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STUDENTS' MATHEMATICAL CREATIVE THINKING SKILLS IN SOLVING PISA PROBLEMS: A CASE IN INDONESIA

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ABSTRACT

This study analyzes students' creative thinking skills in solving PISA questions involving spatial and geometric content. A descriptive qualitative approach was used, selecting three groups of students based on mathematical ability: high, medium, and low. Data were collected through tests, interviews, and documentation. The test consisted of three PISA items designed to assess students' creative thinking indicators: fluency, flexibility, originality, and elaboration. The conclusions of this study show that students with high mathematical ability exhibit a high level of creative thinking, as evidenced by the fulfillment of all indicators: fluency, flexibility, elaboration, and originality. Students with moderate mathematical ability demonstrate limited or moderate creative thinking, fulfilling only the fluency and originality indicators, while elaboration and flexibility are not optimal. Students with low mathematical ability fulfill only the originality indicator, with low fluency and elaboration, and do not demonstrate flexibility.

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INTRODUCTION

Mathematics is a fundamental science that plays a significant role in education. Many daily activities involve mathematics, making it essential in life (Sutama et al., 2019). Additionally, mathematics teaches critical thinking, logic, reasoning, and creative thinking skills (Moma, 2015). It is not only related to abstract objects, calculations, and symbols but also shapes students' mindsets, enabling them to solve problems creatively, critically, logically, and precisely (Eviliasani et al., 2018). Mathematics is a tool for developing calculation skills and trains students to think critically and creatively.

Creativity is the mental ability to express new ideas smoothly and flexibly (Nurlaela et al., 2019). A person's creativity can motivate and guide them to create and produce something beneficial to others continually (Nurdiana & Caswita, 2023). Creativity results from a person's creative thinking. The ability to think creatively enables someone to produce new and innovative ideas, both as concepts and tangible work (Noviyana, 2017). Creative thinking skills in mathematics involve finding innovative solutions to complex and unstructured problems, which can help students tackle math problems more effectively. Creative thinking enables students to view issues from multiple perspectives, allowing them to develop diverse and adaptive solution strategies. Mathematical creative thinking is the ability to solve mathematical problems through structured thinking, logic, and relevant concepts, aiming to integrate key ideas in mathematics to yield more effective solutions (Sanders, 2016).

The outcomes of mathematics learning in identifying mathematical creative thinking skills can be measured through several aspects of the innovative thinking indicators themselves. The indicators used to assess students' mathematical creative thinking skills in problem-solving include four main indicators: fluency, flexibility, originality, and elaboration (Andiyana et al., 2018). Similarly, Dahlan (2016) explains that creative thinking skills can be assessed using four criteria: fluency, flexibility, originality, and elaboration.

One type of mathematics problem that requires creative thinking skills to solve is the PISA (Program for International Student Assessment) problem. PISA is an international evaluation organized by the Organization for Economic Co-operation and Development (OECD) to measure the abilities of 15-year-old students in reading, mathematics, and science. PISA mathematics questions assess students' ability to apply mathematical concepts to solve complex and unstructured real-world problems. These questions require students to think critically and creatively to find alternative solutions and connect multiple mathematical concepts within a single context. Mathematics in PISA includes mathematical reasoning and the ability to describe, explain, and predict phenomena using mathematical concepts, procedures, and tools (OECD, 2017).

Field observations show that students' creative thinking skills in mathematics are still relatively low. This is evident from the PISA survey results, which indicate that Indonesian students' mathematics performance remains below the international average. According to the 2018 PISA results published by the OECD, Indonesian students ranked 7th from the bottom (out of 73 countries) in mathematics, with an average score of 379 compared to the overall average score of 489 (Tohir, 2019). In the 2022 PISA results, Indonesian students scored 366 in mathematics, a decline compared to the 2015–2018 PISA assessments (Ahdiat, 2024). The low level of creative thinking skills is also reflected in research. Handayani et al., (2022) report that students continue to face difficulties in solving PISA questions. This aligns with research by Apriansyah and Ramdani (2018) which reveals that creative thinking ability in mathematics among Indonesian students remains low, with fewer than 50% demonstrating adequate skills.

