Strategic flexibility and performance of students in solving open problems

R. RAMADHONA, MANUHARAWATI, A. WINTARTI

ABSTRACT

Introduction. Strategic flexibility is a person's ability to utilize several strategies, switch to other strategies, and use strategies appropriately to get an appropriate solution. Strategic flexibility requires a person to think outside the box, thereby improving critical and creative thinking skills. This is very important, especially in fields that require innovation. In today's rapidly changing world, characterized by technological advances, strategic flexibility is essential to adapt to unforeseen circumstances, and ensure competitiveness in both personal and professional contexts. So that someone with high strategic flexibility is able to take advantage of emerging opportunities with agility and confidence. *This study aims* to see the relationship between performance and students' strategic flexibility in solving open-ended mathematical problems.

Material and methods. This research is qualitative research, with 72 participants from two universities in East Java, Indonesia. While the research sample consisted of 13 people, seven students from UNESA and six from UMM. The instrument used was an open mathematical task. Participants' answers were analyzed descriptively qualitatively based on strategic flexibility indicators. Then categorize the mistakes they made. To determine the significant relationship between the level of strategic flexibility and performance, Chi-squared test was used.

Results. The findings of this study suggested that students with low performance did not propose strategies and could not produce solutions. Therefore, these students were categorized into the non-flexible category. If given the order to re-understand the problem presented, students with basic performance could produce several strategies and switch to another strategy when the first strategy did not find a solution. In addition, students with high performance and moderately flexible could not propose a unique strategy. However, students with high performance who were very flexible could propose and produce a unique strategy and solution. A significant relationship existed between performance and students' strategic flexibility in solving open mathematical problems with p value of Chi-Squared test was found to be 0.006 which is smaller than 0.05.

Conclusion. This research was found that high ability students produced several unique strategies. So this unique strategy can be added as an indicator of strategic flexibility. Apart from that, it can be used to see students' strategic flexibility based on differences in learning styles, gender and difficulty of task.

KEYWORDS

performance, solving problem, strategic flexibility

For Citation: Ramadhona, R., Manuharawati, & Wintarti, S. (2025). Strategic flexibility and performance of students in solving open problems. *Perspektivy nauki i obrazovania = Perspectives of Science and Education*, (3), 170–182. https://doi.org/10.32744/pse.2025.3.11

Received: 11 December 2024 | Approved: 22 February 2025 | Published: 30 June 2025

INTRODUCTION

One of UNESCO's main focuses is ensuring that teachers around the world have the skills, knowledge and support they need to provide quality education. The main emphasis of UNESCO's strategy is to support teachers in achieving quality learning [1]. Additionally, UNESCO focuses on open and distance learning dialogue, digital transformation, accreditation, student mobility and quality assurance issues [2]. Therefore, as a pre-service teacher, we must have many strategies and think flexibly in learning.

Problems can be encountered anywhere, whether at school, in the work environment, or everyday life. In solving mathematical problems, strategies that can be used include heuristic approaches, algorithms and problem solving schemes [3]. A skilled problem solver must know several strategies as well as the ability to evaluate the strengths and weaknesses of each strategy according to different problem characteristics [4]. Moreover, a flexible person can switch strategies from the latter fluently and use another strategy that is more appropriate for solving the problem [5].

Strategic flexibility is a person’s ability to utilize several strategies, switch to other strategies, and use strategies correctly to get the right solutions. It is consistent with what Ru-De et al said that strategic flexibility is the ability to use multiple strategies and change strategies flexibly according to the problem [4]. In line with that Hüseyin et al. said, strategic flexibility includes not only knowledge and use of strategies, but also awareness of which strategies will be effective in a particular situation [6].

Successful performance depends on accuracy in choosing a strategy. Using strategies flexibly can help individuals solve problems quickly and accurately [7]. In other words, the level of performance in solving problems is related to the strategic flexibility. This is in line with what is suggested by Carlos and Irene that prospective teachers with very flexible categories make fewer mistakes in solving problems than those in other categories [8]. Therefore, students' strategic flexibility in solving problems needs to be increased. One way to do this is to give tasks with multiple answers or solutions.

An open problem is defined to have several different solutions [9]. It provides opportunities and stimulation for students to explore various solutions, methods, or strategies [10]. Flexibility can be improved by solving non-routine problems and considering several approaches commonly used in solving routine problems [10; 11]. Only open-ended problems are considered suitable for developing the reasoning skills required by students [13]. Therefore, open mathematics problems were designed in this study to provide opportunities for students to develop their abilities in determining problem-solving strategies. Through open problems, teachers can facilitate the strategic flexibility possessed by their students.

Research has been carried out regarding flexibility. Seher and Ramazan found that prospective elementary school mathematics teachers have the ability to use problem-solving strategies, but the use of different strategies was found to be rather limited [14]. Meanwhile, Mehmet et al. show that prospective mathematics teachers use guess and check strategies to solve problems in the form of story problems [15]. Moreover, a strategy that students rarely use in solving problems is forming equations [16]. Students solve combinatorial problems by listing possible arrangements, using formulas, and filling in the places [17]. Lisa et al. investigated students' flexibility in adding whole numbers [18]. Marian also investigated practical and potential aspects of student flexibility in subtracting multi-digit numbers [19]. Star et al. explored the flexibility of students from three countries in solving linear equation problems [20]. Lastly, Arnal investigated the flexibility of teachers who take part in training in calculating the area of an area [21].

