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Analysis of Students' Mathematical Problem-solving Ability on Number Matter

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Abstract

The ability to solve problems is very important for students to engage in the process of learning mathematics. In this study, students' ability to solve mathematical problems will be studied using Polya's indicators. The purpose of this study is to characterize the ability of grade IX Junior High School students to solve mathematical problems directly. The type of research conducted here is descriptive qualitative research. The subjects used in this study were about thirty students from State Junior High School 25 Pekanbaru for the 2023/2024 academic year in Class IX.3. Data collection was carried out by giving a validated test instrument, which was then sorted based on the mathematical problem-solving ability test scores. The data analysis technique used the Miles and Huberman model, namely data reduction, data analysis, and data estimation. The results of the analysis for each indicator of mathematical problem-solving ability reached an average of 38.325% and fell into the low category because many students solved the problem of integer material not by the stages of the indicator and errors were found in students' answers. Based on these results, it can be concluded that students' mathematical problem-solving skills are classified as weak/low.

Keywords: Integers, Polya, Problem-solving ability.

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1. Introduction

Education plays a crucial role in human development, fostering personal growth across various domains and enhancing overall quality of life (Nourdad et al., 2018). It is fundamental for human well-being and accelerates the achievement of important development goals (Paci-Green et al., 2020). Education empowers individuals to better interpret their environment, recognize their rights, and improve their own and others' lives (Kurmanayeva et al., 2021). It is essential for increasing job opportunities and developing critical skills needed in various fields. Moreover, education is a key factor in sustainable development, as it supports the realization of human potential and societal progress (Hubert et al., 2024). To effectively address sustainable development, education should focus on three dimensions: increasing access and attainment, improving quality, and inspiring transformative learning (Widad Ma et al., 2024). Without education, all other resources remain latent potentials for human development (Laistner, 2023).

Mathematics education in Indonesia faces significant challenges despite being a mandatory subject at all levels of formal education. While the curriculum aims to develop higher-order thinking skills and prepare students for real-world problem-solving (Zhou et al., 2023), the implementation has fallen short of its goals. Students' performance in national and international assessments remains poor (Mailisman et al., 2020)(Hadi, 2002). The traditional teaching approach has led to misconceptions and a focus on passing exams rather than developing critical thinking skills (Kania et al., 2023). To address these issues, Realistic Mathematics Education (RME) has been proposed as a promising approach to improving mathematics education in Indonesia (Suharta et al., 2021). However, successful implementation requires proper teacher training and adaptation to the Indonesian context. The mathematics curriculum in Indonesia has undergone several reforms throughout its history, influenced by both internal and external factors (Angraini et al., 2024).

Problem-solving is a fundamental skill in mathematics that extends beyond its boundaries, finding applications in various disciplines and real-life scenarios (Uegatani et al., 2021). It involves a range of processes, including analyzing, interpreting, reasoning, and reflecting, and requires deep mathematical knowledge, general reasoning ability, and heuristic strategies (Szabo et al., 2020). A contextual approach to learning design can improve mathematical problem-solving skills by providing real-world scenarios, drawing from theories like situated cognition and social constructivism (Sukinawan & Haq, 2024). Problem-solving can be viewed as a goal, method, and skill, with the need for ample support for novice learners (Nhat et al., 2024). Traditional approaches to teaching problem-solving have often been narrow, focusing on simple verbal problems with limited real-world application (Bintara, 2021). A broader, panoramic approach to problem-solving is recommended to increase student achievement and promote a fuller appreciation of its value across various circumstances. This skill is central to achieving educational goals in mathematics. Students who master problem-solving are better equipped to tackle mathematical challenges and adapt these skills to other contexts.

Problem-solving is a complex cognitive process that requires a range of skills and knowledge. It involves representing the problem, planning, executing, and monitoring solutions (Looi et al., 2007). Effective problem-solving relies on various cognitive processes, including perception, attention, memory, and thinking (Elaby et al., 2022). Experts differ from novices in their problem-solving approach, demonstrating more structured and interconnected mental representations, schema-driven behaviour, and convergent thinking (Vanutelli et al., 2021). To develop problem-solving skills, interactive and self-managed experiences are beneficial, promoting motivation and metacognitive skills like self-monitoring (Jaenudin et al., 2020). Constructivist learning environments that encourage collaborative, active, and creative problem-solving can advance students' cognitive and metacognitive processes (Alghadari et al., 2020). Future research should focus on designing adaptable, real-world learning environments to elicit these processes and improve problem-solving training. Consequently, students are expected to approach mathematical problems systematically and logically (Rosita et al., 2021). This study focuses on developing students' problem-solving skills through the specific mathematical topic of integers, given its foundational role in the mathematics curriculum.