This low level of ability highlights the need for improvements in teaching methods that emphasize the development of student creativity. Indonesian students' limited achievements in PISA mathematics are often attributed to a lack of practice with PISA-oriented problems (Zulaiha, 2019). Murtiyasa and Perwita (2020) also note that insufficient practice solving PISA questions contributes to Indonesian students' low performance. Thus, it is essential to conduct targeted training that emphasizes solving math problems aligned with PISA.

PISA mathematics includes four main content areas: Space and Shape, Change and Relationship, Quantity, and Probability/Uncertainty. This study focuses on the "space and shape" content, which covers concepts and skills related to traditional geometry, spatial visualization, measurement, and algebra (Handayani et al., 2018). This content was chosen because geometry requires creative thinking skills for effective problem-solving. Moreover, geometry is familiar to students, as it is taught at all educational levels, from elementary through high school.

Previous research that aligns with this study includes work by Handayani et al. (2018) in their article “Analysis of Mathematical Creative Thinking Ability of Junior High School Students in Solving 'PISA' Adoption Questions”. The results showed that 1 student was categorized as not creative, 22 students as less creative, 2 students as creative, and none as quite creative or very creative. Based on this prior research, the novelty of this study lies in analyzing the creative thinking abilities of high school students in solving PISA questions, specifically focusing on space and shape content while considering students' mathematical ability levels. This study aims to understand students' creative thinking abilities in solving PISA questions related to Space and Shape content, viewed concerning their mathematical skills, and to provide new insights into the relationship between these factors.

METHOD

This qualitative study uses a descriptive approach conducted at MAN 1 Lampung Selatan. The study involved three students from class XI.2, selected through purposive sampling based on their high, medium, and low mathematics abilities. Subject selection was based on students' math test scores, with one student chosen to represent each level of creative thinking ability within the class. Data were collected through tests, interviews, and documentation. Data analysis followed three stages: data reduction, data presentation, and conclusion drawing (Miles et al., 2014). Data reduction involved removing irrelevant information from the interviews. Data presentation systematically categorized and presented the research findings. Finally, drawing a conclusion allowed researchers to formulate conclusions based on the collected and analyzed data.

The test instruments included three PISA items focusing on Space and Shape content. Each question was designed to meet the indicators of students' mathematical creative thinking abilities. Researchers then analyzed students' answers to assess and describe their creative thinking abilities.

RESULT AND DISCUSSION

This study involved three students with high, medium, and low mathematical abilities from class XI.2 at MAN 1 Lampung Selatan. The students were given three PISA questions focused on Space and Shape content, each meeting the indicators of creative thinking: fluency, flexibility, originality, and elaboration. Below is the PISA questions used in the research:

Ice cream shop

Description: Here is the floor plan of Mery's ice cream shop. Mery plans to renovate her shop. The service area is surrounded by cashiers, as shown in Figure 1.

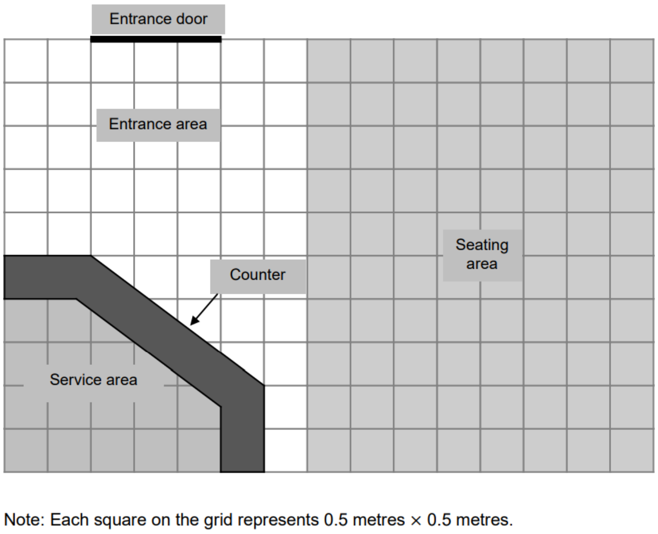

Figure 1. Floor Plan of Mery's Ice Cream Shop

Question:

1. Mery wants to install new edges along the outer edge of the counter. What is the total length of edging needed?
2. Mery will also install new flooring in her shop. What is the total floor area of the store, excluding the service area and the cash register? *(Try to solve this problem using at least two different methods).*

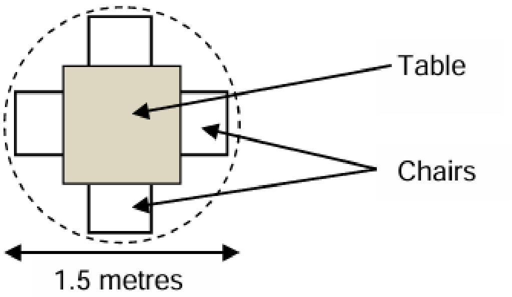

Figure 2. Seating Set

3. Mery wants to place a set of tables and four chairs (as shown in Figure 2) in her shop. Each circle represents the floor space required for one set. To ensure customers have enough space, each set should be positioned according to the following rules:
   – Each set should be at least 0.5 meters away from the wall.
   – Each set should be at least 0.5 meters away from other sets.

   What is the maximum number of sets Mery can fit into the seating area of her store source?

(Adaptated from OECD (2012))

Furthermore, the researcher will analyze the responses of the three subjects to determine whether they have met the indicators of creative thinking based on the answers and interviews conducted. Each subject will be discussed in detail: Subject 1 with high mathematical ability (S1), Subject 2 with moderate mathematical ability (S2), and Subject 3 with low mathematical ability (S3).