Lieven said that strategic flexibility is recognized as an important construct in mathematics education research and practice [22]. Additionally, Jon et al. also suggested exploring differences in flexibility within and between countries that differ in educational systems, teaching practices, and/or cultural norms [20]. Therefore, strategic flexibility is a relevant area to research. This study explores the relationship between student performance and strategic flexibility when solving open problems. This is an important issue that can contribute to providing insight into flexible thinking in problem-solving. Specifically, the research questions (RQ) are:

RQ 1: what is the students’ levels of performance in solving open problems?

RQ 2: what is the students’ levels of strategic flexibility in solving open problems?

RQ 3: is there significant correlation between performance and strategic flexibility students in solving open problems?

LITERATURE REVIEW

Strategic Flexibility

Flexibility is very necessary in solving problems and finding the right solution. This means that flexibility is needed to know several strategies and choose the best strategy for a particular problem [22; 24]. Taliha and Yeliz also said that flexibility is a person's skill to change his or her behaviour when facing changing situations [16]. This is also in line with Krems in Iliada et al. who state that flexibility is a person's ability to adapt his problem-solving skills when tasks are modified [26]. Therefore, flexibility is a person's ability to change his or her behaviour according to the situation.

Some researchers call mathematical flexibility the ability to generate different strategies and choose the most appropriate strategy for a particular mathematical problem [20; 26]. Furthermore, Lieven defined strategic flexibility as knowledge about various strategies and the tendency to choose the most appropriate strategy [22]. Hüseyin et al. said that strategic flexibility includes knowledge and use of strategies and awareness of which strategies will be effective in a situation [6]. Correspondingly, Ru-De et al. said that strategic flexibility is the ability to use several strategies and change strategies flexibly according to problems [4]. A flexible problem solver must know various strategies and know which strategies are more efficient than others under certain circumstances [25]. Therefore, it can be concluded that strategy is the ability to use various strategies and adapt strategies to face changes quickly and precisely.

There are three phases in the flexibility assessment. First, participants are asked to solve the questions as quickly and accurately as possible. Second, participants will re-solve questions that have been solved previously using as many different methods as possible. Lastly, they will evaluate the methods created previously and choose which method is the best [28]. Cigdem and Yeliz used four criteria to see strategic flexibility: selecting and using the most appropriate strategy, changing strategies when it is not successful in solving a problem, using various strategies to solve a problem, and changing strategies between problems [11]. Furthermore, Taliha and Yeliz utilized four indicators to see strategic flexibility in solving a problem, namely switching strategies when it does not work, trying to solve the problem again after being successful with a different strategy, being able to use several strategies simultaneously to solve the problem, checking the correctness of the solution with different strategies [29]. Based on the assessment methods that previous researchers have used, it appears that the indicators used to view strategic flexibility by Taliha and Yeliz are more transparent and measurable, and so were used in the present study. Then, to determine the level of strategic flexibility in solving open problems, the levels of flexibility by Carlos and Irene [8] was adapted. These levels are as follows:

- Non-flexible. If students proposed one standard strategy and the correct solution
- Moderately flexible. If students proposed two or more different standard strategies and correct solutions
- Very flexible. If students propose two or more different unique strategies and correct solutions

Mathematical Open Problems

A problem is a situation that every living creature encounters continuously as long as it is alive. Stephen and Jesse said that a problem is a situation, whether quantitative or not, faced by an individual or group of individuals that requires a solution, and the individual does not see a clear path to the solution [30]. Everyone has different problems and has their own way of solving them. A problem can be solved by an individual if he or she wants to find a solution, improvise, and develop the initiative to find a solution [16]. It can be said that a problem is a situation that requires someone to find a solution using various strategies.

Pehkonen classified problems based on the initial situation and final goal situation into four categories, namely:

1. Problems start from a closed situation, and the goal situation is also closed. This problem is often called a closed problem, namely a problem that is clearly formulated, and the data to solve it are also clear.
2. Problems that start from an open situation and end with a closed goal situation are often called open-start problems. Each type of problem is emphasized differently, but the final solution is always one.
3. Problems that start from a closed situation, and the goal situation is open. This problem has different ways and solutions to solve the problem, or is known as an open-ended problem.
4. Problems that start from an open situation and the goal situation are open. This problem emphasizes that students can develop new problems based on the initial problems given.

Based on the problem classification, the problem is open if the initial and/or goal situations are open [31]. Therefore, from the four types of problems mentioned above, there are three open problems.

An open problem means a question that cannot be answered simply by "yes", "no", or "do not know", thereby allowing for spontaneous and unstructured responses [32]. Open problems are designed so that there may be more than one correct answer or more than one way to get an answer [33]. Therefore, the open problem referred to in this research is a mathematical situation designed to have many ways or strategies to solve it and has different solutions.

