

Figure 1. Mathematical modeling of the contextual SPLTV problem by S1

The student categorized as having high *self-regulation* (S1) was able to continue solving the system of linear equations in three variables systematically after constructing the mathematical model. S1 applied an elimination strategy by subtracting two equations containing the same variables to eliminate one variable. Each subtraction step was written clearly and sequentially, allowing the value of one variable to be obtained first.

During the elimination process, S1 successfully determined the value of variable $y$by subtracting the equation representing the total number of packages from another relevant equation. The obtained value of $y$was then used to simplify the remaining equations. Subsequently, S1 substituted the value of $y$into an equation containing two variables to determine the value of variable z, followed by a final substitution to obtain the value of variable x. All calculation steps were written clearly and systematically, and no computational errors were identified.

The final results obtained by S1 were 25 packages for X, 110 packages for Y, and 75 packages for Z. However, the solution did not include a reflective verification of the final results against the contextual constraints of the bonus noodle promotion. This indicates that although S1 demonstrated strong procedural accuracy and systematic problem-solving, the self-evaluation stage was not fully optimized. The elimination process and final results of S1's SPLTV solution are shown in Figure 2.

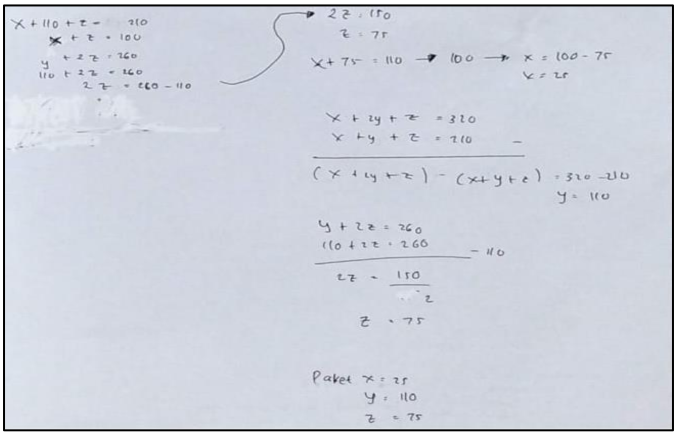
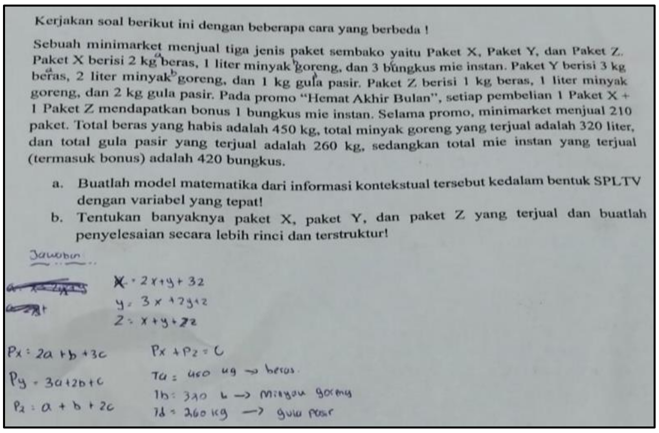


Figure 2. Elimination process and final results of the SPLTV solution by the student (S1).

3) Description of Subject Work with Medium *Self-Regulation* (S2)

Before working on the creative mathematical thinking test, the student with a moderate level of *self-regulation* (coded as S2) was asked to read the problem slowly using the *think-aloud* technique. At the initial stage, S2 was able to read the contextual information in the problem but still required guidance from the researcher to confirm key information on the types of basic-needs packages, the composition of each package, the promotional conditions, and the total quantities of items sold. This indicates that S2's planning ability (*self-planning*) had begun to develop but was not yet fully independent.

After reading the problem, S2 began solving it by defining variables to represent the number of packages sold. S2 assigned the variables x, y, and $z$to represent packages X, Y, and Z, and attempted to construct a system of linear equations in three variables based on the total number of packages sold, the total amount of cooking oil, the total amount of rice, and the total amount of sugar. However, during the mathematical modeling stage, S2 inconsistently wrote the coefficients in several equations, resulting in an SPLTV model that was not yet fully accurate. The mathematical modeling process carried out by S2 is shown in Figure 3.


