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Solving Mathematics Problems Based on Visual Information Processing

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Solving mathematical problems involves a complex process and requires the ability to comprehend and manipulate visual information. When an individual encounters a problem, the ability to represent data, plan solution steps, and visualize relationships between variables is crucial. This research aims to explore in-depth how visual information is processed during mathematical problem-solving. The findings indicate that Subject S1, with high visual ability, adeptly represents the problem, articulates known and unknown elements, and exhibits a strong conceptual understanding. Students with robust visual conceptualization skills can plan and solve problems using elimination and substitution methods. By verifying results using different methods reflects a solid conceptual understanding. On the other hand, Subject S2, with low visual ability, struggles to represent the problem and tends to focus directly on the solution. This suggests a lack of conceptual understanding, limitations in visual representation, and deficiencies in verification skills. Finally, the visual representation only used visual representation with mathematical modeling. Further research should investigate similar studies involving other types of representations, such as

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diagrams and graphs. In conclusion, teachers need to enhance students' conceptual understanding, metacognitive awareness, and practice verification skills to develop their mathematical problem-solving abilities

Keywords: Solving mathematics problems; visual information processing; linear equation in two variables.

1. INTRODUCTION

In the 21st century, problem-solving has been recognized as a crucial competency that students need to possess [1]. Several countries emphasize problem-solving as a vital skill that students should acquire in their curriculum, including Indonesia [2]. Contemporary problem-solving models assert that a key element in the problem-solving process is understanding the form of the problem representation presented in assessments [3]. Therefore, this understanding is considered essential because effective problem-solving requires individuals to analyze problems, recognize patterns, and design effective solution strategies. In this context, precision in understanding the structure and content of problems becomes a foundational element for success in solving problem-solving tasks in everyday life. There are four key steps in problem-solving: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back [4].

Solving mathematical problems requires a set of cognitive skills, including in-depth visual information processing. When students encounter mathematical problems, they often need to create visual representations of the given information, such as diagrams, graphs, or mathematical models, to better understand the problem. A profound understanding of how visual information is processed in this context can provide valuable insights into the cognitive mechanisms involved and lay the foundation for the development of more effective teaching methods.

Based on this, the problems frequently tackled by students at the junior high school level are often designed with higher-level mathematical concepts. Therefore, to solve more complex mathematical problems, a strong visual representation skill is essential. In this context, understanding abstract mathematical concepts is often aided by strong visualization skills. With proficient visual representation abilities, students can more easily comprehend and resolve mathematical problems involving more complex concepts. For example, when solving problems such as systems of linear equations with two variables or mathematical patterns, the ability to visually map the situation and identify the relationships between key elements greatly facilitates finding solutions. Therefore, early comprehension of visual representation capabilities at the junior high school level can help students prepare themselves to handle higher-level mathematical problems in the future.

Furthermore, in solving mathematical problems, visual information plays a crucial role in helping students organize information, identify patterns, and formulate solution strategies. Therefore, utilizing visual representation becomes an effective way to support the understanding and resolution of problems [4]. Consequently, Visual representation is a skill necessary for problem-solving because students possess a natural ability to process visual information more efficiently and quickly compared to information presented in textual or numerical forms.

Wahyuni & Fatimah, [5] emphasized that where a complex problem can become simpler by using representations that are appropriate to the given problem. Furthermore, Hidayat [6] asserts that representation is a concrete form of abstract mathematical ideas, manifested in the form of images (visual), words (verbal), or mathematical symbols, making it easily understandable.

Representation also facilitates students in understanding concepts and solving given mathematical problems [7]. The research finding Subekti et al. [8] indicate that factors influencing the level of mathematical visual representation ability include the learning model used, learning style, gender, and the teacher's role in the learning process.

This visual information processing involves the brain in recognizing, interpreting, and connecting visual elements to form a deep understanding of the mathematical problems at hand. Therefore, visual representations of mathematical concepts provide a strong foundation for long-term mathematical understanding [9].

Visual thinking plays a significant role in the understanding and reviewing stages of mathematical problem-solving [10]. This aligns with Ulya's research [11], indicating a high-level positive correlation between students' cognitive styles and their problem-solving abilities. The correlation coefficient of 0.624 suggests a significant relationship, while the determination coefficient of 0.390 indicates that approximately 39% of students' problem-solving abilities are influenced by cognitive styles. Furthermore, the research finding Arum et al. [1] show that there is a significant and linear influence between visual representation ability and physics learning outcomes, with a contribution of 66.6%, representing the coefficient of determination (R Square).