Munroe said that open problems aim to enable students at various levels in the class to solve problems based on their abilities, experience, and understanding of the problems given [33]. Aleksandra and Mirko also said that the benefit of providing open problems in lessons is that each student can uniquely answer their problems, and students participate more actively in the lesson by expressing their ideas [34]. Therefore, it can be concluded that the benefit of open problems is that they can help students develop their potential in applying various problem-solving strategies to get solutions to the problems given.

Students' Problem-Solving Performance

To see student performance or strategic competency, Yasemin and Tenzin divide into three levels based on the ability to design strategies and then implement these strategies without errors to obtain the correct solution [35]. In this study, the levels of performance by Carlos and Irene were adapted. The levels include:

- Performance is low: when participants propose at least one solution but there are errors, they do not get the right solution.
- Performance is basic: when the participant does not make errors to get a valid strategy, but there is containing a mathematical error at solution.
- Performance is high: when the participant makes no errors to get a satetegy and correct of the solutions.

MATERIALS AND METHODS

Participants

This research was conducted at two universities in East Java, Indonesia. The participants were 42 students from Universitas Negeri Surabaya (UNESA) and 30 students from Universitas Muhammadiyah Malang (UMM). The research sample was selected utilizing simple random sampling. Furthermore, thirteen selected students were active mathematics education study program students, consisting of seven students from UNESA and six from UMM. Furthermore, the participants had already studied geometry and passed a minimum of 21 credits.

Instrument

In this study, an open problem-solving task was designed, which was validated by two experts of mathematics education. The validation results show that the designed task could be utilized to exploring strategic flexibility data in solving open problems. The open problem-solving task and solution alternate can be seen in Figure 1.

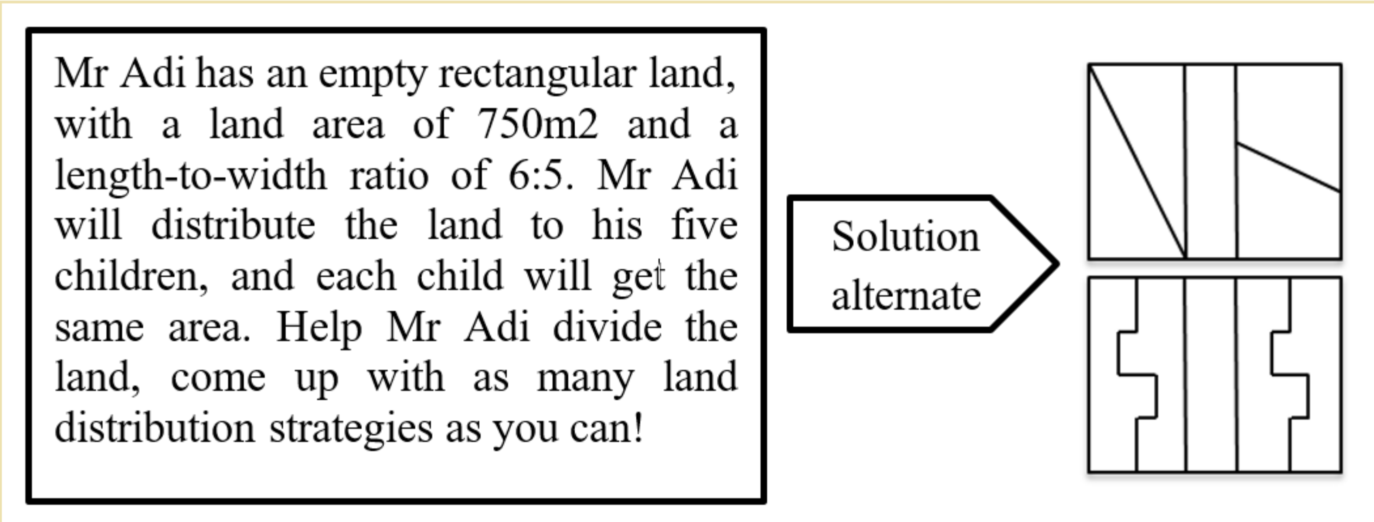


Figure 1 Open Problem-Solving Tasks

Data Collection

The data collection procedure began by giving an open problem-solving task to the 13 participants, after which an interview was conducted based on the results of the task that had been obtained.

Data Analysis

To answer RQ 1 and RQ 2, descriptive analysis was conducted. To study the participants' performance, their works were consulted and the errors they made were categorized. To study strategic flexibility, the indicators of strategic flexibility were analyzed and the strategies proposed by the participants were categorized. To answer RQ 3 whether there is a significant relationship between the level of strategic flexibility and performance, Chi-square test was used $\chi^2=\Sigma[(O_i-E_i)^2/E_i]$, and its power was measured utilizing Spearman's rank correlation coefficient, with the help of the Minitab application.