Integer operations form a critical component of junior high school mathematics, but students often face difficulties in understanding and applying these concepts. Research indicates that while students can generally compare positive and negative integers using number lines (Sukiyanto et al., 2023), they struggle with mixed operations involving both positive and negative numbers (Hanifa et al., 2024). Common challenges include understanding negative numbers as abstract concepts and applying integer operations to real-world problems (Leung, 2008). Students may be able to restate concepts and provide examples, but often fail to represent them visually or classify objects according to specific properties (Wibowo et al., 2021). These difficulties can stem from students viewing numbers as formal symbols without concrete representations (Thomas, 2016). To address these issues, teachers should consider students' prior knowledge and diverse responses when introducing new material, as inadequate teaching methodologies can contribute to learning obstacles (Szabo et al., 2020). Research indicates that a lack of conceptual understanding can hinder students' ability to solve mathematical problems effectively (Kania et al., 2024). Students who rely solely on memorization without grasping underlying concepts often struggle to determine the appropriate methods or formulas to solve problems, particularly in integer-related topics.

This research explores mathematical problem-solving skills using Polya's four-step approach. Studies demonstrate its effectiveness in enhancing students' abilities to identify key information, plan solutions, and verify answers (Kania, 2018). Polya's method significantly improves students' mathematics performance and develops structured thinking (Karlina, 2022). In contrast, Krulik and Rudnick's approach is examined about thinking styles, revealing varied problem-solving strategies among students (Dag & Durdu, 2017). The application of Polya's methodology, combined with ICTs, strengthens problem-solving skills in differential equations, emphasizing critical thinking and reasoning (Pramasdyahsari et al., 2023). These studies collectively highlight the importance of systematic problem-solving approaches in mathematics education, demonstrating their potential to enhance students' analytical and critical thinking abilities across different educational levels and mathematical domains.

The primary objective of this study is to describe the problem-solving abilities of Grade IX junior high school students when solving problems related to integers. This research aims to contribute unique insights by offering a structured methodology to improve problem-solving skills, thereby assisting educators, mentors, and researchers in designing effective instructional strategies. The findings are expected to serve as valuable references for teachers in fostering students' mathematical competencies and enhancing their ability to address real-world challenges.

Research on the problem-solving abilities of junior high school students in mathematics, particularly with integers, reveals several key findings. A realistic mathematics approach can improve students' problem-solving skills across various integer subtopics (Yuhani et al., 2018). Analysis based on Polya's problem-solving steps shows that students who can identify important information and plan solutions are more likely to solve problems systematically and verify their answers (Kania et al., 2022). The Problem-Based Learning model has been found to enhance mathematical problem-solving skills in junior high school students (Hanifah et al., 2024). These findings provide valuable insights for educators to develop effective strategies for improving students' mathematical problem-solving competencies.

2. Methods

This study employed a qualitative method, specifically using the descriptive phenomenological research approach to explore the lived experiences of social science professionals across different generations. The study aimed to uncover the essential meanings of these experiences by analyzing participants' narratives, focusing on how social dynamics influenced their career This research employed a descriptive method to analyze and describe students' mathematical problem-solving abilities on integer material. According to Prahmana et al. (2019), descriptive methods collect data in the form of text, graphs, or descriptions rather than numerical values. The research adopted a qualitative approach, which seeks to understand phenomena experienced by research subjects—including actions, motivations, and behaviors—holistically and within their natural contexts using descriptive language.

The study focused on ninth-grade students from State Junior High School 25 Pekanbaru, with a sample size of 30 students. The sample was selected using purposive sampling, which considers specific criteria such as students' academic performance, prior mathematical achievements, and their ability to engage with the research material effectively (Sugiyono, 2016). These criteria were established to ensure the selection of subjects who could provide meaningful insights into the research focus on mathematical problem-solving abilities.

Data were collected through a test consisting of three topics related to integer material. Each topic was designed to assess four indicators of mathematical problem-solving skills as defined by Polya's framework (1957): Understanding the problem, Planning the solution, Implementing the solution plan, and checking the solution.