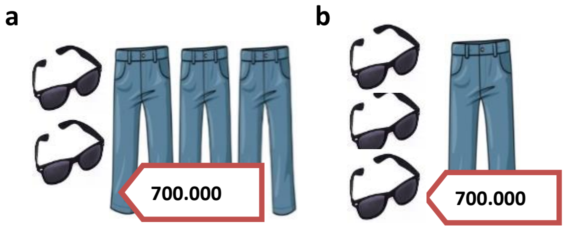
Previous studies have provided insights into the importance of visual thinking, visual information processing, and cognitive styles in understanding and enhancing students' cognitive abilities in the context of problem-solving. However, they have not specifically addressed differences in visual information processing abilities among individuals, such as visual clarity, and sensitivity to visual representations, which can influence how someone integrates visual information when solving mathematical problems.

This understanding provides a foundation for the development of more focused learning strategies that support the enhancement of students' problem-solving skills, especially in the context of visual information processing. Thus, the relationship between visual thinking and visual information processing forms a crucial basis for mathematical problem-solving, where these two aspects mutually support and complement each other to achieve better understanding and effective solutions. Therefore, new innovations in teaching are needed to ensure that the understanding process can proceed effectively (Danial, Faisyah, 2021), [12].

This study aims to explore more deeply how visual information is processed during mathematical problem-solving. With a focus on the generated visual representations, this research will provide a more profound understanding of the dynamics of cognitive processes during mathematical problem-solving.

2. METHODOLOGY

This research employs an exploratory qualitative approach. The subjects in this study are students selected using purposive sampling techniques, specifically those with high and low visual abilities from the eighth-grade students of Junior High School of 1 Sinjai who are currently learning the material on a system of linear equations with two variables. This involves presenting non-routine problems to the students; Pay attention to the following picture.



Picture 1: Question

Based on the picture, how much the price if one glasses and two pants?

The data analysis technique employed was analysis of qualitative descriptive based on the mathematical problem-solving test and interviews. The data analysis process follows the interactive model of Miles & Huberman [13] which consists of three concurrent interactive flows: data reduction, data display, and conclusions drawing/verification.

3. RESULTS AND DISCUSSION

Based on the mathematical problem-solving test that has been completed by both subjects, here is the explanation:

3.1 Subject S1

The results of the mathematical problem-solving test for Subject S1 can be seen in Fig. 1:

Based on the Fig. 1, Subject S1 rewroted the known information and the question posed by the problem, stating: "Given: the price of 2 glasses and 3 pants is 700,000, and the price of 3 glasses and 1 pant is 700,000. Asked: what is the price if 1 glass and 2 pants?". Subsequently, Subject S1 proceeded with a step-by-step solution by representing glasses as x and pants as y. Subject S1 then formulated the mathematical model as $2x + 3y = 700{,}000$ and $3x + y = 700{,}000$. Next, Subject S1 eliminated the variable y to find the value of x, resulting in x being 200,000. Subject S1 then employed the substitution method to find the value of y, yielding y as 100,000. Subject S1 substituted the values of x and y into the core question equation $x + 2y =$ ...?. Finally, the subject made conclution that the price of 1 glass and 2 pants is 400,000.

Based on the answer from Subject S1, an interview was conducted as validation and investigation to understand how the subject approached solving the given problem.