Kerjakan soal berikut ini dengan beberapa cara yang berbeda !

Sebuah minimarket menjual tiga jenis paket sembako yaitu Paket X, Paket Y, dan Paket Z. Paket X berisi 2 kg beras, 1 liter minyak goreng, dan 3 bungkus mie instan. Paket Y berisi 3 kg beras, 2 liter minyak goreng, dan 1 kg gula pasir. Paket Z berisi 1 kg beras, 1 liter minyak goreng, dan 2 kg gula pasir. Pada promo "Hemat Akhir Bulan", setiap pembelian 1 Paket X + 1 Paket Z mendapatkan bonus 1 bungkus mie instan. Selama promo, minimarket menjual 210 paket. Total beras yang habis adalah 450 kg, total minyak goreng yang terjual adalah 320 liter, dan total gula pasir yang terjual adalah 260 kg, sedangkan total mie instan yang terjual (termasuk bonus) adalah 420 bungkus.

a. Buatlah model matematika dari informasi kontekstual tersebut kedalam bentuk SPLTV dengan variabel yang tepat!
b. Tentukan banyaknya paket X, paket Y, dan paket Z yang terjual dan buatlah penyelesaian secara lebih rinci dan terstruktur!

Figure 3. Mathematical modeling of the contextual SPLTV problem by S2

After constructing the model, S2 continued the solution by applying an elimination strategy. S2 attempted to eliminate one variable by subtracting two equations containing the same variables. The elimination process was written down; however, the steps were not always explained in detail, and several algebraic errors were observed, some of which were crossed out and corrected. This indicates that S2 demonstrated attempts at *self-monitoring*, although this process was not carried out consistently.

S2 then substituted the obtained variable values into other equations to determine the remaining variables. The substitution process followed the appropriate solution direction; however, the calculated results did not fully match the correct solution. These inaccuracies are likely attributable to imprecision during the initial modeling stage and the earlier elimination process, which, in turn, affected the final results.

Furthermore, S2 did not recheck the final results against the problem context, particularly regarding the appropriateness of the number of bonus noodle packages obtained. S2 directly recorded the calculated results without performing a logical evaluation of their reasonableness. This suggests that the *self-evaluation* stage had not yet been optimally developed in S2. The elimination process and calculation results are presented in detail in Figure 4.

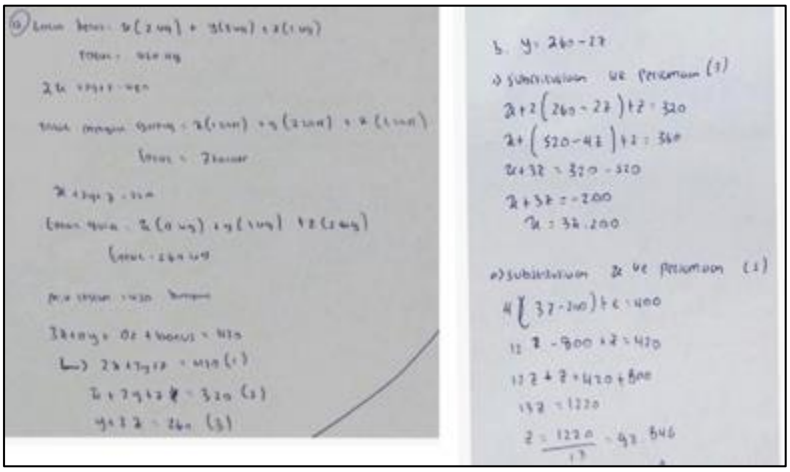


Figure 4. Elimination process and final results of the SPLTV solution by the student (S2).