The development of these topics was guided by their alignment with the junior high school mathematics curriculum and input from expert educators to ensure clarity, relevance, and validity. Each test item was scored based on a scoring rubric (Pertiwi, 2020), with each item assigned a maximum score of 10 points. The total possible score across all items was 30 points, with a time allocation of 60 minutes for students to complete the test.

The collected data were analyzed using the Miles and Huberman model, which involves three stages: Data Reduction: Organizing and summarizing the raw data to focus on the most relevant information related to problem-solving indicators. Data Display: Presenting the data in an organized format, such as tables or graphs, to facilitate interpretation. Conclusion

Drawing and Verification: Identifying patterns, relationships, and insights from the data to draw meaningful conclusions. Based on the test results, use the following formula to determine the results.

$$Value = \frac{Student\ Score}{Maximum\ Number\ of\ Score}x\ 100$$

This model was instrumental in understanding the nuances of students' problem-solving processes and categorizing their abilities into distinct tiers. To determine students' performance levels, their total scores were categorized into three tiers: High, Medium, and Low. The categorization was based on predefined score ranges aligned with national standards and previous research. Each student's task was then evaluated based on the following qualifications.

Table 1 - Tier Categories

Score	Category
$70 \leq 100$	High
$55 \leq 69$	Medium
$0 \leq 54$	Low

The test items and scoring rubric underwent pilot testing and expert review to ensure reliability and validity. Feedback from mathematics educators helped refine the questions and scoring criteria, ensuring they were clear, appropriate, and aligned with the study's objectives. This methodological approach, combining descriptive analysis and qualitative insights, was chosen to capture the depth and complexity of students' problem-solving abilities in mathematics. By focusing on integers and aligning data collection and analysis with established frameworks, this study aims to provide a reliable basis for improving teaching strategies and fostering mathematical competencies among junior high school students. The topics used can be seen in Table 2 below.

Table 2 - Test Question

Problem-Solving Indicator	Questions
Understanding the problem Planning the Solution Implementing the Plan Checking Back	1) A farmer has 27 chickens. Every month, the chickens increase by 5 chickens. How many chickens does the farmer have after 4 months? 2) Lauren is taking the national exam. The provisions in the assessment of the exam: a) if the student answers the question correctly, 3 points are given and b) if the student answers the question incorrectly then -1 point is given. Out of 100 questions, Lauren answered 98 questions and 50 of them were answered correctly. Determine the points earned by Lauren! 3) A farmer has a rectangular field. He wants to build a fence around the field.The length of the field is 120 meters and the width is 80 meters. The farmer wants to build a fence with a height of 2 meters. What is the total length of wire required by the farmer?

3. Results and Discussion

3.1 Results

The number of points is determined by looking at the trends of the indicators related to math ability. Based on the research method after determining students' scores, the next step is to classify students into three categories: high, medium, and low.

Below are the results of the overall percentage of students' answers, which are analyzed based on the scores and classified into three categories: high, medium, and low, according to the indicators of students' ability to solve mathematical problems. The overall results of student presentations can be seen in Table 2 below.

Table 3 - Percentage Results of Overall Student Answers

Category of Mathematical Problem-solving Ability	Number of Students (People)	Percentage
High	3	10%
Medium	13	43,3%
Low	14	46,7%
Total	30	100%

Based on Table 2, of the 30 students who completed the mathematical problem-solving ability test on integer material, the results revealed distinct proficiency levels categorized as high, medium, and low. Three students (10%) were classified in the high category. These students successfully addressed three problem-solving indicators: understanding the problem, correctly executing the solution plan, and re-evaluating their work to make conclusions. However, they faced challenges during the solution planning stage, as they were unable to construct or present the required mathematical model for solving the problem. This limitation highlights a gap in translating problem understanding into effective planning, which may indicate an insufficient emphasis on modeling skills in the teaching process.

Thirteen students (43.3%) fell into the medium category. These students demonstrated the ability to understand the problem, with most being able to write down the known information. However, one student in this group only identified the known aspects of the problem but failed to articulate what was being asked. Additionally, students in this category struggled with the planning stage, often skipping the creation of a mathematical model and proceeding directly to numerical operations. Despite this, they generally performed well in executing the plan by correctly carrying out integer operations. However, the re-evaluation stage was neglected, as students did not verify their solutions or draw conclusions.

The remaining 14 students (46.7%) were categorized as low proficiency. These students struggled across all problem-solving indicators, with significant challenges in understanding the problem and constructing appropriate solutions. This finding suggests a fundamental gap in conceptual understanding and procedural skills related to integer operations, which may stem from inadequate foundational knowledge or ineffective instructional strategies.