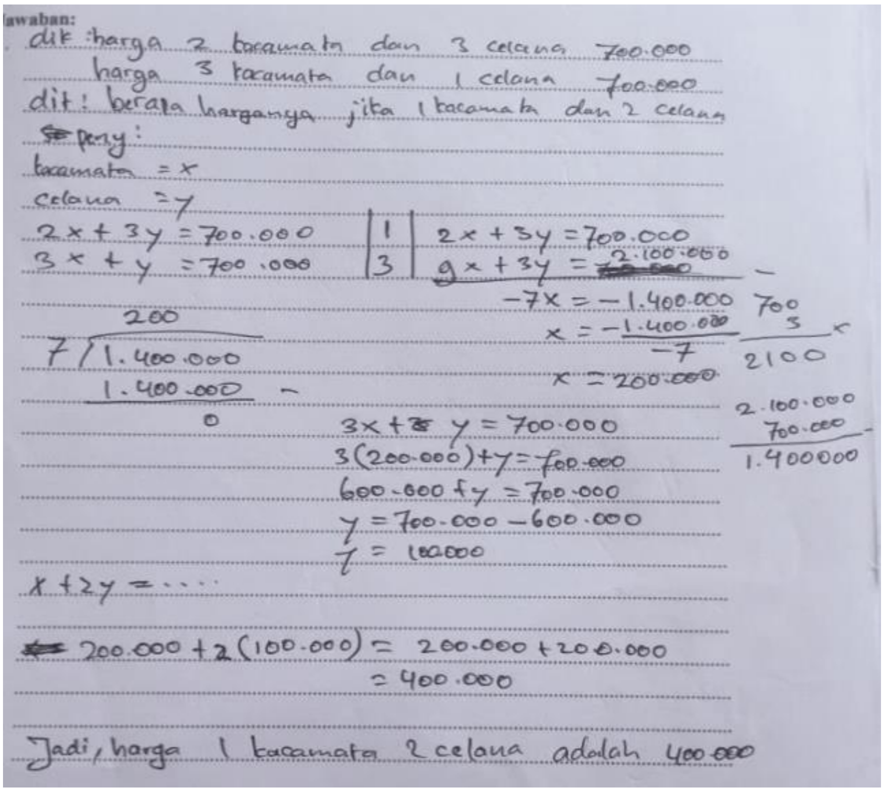


Fig. 1. S1's outcome of completing the task

Table 1. The interview results of subject S1

Q	Have you read the entire question? If so, is there any interesting information in it?
S1	Yes, the interesting information is that 2 glasses and 3 pants with the price 700,000, and 3 glasses and 1 pant with the price 700,000.
Q	Can you understand the question well?
S1	Yes. Understood sir.
Q	What comes to mind after reading the question?
S1	To finding the price, which is how much for 1 glasses and 2 pants.
Q	What are your steps or strategies to solve the problem?
S1	First, write down what is known and what is asked by the problem. Second, create an illustration, namely glasses are represented as x and pants as y. Third, write down the mathematical model. Fourth, proceed with the solution steps by first using elimination, then using substitution. Lastly, use substitution to find the price if 1 glass and 2 pants. The last, check the answer.
Q	Do you often solve problems like this one? If so, when?
S1	Yes, often. Whether given as assignments by the teacher or not, I often tackle problems like this. I enjoy working on practice exercises from textbooks, even without specific assignments from the teacher.
Q	How do you ensure that the results you obtained are correct?
S1	By checking the solution steps again and working on them using a different method, if the values are the same, then the answer is correct.

Based on the research data analysis result, it is shown that subject S1 with high visual ability is able to represent the problem well by writing down the known and asked elements. This is because during the process of analyzing the problem, the student is capable of capturing visual details with a high level of accuracy and efficiently recognizing and understanding visual patterns.

When planning the solution, Subject S1 with high visual ability rewrites the solution plan by writing an illustration and a mathematical model. Subsequently, Subject S1 proceeds with the solution steps using the elimination and substitution methods. Afterward, the subject writes a conclusion. When Subject S1 double-checks using a different solution method, he is able to find the same values or results. This indicates that Subject S1 has a good understanding of the concepts, recognizes the importance of verification, and possesses strong metacognitive skills in checking for accuracy [14].

3.2 Subject S2

The result of the mathematical problem-solving test for Subject S2 can be seen in Fig. 2.

Based on the Fig. 2, subject S2 immediately wrote down the mathematical model $2x + 3y = 700{,}000$ and $3x + y = 700{,}000$, and the subject proceeded with the solution steps by eliminating the variable y to find the value of x, resulting in the value of x is 200,000. Next, the subject employed the substitution method to find the value of y, resulting in y is 100,000.

Based on the answer from Subject S2, an interview was conducted as validation and investigation to understand how the subject approached solving the given problem.