RESULTS

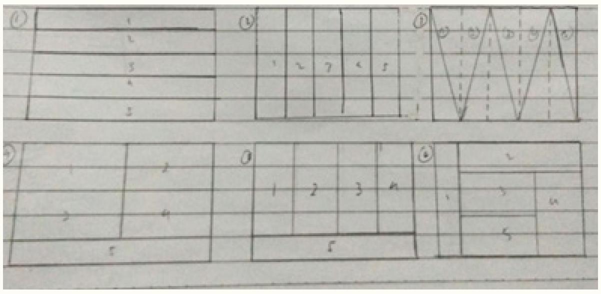
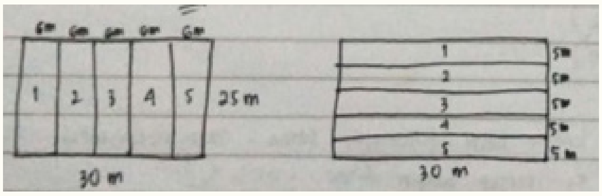
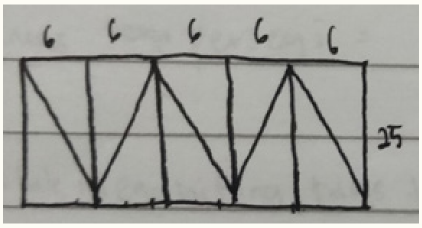
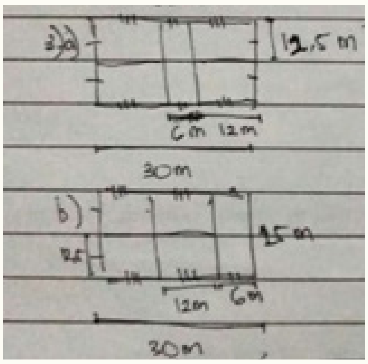
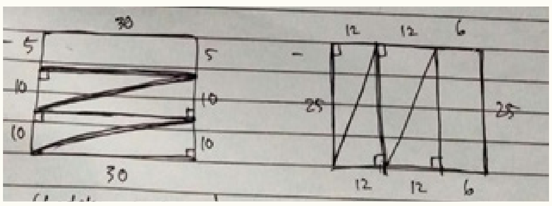
Answering the research questions that have been formulated, the research results are divided into three parts.

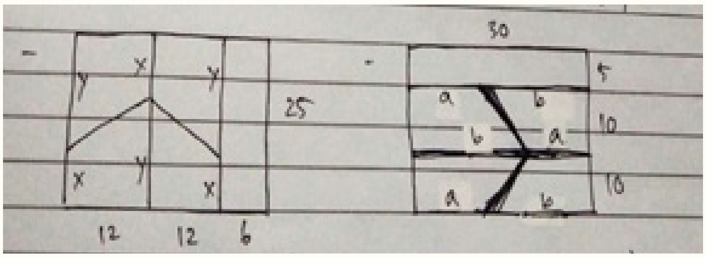
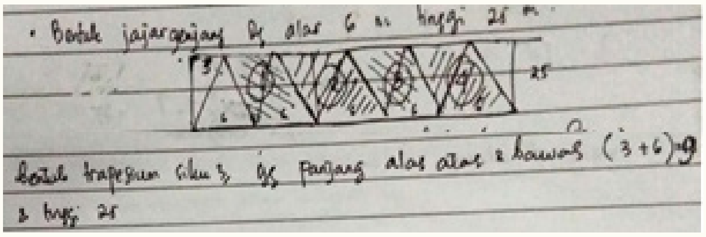
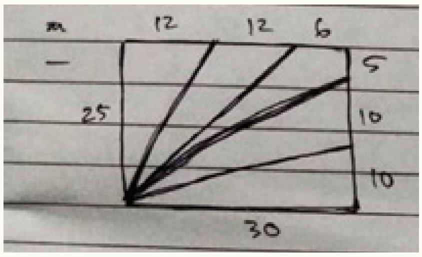
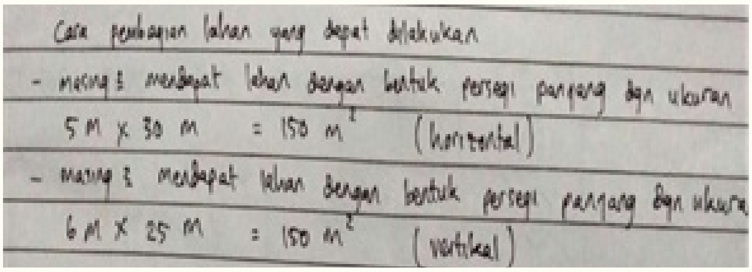
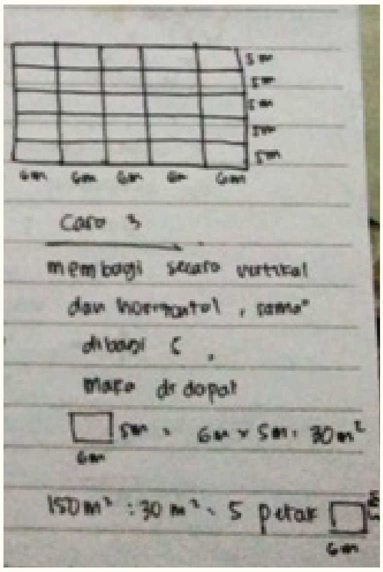
Students' performance in solving open problems

In terms of performance, the study analyzed the strategies used to get the solution and the errors made to get the solution. From the 13 participants, there were 58 participant-generated strategies. Strategies that produce wrong solutions were 4, while those that produce correct solutions were 54. The strategies used can be grouped as shown in Table 1.