The distribution of proficiency levels—10% high, 43.3% medium, and 46.7% low—offers critical insights into students' problem-solving abilities. The relatively small proportion of high-proficiency students may reflect broader systemic or contextual challenges. For instance, the effectiveness of current teaching methods could play a role, particularly if instructional strategies do not sufficiently emphasize critical thinking, mathematical modeling, or iterative problem-solving.

External factors, such as the disruptions caused by the COVID-19 pandemic, may have also contributed to these outcomes. Limited in-person instruction and the challenges of remote learning could have disproportionately impacted students with lower baseline abilities, further widening the achievement gap. Additionally, curriculum design and teacher preparation may not adequately address the cognitive demands of problem-solving, particularly in fostering skills such as planning and re-evaluation.

These findings underscore the need for targeted interventions to support students across all proficiency levels. For high-proficiency students, additional emphasis on mathematical modeling and planning could further enhance their problem-solving skills. For medium- and low-proficiency students, remedial support and differentiated instruction could address foundational gaps and encourage a more comprehensive engagement with all problem-solving stages.

Furthermore, integrating problem-solving frameworks like Polya's method into classroom practice can provide a structured approach to developing these skills. Teachers could benefit from professional development opportunities that equip them with strategies to foster conceptual understanding, emphasize re-evaluation, and guide students in creating mathematical models. In table 3 below are the results of the overall percentage of student answers per indicator.

Table 4 - Results of the Overall Percentage of Student Answers Per-Indicator

Indicators of mathematical problem solving	Number of Students (People)	Percentage	Category
Understanding the problem	15	50%	Low
Planning the Solution	3	10%	Low
Implementing the Plan	24	80%	High
Checking Back	4	13,3%	Low

The results of students' answers per indicator are shown in Table 3 above. Of the total number of students, about 15 could understand the problem with a presentation that reached 50% of the total. This indicates that students have not done this task well because some of them only summarize what is known and what is asked. Furthermore, at the completion stage, only three students were able to complete this task with an accuracy rate of 10% due to difficulties in making the mathematical model to be used. Furthermore, in the third indicator, namely planning, 24 students can meet the requirements with a percentage of around 80% which is included in the high category because many students only perform mathematical operations without making a model. In the last category, namely checking back, there are approximately 4 students with a percentage of 13.3% who fall into the low category because many students still do not check back their answers and do not write the conclusions of the answers obtained. Based on the results that have been obtained, it is found that there are quite a lot of students who are unusual and have difficulty in answering questions related to difficulties in solving problems with indicators of mathematical problem-solving ability, especially with the integer material mentioned above. As a result, the percentage of students who passed the test was 38.325%, which falls into the low category.

The following are the results of the description of errors in the answers of high, medium and low category students analyzed by the stages of indicators in solving mathematical problem-solving ability questions on integers.

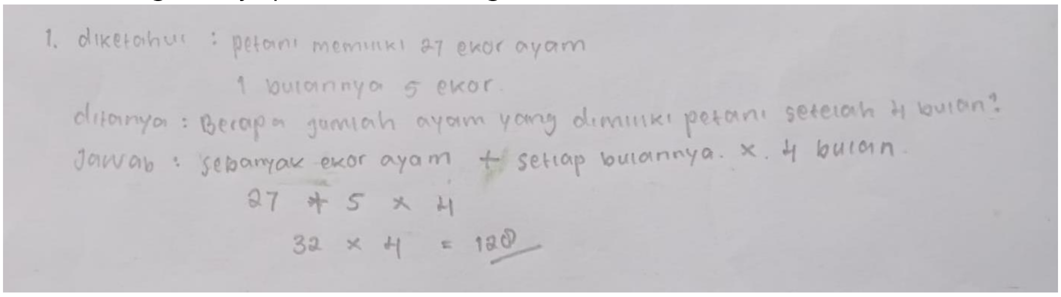
1. diketahui : petani memiliki 27 ekor ayam
1 bulannya 5 ekor.
ditanya : Berapa jumlah ayam yang dimiliki petani setelah 4 bulan?
Jawab : sebanyak ekor ayam + setiap bulannya. x. 4 bulan.
27 + 5 x 4
32 x 4 = 128

Figure 1 Students in the High Category

It can be seen in Figure 2 that students with high categories have understood the problem well. Students understand the information known and asked in the problem correctly, namely, students write known: the farmer has = 27 chickens, every month = 5 Chickens and write the question, namely how many chickens the farmer has after 4 months. Students have made a good plan by making a mathematical model that is as many chickens plus each month multiplied by 4 months.