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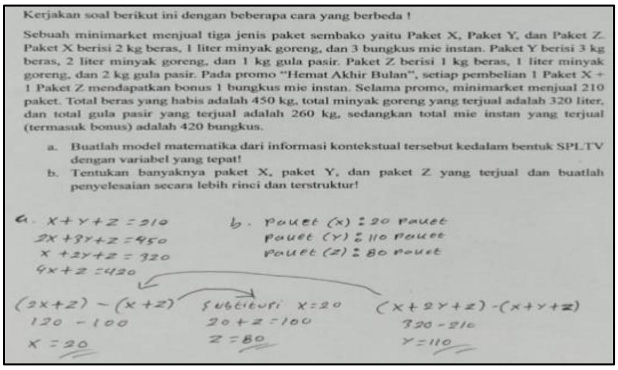
4) Description of Subject Work with Low *Self-Regulation* (S3)

Before working on the creative mathematical thinking test, the student categorized as having low *self-regulation* (coded as S3) was asked to read the problem using the *think-aloud* technique. At this stage, S3 experienced considerable difficulty in reading and understanding the problem's contextual information. S3 frequently paused while reading, appeared hesitant, and required repeated guidance from the researcher to continue and comprehend the problem. Key information related to the types of basic-needs packages, the composition of each package, the promotional conditions, and the total quantities of items sold could not be independently identified by S3. This indicates that S3's planning ability (*self-planning*) was very limited.

After reading the problem, S3 attempted to solve it by writing several equations related to packages X, Y, and Z (Figure 1). However, S3 did not consistently define the variables beforehand and directly wrote equations without clear explanations. At the mathematical modeling stage, the equations constructed did not accurately reflect the information provided in the problem. Several coefficients and constants were inconsistent with the contextual data, resulting in an inaccurate system of linear equations in three variables (SPLTV).

During the solution process, S3 attempted to eliminate variables by subtracting equations. However, the elimination steps were not written systematically and did not clearly indicate the intention to eliminate a specific variable. In addition, several basic algebraic errors were identified, including incorrect arithmetic operations and improper transposition of terms, which S3 failed to recognize or correct. This suggests that *self-monitoring* skills were not yet well developed.

S3 also attempted to substitute the obtained variable values into other equations, but the substitutions were performed without verifying the correctness of the previous results. Consequently, the calculated outcomes did not correspond to the correct solution. These errors occurred sequentially, beginning with inaccurate modelling and continuing through the elimination and substitution processes, ultimately affecting the final results. Furthermore, S3 did not recheck the final answers by relating them to the problem context, particularly regarding the appropriateness of the number of bonus noodle packages obtained. The mathematical modeling and the elimination process carried out by S3 are shown in Figure 5.



Kerjakan soal berikut ini dengan beberapa cara yang berbeda !

Sebuah minimarket menjual tiga jenis paket sembako yaitu Paket X, Paket Y, dan Paket Z. Paket X berisi 2 kg beras, 1 liter minyak goreng, dan 3 bungkus mie instan. Paket Y berisi 3 kg beras, 2 liter minyak goreng, dan 1 kg gula pasir. Paket Z berisi 1 kg beras, 1 liter minyak goreng, dan 2 kg gula pasir. Pada promo "Hemat Akhir Bulan", setiap pembelian 1 Paket X + 1 Paket Z mendapatkan bonus 1 bungkus mie instan. Selama promo, minimarket menjual 210 paket. Total beras yang habis adalah 450 kg, total minyak goreng yang terjual adalah 320 liter, dan total gula pasir yang terjual adalah 260 kg, sedangkan total mie instan yang terjual (termasuk bonus) adalah 420 bungkus.

a. Buatlah model matematika dari informasi kontekstual tersebut kedalam bentuk SPLTV dengan variabel yang tepat!
b. Tentukan banyaknya paket X, paket Y, dan paket Z yang terjual dan buatlah penyelesaian secara lebih rinci dan terstruktur!

a. $x+y+z=210$
$2x+3y+z=450$
$x+2y+z=320$
$4x+z=420$

b. Paket (x) : 20 paket
Paket (y) : 110 paket
Paket (z) : 80 paket

$(2x+z)-(x+z)$
$120-100$
$x=20$

Subtitusi $x=20$
$20+z=100$
$z=80$

$(x+2y+z)-(x+y+z)$
$320-210$
$y=110$

Figure 5. The mathematical modeling and final results of the SPLTV solution by (S3).