Table 1

Description of Strategy

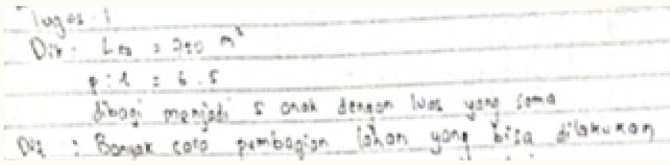
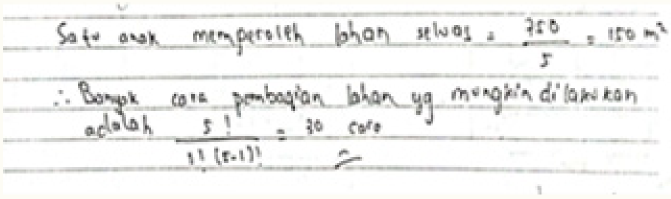
Strategy Code	Description	Example
Pictures (P)	Dividing the land by making pictures without measurements	
Pictures and Numbers (PN)	Divide the land into rectangles of the same size	
	Divide the land into triangles of the same size	
	Divide the land into rectangular shapes but different sizes	
	Divide land into rectangular and triangular shapes, along with their dimensions	

	Divide land into rectangular and trapezoidal shapes, along with their dimensions	
	Divide land into parallelograms, right triangles and right trapezoids, along with their dimensions	
	Divide the land uniquely	
Verbal and Calculation (VC)	Explained the distribution of land in words and using the formula of area	
Pictures and Verbal (PV)	Explained land division with pictures followed by words	
Invalid Strategy (I)	Incorrectly identifying concepts, creating incorrect images, and strategy	Using formula of combination

Errors made by the participants in finding solutions were divided into three, namely conceptual errors, procedural errors, and final solution errors. A description of the types of errors can be seen in Table 2.

Table 2

Description of types of errors

Type of error	Description	Example
Conceptual errors	Participants incorrectly identified the thing asked in the problem;	
	participants used the wrong concept	
Procedural errors	Participants made mistakes in using the formula	
Final solution errors	The final solution obtained by the participant was incorrect	Known: Area (L) = $750m^2$ Length width ratio (p:l) = 6:5 Divided among five children equally Asked: There are many ways to divide land Answer: Each child gets an area of land 750/5 = 150 There are many possible ways to divide the land 5!/1!(5-1)! = 30 ways

Based on the strategy analysis and mistakes, one participant (0.08%) had a low-performance level and misunderstood the concept, so the solution was also wrong. Three participants (0.23%) had a basic performance level and made mistakes in identifying, but the final solution obtained was correct. Meanwhile, nine participants (0.69%) had high performance levels and made no mistakes in finding solutions.

Students' strategic flexibility in solving problems

In terms of the strategic flexibility, the findings were analyzed based on the indicators of strategic flexibility:

1. *Switch strategy when it does not work*

Three participants (0.23%) changed their strategy after realizing the mistakes they had made. As an example, the subject understood the problem, starting by rewriting important information from the problem presented. However, the participants did not realize that the task asked not how many ways to divide but how to divide the land. Consequently, the participant used a combination formula to determine the number of ways of division. Then, the researchers interviewed the participant and tried to give the participants instructions for reading and understanding the problem again.

After being given more time to read, understand, and complete it, the participants realized his mistake. Then, they tried to determine how to divide the land, as seen in Figure 2. The subject divided the area of 750 by 5 to determine the area of land obtained by one child, so that $150m^2$ was obtained. After that, the participant describes the form of land division by dividing horizontally and vertically with the same size for each child.

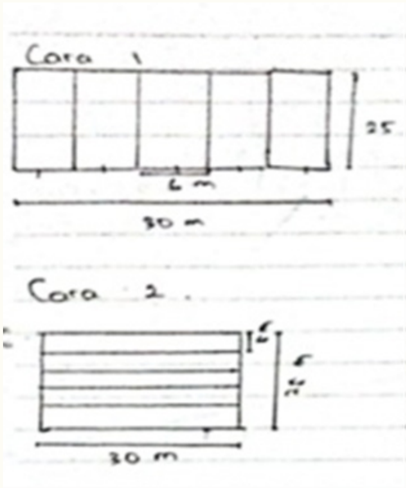


Figure 2 Example of one participant's strategy

Based on the data above, it can be seen that the participant tried to change his strategy after realizing that the solution obtained was incorrect. By trying another strategy, the particpant got the correct solution.

2. Solving the problem again with a different strategy

After succeeding in getting a solution, the participant tried to divide the land with different sizes obtained by the child and changed the position, but the area obtained for each child remained the same, as shown in Figure 3. There were 12 (0.92%) participants who solve the problem again with a different strategy.