Analysis of S1's Answer

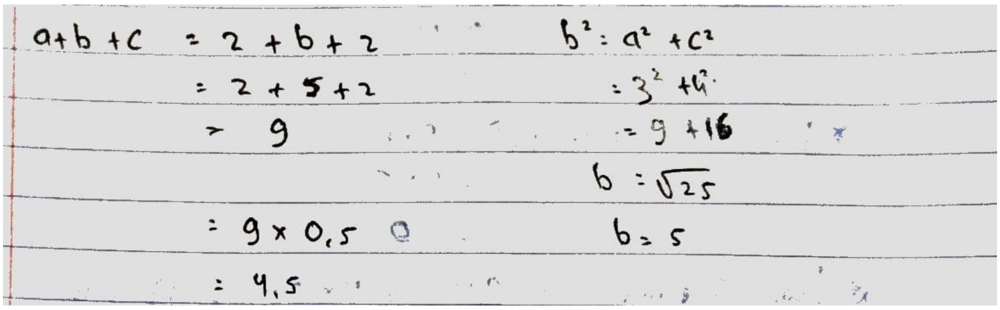

Figure 3. S1's answer no.1

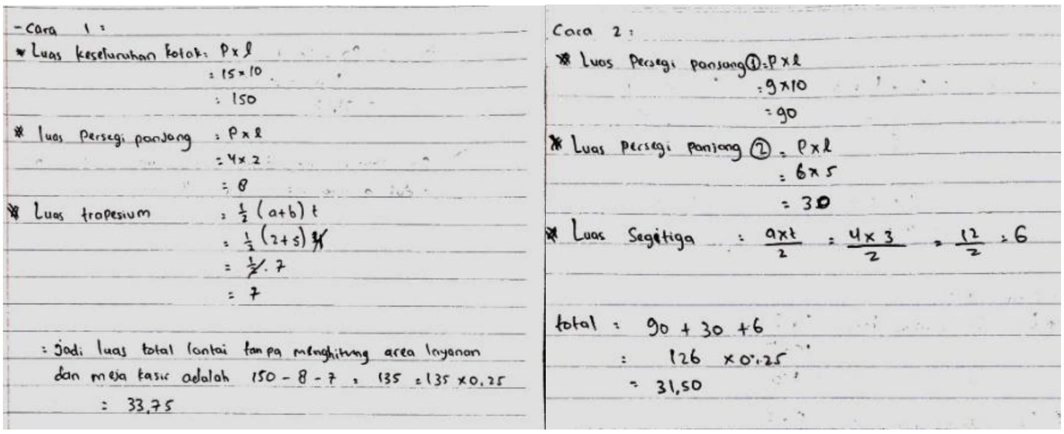

Figure 4. S1's answer no.2

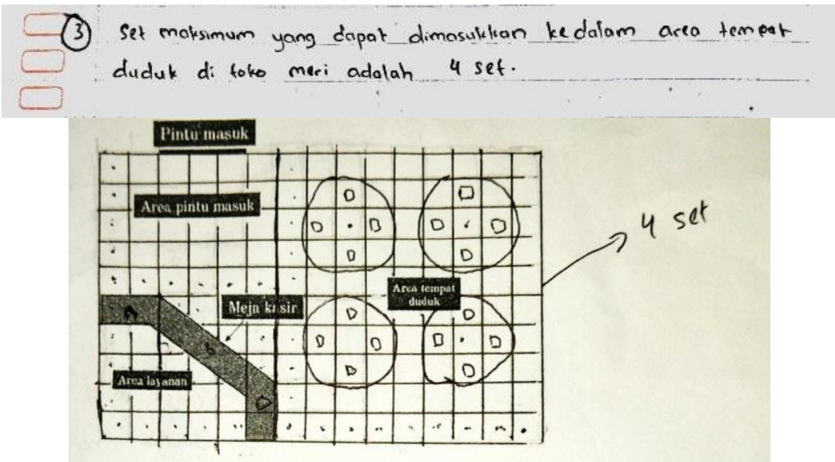

Figure 5. S1's answer no.3

Figures 3, 4, and 5 show the answers from S1, who has high mathematical ability. To analyze the subject's creative thinking skills, the researchers also conducted interviews to clarify responses to each question. This interview aimed to delve deeper into the subject's understanding, verify the accuracy of their thought process, and assess how well the subject applied the indicators of creative thinking in solving each problem. The following are the interview results between the Researcher (R) and S1.

R : *Based on the problems you've completed. Can you explain what is known and what the problem is asking?*
S1 : *Yes, I can. For problem number one, we were asked to find the length of the edge of the cashier's desk, which involves calculating the perimeter of the edge. The problem also states that each box represents 0.5 m x 0.5 m, so each box is a square with sides of 0.5 m.*
R : *For questions 2 and 3, do you understand what is being asked and what information you have from the problem?*
S1 : *For question 2, we are asked to find the total area, excluding the cashier's desk and service area. For question 3, we need to determine how many seating sets can be placed in the seating area, each consisting of one table and four chairs. Each set should be positioned at least 0.5 m from the wall and other sets.*
R : *Can you explain your answer to question 3 and the meaning of the drawing you made?*
S1 : *In question 3, we must determine how many sets can fit in the seating area. I concluded that four sets would fit because each set must be placed 0.5 m away from the wall and other sets, equivalent to the distance of one box. That's why I determined four sets, as shown in my drawing.*
R : *Do you think there are no errors in your answers, and everything is correct?*
S1 : *(Re-reading his answer) Oh, yes, I did make an error in question number 2, specifically in Method 1 for calculating the trapezoid area. I crossed out the numbers 2 and 4 but forgot to change the number 4 to 2, so the result should be 14, not 7.*
R : *That's correct. Why do you think you made that mistake?*
S1 : *I was in a hurry to finish because I was worried about running out of time.*

Based on S1's answers and the interview results, it can be concluded that S1 meets the fluency indicator because he can articulate the known information and what is being asked in the problem, even though he did not write it down on the answer sheet. S1's verbal response demonstrated a good understanding of the problem, thus fulfilling the fluency indicator. This aligns with research conducted by Setiawan et al. (2017) This found that students with high mathematical ability can comprehend the meaning of a problem well, even if they do not always write down the known information and the questions. During the interview, the students could explain the initial details using their own words.