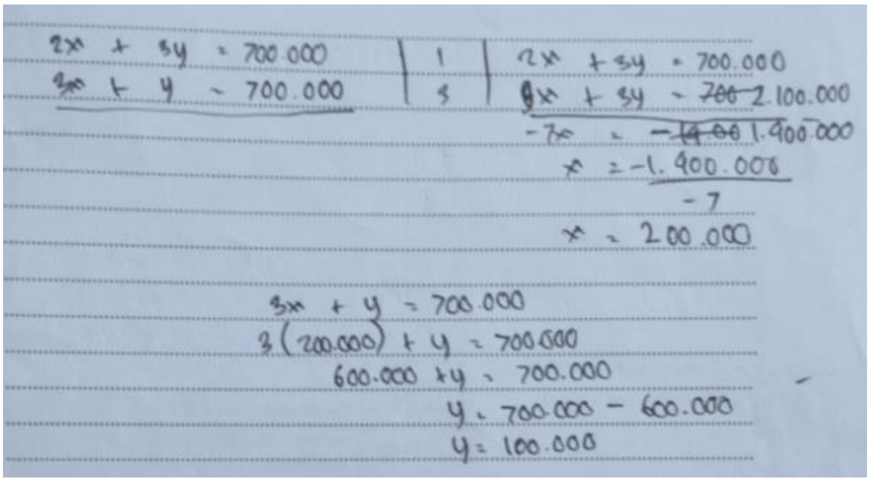


Fig. 2. S2's outcome of completing the task

Table 2. The interview results of subject S2

Q	Have you read the entire question? If so, is there any interesting information in it?
S2	Yes Sir, But there is noting interesting
Q	Can you understand the question well?
S2	Yes Sir.
Q	What comes to mind after reading the question?
S2	This problem can be solved using elimination and substitution.
Q	What are your steps or strategies to solve the problem?
S2	First, make the mathematical model, then solve the problem using elimination and substitution.
Q	Do you often solve problems like this one? If so, when?
S2	No Sir. I only work on assignments if given by the teacher
Q	How do you ensure that the results you obtained are correct?
S2	By paying attention to the substitution method and the result.

Based on the research data analysis result, it is shown that subject S2, with low visual ability, does not represent the problem, neither by writing down the known information, the questions, nor providing examples. Subject S2 immediately focuses on solving the problem. This indicates that Subject S2 lacks a strong understanding of visual concepts, meaning the ability to comprehend and represent information visually.

The lack of experience or practice in understanding and creating visual representations can limit Subject S2's ability to tackle problems involving visual aspects. Creating visual representations often involves creative elements. Insufficient creative skills or visual imagination can make it challenging for Subject S2 to produce accurate representations [15].

When Subject S2 goes through the steps of the solution process, Subject S2 can only find the values of variables x and y. The subject is unable to answer the question perfectly based on the core question of the problem, which is $x + 2y =$ ...?. Subject S2 also failed to perform a proper evaluation of correctness. This could be indicated by the lack of understanding of the concept of a system of linear equations with two variables, a lack of awareness of the importance of verification, a deficiency in skills or strategies to effectively test the accuracy of answers. This might result from a lack of skills in substitution, matching answers with initial conditions, or using other verification methods. Additionally, there is a deficiency in the metacognitive skills of the student. Awareness of thinking processes (metacognition) might be lacking, leading to a lack of realization of the importance of verifying answers. Furthermore, there is a lack of in-depth understanding or reflection on the problem-solving process.

For address this, it is crucial to develop a deeper understanding of the concepts, enhance metacognitive awareness, and provide training in verification skills for students. Involving students in a reflective problem-solving process can assist them in comprehending the significance of testing the accuracy of their answers. This research is expected to aid educators in constructing an understanding of the relationship between visual information processing and mathematical problem-solving abilities. By focusing on the visual aspect in the context of problem-solving, this study provides profound insights into how individuals with high and low visual abilities interact with mathematical challenges. Further research could explore various visual strategies employed by individuals with high visual abilities and how these strategies can be integrated into the learning context in the classroom [16,17].

4. CONCLUSION

The conclusion from these findings research is that the development of mathematical problem-solving skills requires attention to the visual aspects, especially in terms of conceptual understanding, visual representation, and verification skills. Students need to be encouraged to build strong mental images and be aware of the importance of critically verifying solution results. Therefore, strengthening the visual aspects is essential to enhance the effectiveness of mathematics learning. One of the major findings reported in this paper has been that the student tendency in using single visual representation by mathematical modeling.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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