At the stage of carrying out the plan, students write it down under known, at this stage, students can carry out the plan quite well and correctly. Students write the results of $27 + 5x4 = 128$. Students have checked the answer correctly but have not written the conclusion of the answer obtained. So, from the description in Figure 2, the subject can complete the three stages of Polya well.

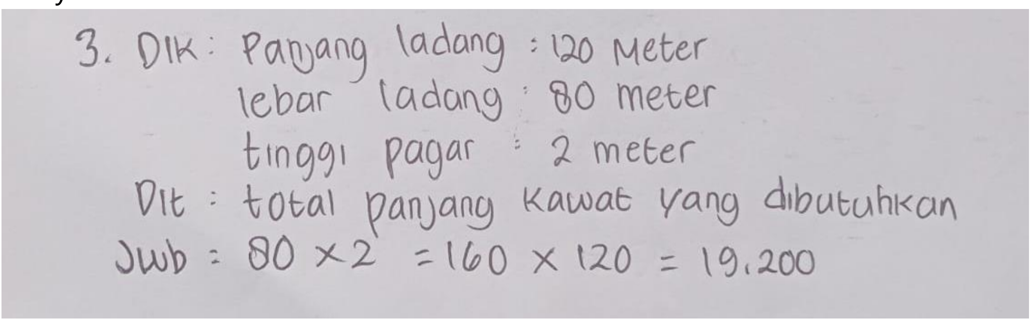
3. DIK: Panjang ladang : 120 Meter
lebar ladang : 80 meter
tinggi pagar : 2 meter
Dit : total panjang kawat yang dibutuhkan
Jwb : 80 x 2 = 160 x 120 = 19.200

Figure 2 Students in the Medium Category

In Figure 3, it can be seen that students with moderate ability have understood the problem quite well. Students have written what is known in the problem, namely the length of the field = 120 meters, the width of the field = 80 meters and the height of the fence = 2 meters, students have also written what is asked, namely the total length of wire needed. Students have not compiled the plan well, because students immediately write the stages of implementing the plan without making the mathematical model, students have difficulty in making the mathematical model. Students have implemented the plan properly and correctly, students write the answer: $80 \, x \, 2 = 160 \, x \, 120 = 19{,}200$. At the stage of checking back students have not concluded the results that have been calculated, students only write the results, namely 19,200.

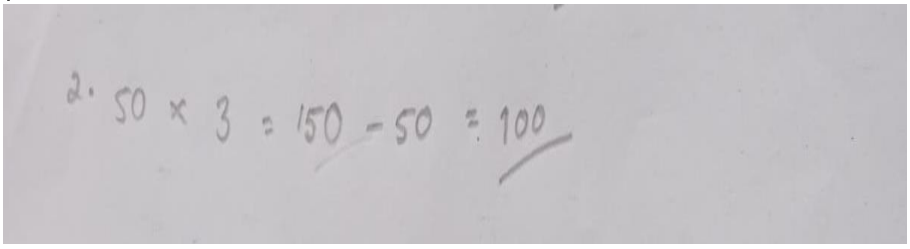

Figure 3 Students in the Low Category

It can be seen in Figure 4 that students with low ability have difficulty in rewriting the important information listed in the problem. Students do not write known and questionable information in the problem. Students have not compiled the plan well, because students immediately write the stages of carrying out the plan without making the mathematical model, students have difficulty in making the mathematical model. Students have implemented the plan well by writing $50 \, x \, 3 = 150 - 50 = 100$. At the stage of checking back, students do not summarize the results that have been calculated, students only write the result which is 100. Students have difficulty summarizing the results of the problems or problems that have been given.

3.2 Discussions

Based on the results of the analysis of student answers above, there is a correlation between the problem-solving abilities of high, medium, and low students with the process used by students in solving problems. Students in the high category can manipulate three-stage indicators; students in the medium category can manipulate two-stage indicators; and students in the low category can only manipulate one-stage indicators. In this study, students' ability to solve mathematical problems was categorized as low. This phenomenon is largely due to the current pandemic conditions, which make learning less effective and learning time reduced. Teaching was conducted straightforwardly and flexibly. During the distance learning sessions, some students who lacked the necessary skills did not participate in the lessons, so many students were unable to complete the problem-solving tasks, which are similar to comprehension tasks, that students are required to complete. The problem-solving phase is where students are expected to understand what is being asked and be able to repeat information from the subject using their language (MD-Ali & Kim, 2018).