S1 was able to solve the problem using more than one method, demonstrating flexible thinking skills. Although a minor error in the calculation in one of the methods affected the precision of the answer, S1 was able to recognize the mistake and explain it during the interview. The flexibility indicator has been met because the subject can consider various perspectives and use alternative methods in answering questions.

S1 solved each problem in detail, indicating a good understanding of the task. Despite minor calculation errors due to a lack of accuracy and urgency from fearing time would run out, the subject still provided thorough answers to each question. The interview results reinforced that the subject could explain the solutions clearly and in detail. Thus, S1 has fulfilled the elaboration (expansion) indicator of creative thinking through his ability to solve problems with detailed steps and explain the solution process. This demonstrates S1's understanding of the problem.

S1 creatively solved problem number 3 by visually drawing each set of tables and chairs to determine the maximum number of sets that could fit into the seating area. By sketching the layout and visualizing the position of each set, S1 considered the distances between the sets and from the wall according to the rules. This indicates that the subject can think initially, as he used the conventional calculation method and developed a unique visual approach to understand and solve the problems more effectively.

Based on the analysis, it can be concluded that S1, with high mathematical ability, also possesses high creative thinking ability. This is evident from the fulfillment of each creative thinking indicator: fluency, flexibility, elaboration, and originality. S1 can solve problems smoothly and systematically, use various methods to reach solutions, provide detailed and in-depth explanations, and demonstrate creative and original approaches to problem-solving. Therefore, S1's creative thinking ability can be categorized as high, as indicated by the achievement of each indicator. It aligns with research conducted by Damayanti and Sumardi (2018). This shows that students with high creative thinking skills can effectively fulfill the indicators of fluency, flexibility, and originality indicators. Additionally, a research by Sutama, Sofia, and Novitasari (2019) supports these findings, indicating that male and female students with high mathematical abilities can optimally fulfill all indicators of creative thinking in problem-solving.

S2 Answer Analysis

Figures 6, 7, and 8 are S2's answers. The answers were analyzed based on the written responses and interviews to clarify the information that had been submitted. This analysis assesses whether each indicator of S2's creative thinking ability is met. The following are the results of the researcher's interview (R) with S2.