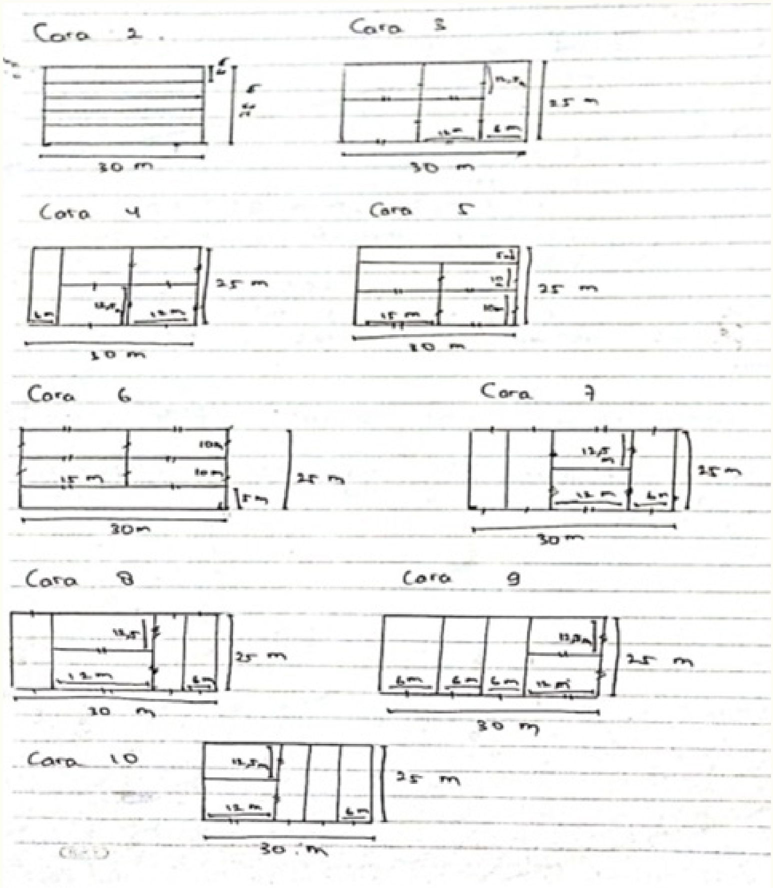


Figure 3 Another way of dividing land

3. Using several strategies simultaneously for solving a problem

Based on the analysis of the students' strategy (Table 1), it can be seen that the participants described the form of land division, which was accompanied by the length and width measurements obtained by each child. This shows that the participants used two strategies simultaneously to solve the problem, namely pictures and numbers, verbal and number, pictures and verbal. Ten (0.77%) participants used two strategies simultaneously.

4. Checking the correctness of the solution with a different strategy

LMS (one of participant) ensures that the solution obtained was already correct by using the concept of the area of a flat shape by multiplying the length and width of the land so that the area obtained remains the same, namely 150m2. This can be seen when LMS explained every method made. LMS always stated that " if it multiplies, the result is the same as 150." This can also be seen from the researcher's interview with LMS when asked whether the solution he made was correct or not, as seen in the follouwing excerpt:

R: How are you sure that this picture is all true?

LMS: By ensuring that the sizes created when multiplied are correct 150 and a total of 750

Therefore, the LMS checked the correctness of the solution obtained by carrying out mathematical calculations, namely ensuring that the measurements obtained by each child produced the same area. There were 10 participants (0.77%) who checked the solutions they had obtained with another strategy.

Regarding the level of strategic flexibility, it was found that one (0.08%) of the participants demonstrated non-flexible, nine (0.69%) of the participants demonstrated moderatly flexible, and three (0.23%) of the participants demonstrated very flexible strategic flexibility.

The relationship between strategic flexibility and student performance

The distribution of participants is based on the level of strategic flexibility and performance in solving open mathematical problems, which can be seen in Table 3.

Table 3

Distribution of students performance based on strategic flexibility

Performance level	Strategic Flexibility level		
	Non-flexible	Moderately flexible	Very flexible
Low	1 (0.077%)	0	0
Basic	0	3 (0.23%)	0
High	0	6 (0.46%)	3 (0.23%)

From Table 3, it can be seen that one (0.077%) Low participant level was included in the non-flexible category because no strategy was proposed for a solution. Then, there were three (0.23%) participants with basic performance and moderately flexible category, because there were strategy errors before reaching the solution. After these participants tried other strategies, they succeeded in finding a solution. Moreover, six (0.46%) participants had high-performance levels in the moderately flexible category because there were no errors in producing solutions, but the strategies and solutions produced were standard strategies. Lastly, three (0.23%) participants with high-performance levels were categorized as very flexible because they could produce unique strategies and solutions.

Statistically, there was a significant relationship between performance and strategic flexibility. Since the p-value (0.006) is below the common significance level of 0.05, we reject the null hypothesis, suggesting a significant association between "Performance level" and "Strategic Flexibility level" in this data set.

DISCUSSION

The strategies that are often proposed by students when solving open mathematical problems in the context of land division are division with the same size and shape, division with different sizes but the same shape, and using the formula of area. This shows that students can produce several strategies within a certain period after they realize that the solutions to the problem are diverse. This aligns with Stacy et al. who state that students' ability to generate strategies is positively influenced by students' perceptions of the number of additional strategies possible [36].