3.2. Discussion

The findings of this study indicate that failures in students' mathematical creative thinking when solving systems of linear equations in three variables (SPLTV) are closely related to differences in *self-regulation* levels and are reflected across the four Torrance indicators: *fluency, flexibility, originality,* and *elaboration* [8], [9]. These results reinforce the view that creative mathematical thinking is not solely determined by procedural mastery, but also by students' ability to regulate their cognitive processes through planning, monitoring, and evaluation [19].

Students with high *self-regulation* (S1) demonstrated strong *fluency* and *elaboration*. S1 was able to generate systematic solution steps and explain procedures clearly and coherently. However, limitations were observed in *flexibility* and *originality*, as S1 relied on a single routine strategy and did not explore alternative solution methods. In addition, although S1 obtained correct numerical results, it did not evaluate the solution in relation to the problem context, particularly the bonus noodle promotion. This suggests that elaboration was limited to procedural detail and did not extend to reflective or contextual validation, which is a critical aspect of creative thinking [8], [9].

Students with moderate *self-regulation* (S2) exhibited partial fulfillment of the creative thinking indicators. Initial *fluency* was evident through attempts to construct an SPLTV model and apply elimination and substitution strategies. Signs of *flexibility* appeared when S2 revised incorrect steps. However, inconsistencies in mathematical modeling and algebraic operations hindered elaboration, and *originality* was not evident, as the solution process followed routine procedures without contextual adaptation. These findings indicate that S2's creative thinking was fragmented due to insufficient *self-monitoring* and *self-evaluation* [11], [12].

In contrast, students with low self-regulation (S3) experienced failure across all four Torrance indicators. Limited *fluency* was reflected in difficulties understanding the problem context, which prevented the generation of relevant solution ideas. *Flexibility* and *originality* were absent, as no alternative strategies or independent reasoning were attempted. The lack of *elaboration* was evident in unsystematic solution steps without justification or evaluation. This confirms that low *self-regulation* severely constrains students' engagement in creative mathematical thinking [11], [13].

Critically, these findings show that failures in mathematical creative thinking on SPLTV tasks are not merely procedural or conceptual errors, but stem from weaknesses in *self-regulation* components, particularly *self-monitoring* and *self-evaluation* [19]. Even students with high *self-regulation* may still experience creative thinking failure when reflective evaluation and contextual reasoning are not optimally performed. This supports the perspective that creative mathematical thinking emerges from the interaction between cognitive competence and metacognitive regulation [7], [10].

Therefore, SPLTV instruction should not focus exclusively on procedural proficiency, but should explicitly foster both creative thinking indicators and self-regulation skills. Instructional *scaffolding* that encourages multiple solution strategies (*flexibility*), demands clear reasoning and justification (*elaboration*), and promotes contextual evaluation of results can help reduce failures in mathematical creative thinking.

Such approaches are particularly important for students with moderate and low *self-regulation* to support the integrated development of all four Torrance indicators [11], [12].

4. CONCLUSION

This study highlights that failures in students' mathematical creative thinking in solving systems of linear equations in three variables (SPLTV) are closely connected to differences in students' self-regulation levels. Overall, the findings emphasize that difficulties in creative thinking in mathematics are not solely due to procedural errors but are strongly influenced by how students plan, monitor, and evaluate their own learning processes.

The results imply that mathematics instruction, particularly in SPLTV topics, needs to move beyond procedural mastery and explicitly integrate the development of self-regulation alongside creative thinking skills. Learning designs that incorporate structured scaffolding, reflective questioning, and opportunities for students to evaluate their own solutions are essential to support more meaningful and flexible problem-solving processes.

This research is bounded by its focus on a limited number of student subjects and a single mathematical topic, namely SPLTV. Additionally, the study emphasizes qualitative analysis of students' problem-solving processes, which may limit the generalizability of the findings to broader student populations or different mathematical content areas.

Future research is encouraged to investigate instructional models that combine self-regulation training with the development of creative thinking across diverse mathematical topics and educational levels. Further studies may also explore integrating technology-assisted learning, including AI-based tools, to support students' self-monitoring and self-evaluation. For the general public, particularly educators and curriculum developers, this research offers insights into the importance of fostering self-regulated, creative learners who are better equipped to tackle complex mathematical problems and real-life challenges.

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