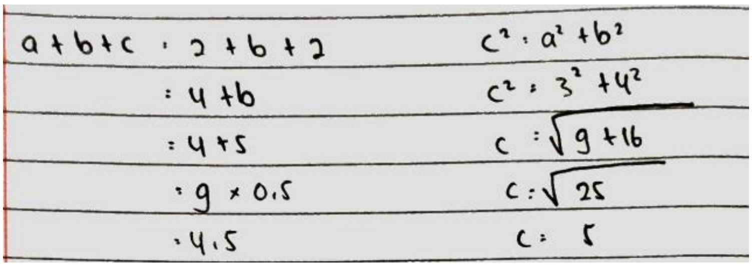

Figure 6. S2’s answer no.1

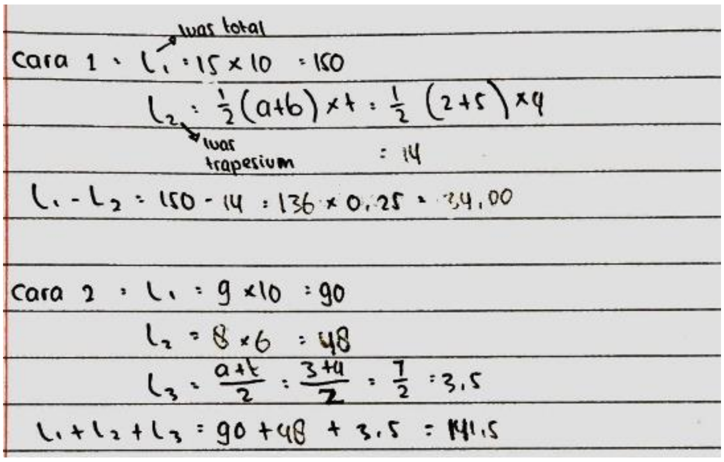

Figure 7. S2's answer no.2

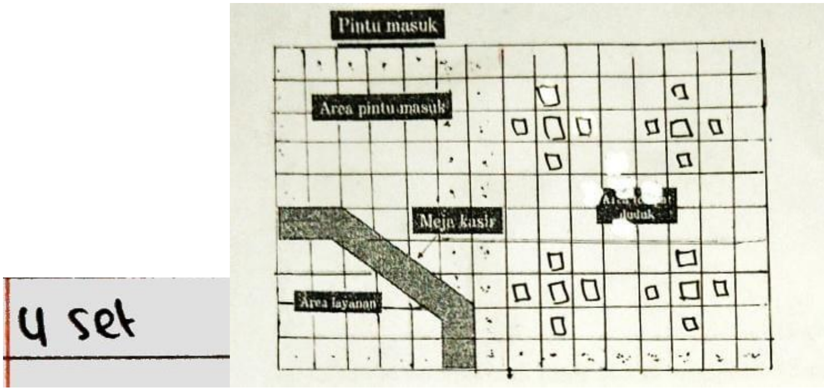

Figure 8. S2's answer no.3

R : *Can you explain what information is known in each problem and what is being asked?*

S2 : *I can. In problem number 1, we are told to find the edge of the cashier's desk. In problem number 2, we are told to find the area, but the cashier's desk and the service area are also included. In problem number 3, we are asked to determine how many sets can be made in the seating area. We know from the question that each box is 0.5 m x 0.5 m, and in question number 3, each set must be 0.5 m from the wall and other sets.*

R : *For the solution step, can you explain how you solved problem number 2?*

S2 : *Here, I solved it in two ways, but I haven't finished yet, and I still don't understand. First, I found the total area of the picture, but because I was confused, I immediately subtracted the area of the trapezoid-shaped part 2 from the total area.*

R : *To get the trapezoidal shape, you can't just take one part; you have to divide it into rectangles first.*

S2 : *I'm confused, Kak. I don't understand how to divide the picture so that it can be calculated. Method 2 is also like that; it's also not finished.*

R : *Okay, for question number 3, can you explain the results of your answer?*

S2 : *For number 3, I made boxes with 4 chairs and 1 table in the middle because it is a set. I made as many sets as possible while keeping them 0.5 m, or one box, from the wall and the other sets, so I got 4 sets.*

Based on the analysis of written answers and interviews with S2, it can be seen that S2 has fulfilled the fluency indicator in creative thinking. Although S2 did not directly write all the known and requested information on the answer sheet, he could explain it well during the interview. In answer number 1, the subject has provided complete and correct answers and explanations. His ability to provide a clear and relevant explanation to the question shows that S2 has met the criteria for fluency in mathematical creative thinking.

The flexibility indicator in S2 has not been sufficiently fulfilled because the subject has been unable to solve the problem in more than one correct way. Although S2 wrote two methods for solving the problem on the answer sheet, both answers were incorrect. The interview results also support this, as the subject admitted that he still has difficulty and is confused about solving the problem. This is in line with research conducted by Hanipah et al., (2018) This showed that some students can understand the problem and estimate the right solution and plan. However, when facing difficulties in implementing the plan, they tend to give up easily and are less thorough in evaluating their answers.

The elaboration indicator in S2 has not been maximally fulfilled. Based on the analysis of written answers, reinforced by the results of interviews, the subject is still unable to provide detailed and structured answers. This can be seen from the answer to question number 2, where the subject did not write the solution with clear and thorough information. Likewise, when interviewed, the subject could still not optimally explain the answers he had written. The explanation given was less in-depth and did not clarify the steps taken to solve the problem, indicating that the subject had not fully understood or been able to elaborate on the answer well.