The participants with low performance could not identify the given problem, so no strategy is proposed and no solution is produced. This is because he does not understand mathematical concepts well. Therefore, these participants could be categorized as non-flexible. Furthermore, the participants with basic performance only improved their strategies for getting solutions to problem-solving after instructions were given to review the problem posed and were allowed to understand and solve the problem to get a new correct solution. This is in line with what Lisa said that students rarely switch from an initial incorrect strategy to another correct strategy [37]. Cigdem and Yeliz also said that students rarely change their strategy if the first strategy used needs to be corrected [11]. This is because students with basic performance need to realize that the solution they get is wrong. Hence, intervention is needed so that students can successfully reach the correct solution.

Furthermore, the participants with basic performance were found to be able to think flexibly because they tried to find other solutions with different strategies after successfully finding a solution using the first strategy. This is in line with what Ann and Tom said that a person's flexibility or inflexibility based on the strategies applied can be seen through whether a person applies several different strategies or only applies one strategy to solve a series of problems [38]. Students need more time to produce different strategies. This is in accordance with Marian [19] statement that when asked, students know more strategies than they use spontaneously when solving problems.

Lastly, the participants with high performance could think flexibly because they proposed unique strategies and solutions. An assessment of participants' flexibility can be done by looking at how many different strategies they use or whether there are any unique strategies they come up with [26; 35].

CONCLUSION

In conclusion, performance of mathematics education study program students in solving problems can be divided into four categories. First, it is low-performance with a non-flexible level of strategic flexibility. The participants in this category have no strategy proposed so no solution could be reached. Second, it is basic performance with a moderately-flexible level of strategic flexibility. In this category, the participants could produce several strategies but there were errors in their strategy. However, they were able to change their strategy so that they got the correct solution. Third, it is high performance with moderately flexible level of strategic flexibility. In this level, the participants were able to propose several strategies and produce the correct solution, but the proposed strategy was a standard strategy that was commonly used. Fourth, it is high performance with very flexible level of strategic flexibility. The participants in this level succeeded to produce several unique strategies and solutions that were different from others. Lastly, there was found a significant relationship between performance and students' strategic flexibility in solving open mathematical problems.

This research is limited because it was only tested on 13 participants. Therefore, this research can be developed to a broader scope for generalizability so that many different strategies can be generated in solving other mathematical open problems.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the Higher Education Financing Center (Balai Pembiayaan Perguruan Tinggi) and the Indonesia Endowment Fund for Education (Lembaga Pengelola Dana Pendidikan) for supporting the publication of this article.