As for the stage of planning the solution, many students find it difficult to solve because they do not write down the formula or mathematical model in the integer material that will be used. In line with the research (Nurjannah et al., 2019), namely, students often make mistakes because they do not write down the formula or mathematical model completely and correctly. In research conducted by (Munengsih et al., 2021) and (Aisyah et al., 2018), it can be seen that some students have not been able to carry out the planning stage of the solution properly and students still cannot make formulas or compile mathematical models to be used at the planning stage. At the stage of carrying out the plan, students have carried it out, but some students are still mistaken and wrong when doing operations so they produce wrong answers.

Students are also less careful and hasty when carrying out plans that give wrong answers (Rizalno & Purwanto, 2022). At the stage of checking back, there are still many students who do not carry it out and also do not make conclusions after performing calculations on whole number operations. The reason students do not carry out this stage is because students think the answer is correct (Koçak, 2020). Meanwhile, this stage can help students develop their knowledge related to problem-solving (Wahyu et al., 2019). From the answers of the three students in the high, medium, and low categories, they have in common that they do not recheck the results of their answers and do not write the conclusion of the answers obtained which is an important point to find out whether the student's answer is correct or not. The results of the answers of students of all categories can understand the problem so that in solving the problem students are correct in answering.

Future research should build upon the current study by exploring mathematical problem-solving abilities across diverse materials and subjects to gain a more comprehensive understanding of the factors influencing these skills. Expanding the scope of research will not only enhance the quality of teaching but also provide a broader framework for addressing challenges in mathematics education. This study has highlighted the importance of understanding and strengthening students' mathematical problem-solving abilities, particularly in the context of whole-number material. Existing literature underscores that problem-solving is a critical skill, bridging academic knowledge with practical application, and fostering cognitive development. Such abilities are foundational in equipping students to tackle real-world problems effectively. The methodology employed in this study—utilizing a descriptive qualitative approach—enabled an in-depth exploration of students' performance. The sample consisted of 30 ninth-grade students from SMP Negeri 25 Pekanbaru, selected through purposive sampling based on specific criteria, including prior academic performance and engagement in mathematics. Data were collected through problem-solving tests involving integer operations and analyzed using the Miles and Huberman model, encompassing data reduction, analysis, and interpretation. Findings revealed significant gaps in students' ability to address critical indicators of problem-solving, particularly in planning solutions and constructing mathematical models. The implications of these findings suggest that educators should adopt targeted strategies, such as: Integrating real-world examples to enhance conceptual understanding. Providing structured problem-solving frameworks like Polya's method to guide students through each step of the process. Implementing formative assessments to identify and address students' misconceptions promptly. In summary, this study underscores the need for strategic interventions to enhance students' mathematical problem-solving skills, emphasizing the critical stages of planning and verifying solutions. For educators, these findings serve as a practical guide to refine teaching methods, while future research should aim to broaden the focus to encompass different topics and student demographics, ultimately fostering improved mathematical proficiency across diverse educational contexts.

4. Conclusions

Based on the results and analysis, it can be concluded that the mathematical problem-solving ability of Grade IX students at SMP Negeri 25 Pekanbaru in solving problems related to whole number material is generally low, with an average performance of 38.325%. Students in the low category exhibited significant challenges, demonstrating mastery of only one problem-solving indicator: understanding the problem. They could identify basic information from the problem but failed to proceed with appropriate procedures or apply further steps in the problem-solving process. Students in the medium category showed moderate ability, mastering two indicators: understanding the problem and implementing the solution plan. However, they often bypassed the planning stage, directly performing operations without constructing a mathematical model. This approach led to inconsistent results. Students in the high category demonstrated competence in three indicators: understanding the problem, implementing the solution plan, and re-examining the results. They could identify relevant information, apply correct procedures, and verify their answers. However, they struggled with the second indicator, planning the solution, as they were unable to construct a clear mathematical model to guide their work. These findings highlight the need for interventions targeting the development of systematic problem-solving skills, particularly in the areas of planning solutions and mathematical modelling. Strengthening these skills could help students progress across all proficiency levels.

Conflict of Interest

The authors declare no conflicts of interest.

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