In the originality indicator, S2 shows the ability to think creatively by using unusual and innovative visual methods to solve problems. This can be seen in the response to problem number 3, where S2 uses a visual approach, drawing to solve the problem and reach the answer. This approach shows originality in thinking and different methods.

Based on the analysis of written answers and interview results, it can be concluded that students with moderate mathematical ability also possess creative thinking skills that fall within the mild category. This is evident from the fulfillment of several indicators of innovative thinking. S2 managed to fulfill the indicators of fluency and originality well. However, the indicators of elaboration and flexibility were not fully met, which is why his creative thinking ability is still classified at a moderate level. This finding is consistent with research conducted by Prihastuti and Utami (2021). Students with moderate creative thinking skills can generally effectively fulfill the fluency and originality indicators.

However, the indicators of flexibility and elaboration still demonstrate less-than-optimal abilities, remaining at a moderate level.

S3 Answer Analysis

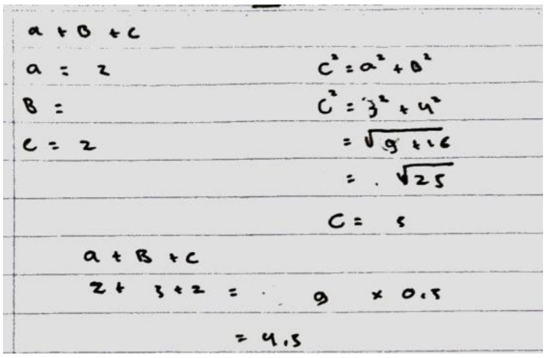

Figure 9. S3's answer no.1

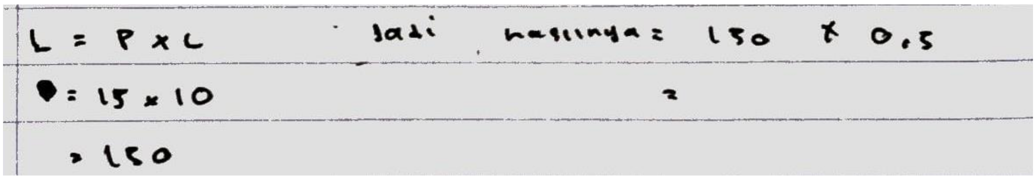

Figure 10. S3's answer no.2

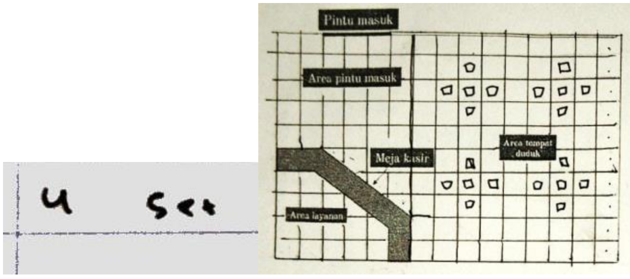

Figure 11. S3's answer no.3

Figures 9, 10, and 11 are the answers provided by S3, a student with low mathematical ability. These answers will be analyzed alongside the results of interviews conducted with S3 to clarify the responses on the answer sheet. The following are the results of the interviews with S3 to gain a deeper understanding of the answers given.

R : *Can you explain the known and unknown information in the problems you have solved?*

S3 : *For number 1, we are asked to find the length of the edge of the cashier's desk. In number 2, we have to calculate the total area, but some parts don't need to be included. As for number 3, we are asked to calculate the number of sets of tables and chairs, each consisting of 4 chairs and 1 table in the seating area. Each set must not touch the wall.*

R : *Can you explain your answer to number 2 in more detail?*

S3 : *For number 2, I don't understand, sis. I can't find a way to solve it.*

R : *What about number 3?*

S3 : *For number 3, I had to calculate the number of sets that could be placed in the seating area. I solved it by estimating the number of sets, then drawing to make it more transparent, and finally, I found that 4 sets could be placed there, sis.*

Based on the results of the written answers and interviews, it can be said that the fluency indicator has been somewhat fulfilled. S3 can convey the known and requested information, even though it is not written on the answer sheet. During the interview, S3 managed to explain the meaning of each problem. However, S3 is still unable to answer the questions correctly, particularly regarding question number 2, which remains unresolved. This indicates that, although the subject has a basic understanding, the ability to apply and complete the problem is still lacking.

For the flexibility indicator, S3 has not been able to fulfill it. This is due to his inability to provide solutions using multiple methods; even the answer in one process is incorrect. This limitation suggests that S3 is not flexible enough in finding alternative solutions to the given problems. Regarding the elaboration indicator, S3 has not fully met the criteria. The subject has been unable to provide a detailed explanation, and the steps taken to reach a solution still contain many errors. Problem-solving was done briefly without giving an in-depth or detailed explanation of the thought process involved. This shows that the subject has been unable to articulate the answer to reach the correct solution.

S3 has demonstrated creative thinking skills for the originality indicator by solving problems using unusual and innovative methods. This is evident in answer number 3, which is also supported through the interviews. In this problem, S3 employs visual images in boxes to represent tables and chairs, then calculates the distance between sets using a creative approach that differs from the typical answers provided. This visual strategy illustrates S3's originality in thinking.

Based on the analysis above, it can be concluded that S3, who has low mathematical ability, also exhibits limited creative thinking ability. S3 only managed to fulfill the originality indicator effectively. However, the indicators of fluency and elaboration are still not fully met, placing S3 in a low category. Meanwhile, the flexibility indicator has not been met, indicating limitations in providing alternative solutions or various problem-solving approaches. Research by Kadir et al. (2022) shows that students in the low category can solve problems but often use methods that yield incorrect answers. Some students do not provide solutions to specific issues. Students in this category generally fulfill only one indicator of creative thinking, highlighting limitations in their ability to solve problems creatively and effectively. This aligns with research conducted by Setiawan et al. (2017), which indicates that students with low mathematical ability can develop ideas or thoughts to solve problems but struggle to generate new ideas or utilize different approaches.

Based on the analysis conducted on the written answers and interview results of the three subjects with high, medium, and low mathematical ability, it can be concluded that a significant relationship exists between mathematical ability and students' creative thinking ability. Previous research analyzing students' creative thinking ability in solving PISA problems based on mathematical ability is still limited. Most studies examine students' creative thinking ability from the perspective of learning achievement. The results indicate that studies analyzing the relationship between learning achievement and mathematical ability yield different conclusions. A research conducted by Nurdiana and Caswita (2024) shows that creative thinking ability is not significantly related to learning achievement; for instance, students who rank one exhibit moderate creative thinking ability, students who rank two display low creative thinking ability, and students who rank three demonstrate high creative thinking ability.

CONCLUSION

Based on the analysis of the written answers and interview results of the three subjects with high, medium, and low mathematical ability, it indicates a significant relationship exists between mathematical ability and students' creative thinking ability.

The findings reveal a strong correlation between mathematical ability and creative thinking. Students with high mathematical ability demonstrate advanced creative thinking by meeting all indicators—fluency, flexibility, elaboration, and originality—through systematic and original problem-solving. Those with moderate mathematical ability exhibit moderate creative thinking, fulfilling fluency and originality but showing gaps in elaboration and flexibility, with limited detail and alternative approaches. Students with low mathematical ability display limited creative thinking, meeting only originality and struggling with fluency, elaboration, and flexibility. Overall, higher mathematical ability aligns with more comprehensive creative thinking skills.

Overall, the results of this analysis confirm the importance of creative thinking skills in learning mathematics. This study suggests that improving students' mathematical ability enhances their academic performance and positively impacts their creative thinking skills. Therefore, providing students with more practice on PISA-style problems is essential, as these often require creative thinking skills to find practical solutions. This approach can help prepare students to tackle complex challenges in both educational settings and everyday life.

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