REFERENCES

1. UNESCO. Unesco Strategy on Teachers. 2012, June 2012, pp. 1–7. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000217775 (accessed 17 July 2024)
2. UNESCO. China UNESCO Country Strategy. UNESCO Multisectoral Regional Office for East Asia, 2022, https://unesdoc.unesco.org/ark:/48223/pf0000388348 (accessed 17 July 2024)
3. Kiki H., I K.B., Ismail, & Liu M. What is the room for guessing in metacognition? Findings in mathematics problem solving based on gender differences. *Perspectives of Science and Education*, 2024, 69 (3), 469–482. DOI: 10.32744/pse.2024.3.28
4. Ru-De L. et al. Turning potential flexibility into flexible performance: Moderating effect of self-efficacy and use of flexible cognition. *Frontiers in Psychology*, 2018, vol. 9, no. May, pp. 1–10. DOI: 10.3389/fpsyg.2018.00646.
5. Koen L., Viki. S., Patrick. O., and Lieven. V. The British Psychological Society Does switching between strategies within the same task involve a cost. *The British Psychological Society*, 2009, pp. 753–771. DOI: 10.1348/000712609X402801.
6. Hüseyin O. G., Yeliz Y., Çiğdem A. Non-routine problem solving and strategy flexibility: A quasi-experimental study. *Journal of Pedagogical Research*, 2021, vol. 5, no. 3, pp. 40–54. DOI: 10.33902/jpr.2021370581.
7. Aiso H., Jon R. S., Lieven V. Flexible and adaptive use of strategies and representations in mathematics education. *ZDM - International Journal on Mathematics Education*, 2009, vol. 41, no. 5, pp. 535–540. DOI: 10.1007/s11858-009-0214-4.
8. Carlos S., Irene F. Pre-service teachers' flexibility and performance in solving Fermi problems. *Educational Studies in Mathematics*, 2023, vol. 113, no. 2, pp. 207–227. DOI: 10.1007/s10649-023-10220-5.
9. Jerry P. B. The 'open approach' to teaching school mathematics. *Journal of the Korea Society of Mathematical Education Series D: Research in Mathematical Education*, 2006, vol. 10, no. 3. pp. 45–62.
10. Ariadi W. How do open-ended problems promote mathematical creativity. A reflection of bare mathematics problem and contextual problem. *J. Phys. Conf. Ser.*, 2018, vol. 983, no. 1. DOI: 10.1088/1742-6596/983/1/012114.
11. Cigdem A., Yeliz Y. Common and flexible use of mathematical non routine problem solving strategies. *American Journal of Educational Research*, 2015, vol. 3, no. 12, pp. 1519–1523. DOI: 10.12691/education-3-12-6.
12. Ernvall H., Anne M., Hästö P., Krzywacki H., & Parikka S. Procedural flexibility in early university mathematics. *FMSERA Journal*, 2022, vol. 5 , no. 1 , pp. 46-60. Available at: https://journal.fi/fmsera/article/view/115676
13. Janka M., Kristina O. B., Sona C. Relations between generalization, reasoning, and combinatorial thinking in solving mathematical open-ended problems within mathematical contest. *Mathematics*, 2020, vol. 8, no. 12, pp. 1–20. DOI: 10.3390/math8122257.
14. Seher A., Ramazan A. Pre-service elementary mathematics teacher's use of strategies in mathematical problem solving. *Procedia Social and Behavioral Sciences*, 2010, vol. 9, pp. 1282–1286. DOI: 10.1016/j.sbspro.2010.12.321.
15. Mehmet F. O., Ceylan S., Gursel G., Tugrul K. The investigation of prospective mathematics teachers' non-algebraic solution strategies for word problems. *International Journal of Mathematical Education in Science and Technology*, 2019, vol. 5211. DOI: 10.1080/0020739X.2019.1597936.
16. Taliha K., Yeliz Y. Gifted eighth, ninth, tenth and eleventh graders' strategic flexibility in non-routine problem solving. *The Journal of Educational Research*, 2021, p. DOI: 10.1080/00220671.2021.1937913.
17. Rezky R., Manuharawati, Atik W. Strategic competence of pre-service mathematics teachers in solving environment and culture-based combinatorial problems. *BIO Web Conf.*, 2023, vol. 79, p. 10002. DOI: 10.1051/bioconf/20237910002.
18. Lisa L., Jessica B., Ian W., Randolph P. Flexibility across and flexibility within: The domain of integer addition and subtraction. *Journal of Mathematical Behavior*, 2023, vol. 70, no. December 2022, p. 101031, DOI: 10.1016/j.jmathb.2023.101031.
19. Marian H. Flexibility and adaptivity in arithmetic atrategy use : What children know and what they show multi-digit subtraction. *Journal of Numerical Cognition*, 2022, vol. 8(3), 367–381. https://doi.org/10.5964/jnc.7277.
20. Jon R. S. et al. Exploring students' procedural flexibility in three countries. *International Journal of STEM Education*, 2022, vol. 9, no. 1. DOI: 10.1186/s40594-021-00322-y.
21. Monica A. P. Mathematical flexibility of degree of primary education students in solving an area problem: Pick's theorem. *Mathematics. Teaching-Research Journal,* 2020, vol. 12, no. 4, pp. 21–35.
22. Lieven V. Strategy flexibility in mathematics. *ZDM - Mathematics Education*, 2023. DOI: 10.1007/s11858-023-01491-6.
23. Jon R. S., Kristie J. N. The nature and development of experts' strategy flexibility for solving equations. *ZDM - The International Journal on Mathematics Education*, 2009, vol. 41, no. 5, pp. 557–567. DOI: 10.1007/s11858-009-0185-5.
24. Jon R. S., Colleen S. The development of flexibility in equation solving. *Contemporary Educational Psychology*, 2006, vol. 31, no. 3, pp. 280–300. DOI: 10.1016/j.cedpsych.2005.08.001.
25. Jon R. S., Bethany R. J. Flexibility in problem solving: The case of equation solving. *Learning and Instruction*, 2008, vol. 18, no. 6, pp. 565–579. DOI: 10.1016/j.learninstruc.2007.09.018.
26. Iliada E., Marja V. D. H. P., and Angeliki K. Exploring strategy use and strategy flexibility in non-routine problem solving by primary school high achievers in mathematics. *ZDM - Int. J. Math. Educ.*, 2009, vol. 41, no. 5, pp. 605–618. DOI: 10.1007/s11858-009-0184-6.
27. Wei H. et al. A systematic review of mathematical flexibility: Concepts, measurements, and related research. *Educational Psychology Review*, 2023, vol. 35, no. 4. Springer US.
28. Le X. et al. Measures of potential flexibility and practical flexibility in equation solving. *Frontiers in Psychology,* 2017, vol. 8. doi: 10.3389/fpsyg.2017.01368.
29. Taliha K., Yeliz Y. Indicators of gifted students' strategic flexibility in non-routine problem solving.

International Journal of Mathematical Education, 2022, no. August. DOI: 10.1080/0020739X.2022.2105760.
30. Stephen K., Jesse A. R. Problem solving: A handbook for elementary school teachers. 1988. Library of Congress Cataloging-in-Publication Data, United States of Amerika.
31. Erkki P. Use of open-ended problems in mathematics classroom. 1997. University of Helsinki.
32. Mary M. C. et al. An investigation of preservice teachers' use of guess and check in solving a semi open-ended mathematics problem. *Journal of Mathematical Behavior*, 2012, vol. 31, no. 1, pp. 105–116. DOI: 10.1016/j.jmathb.2011.10.002.
33. Lloyd M. The open-ended approach framework. *European Journal of Educational Research*, 2015, vol. 4, no. 3, pp. 97–104. DOI: 10.12973/eujer.2015.p97.
34. Aleksandra M., Mirko D. Using open-ended problems and problem posing activities in elementary mathematics classroom. *Int. MCG Conf.*, 2015, no. June, pp. 34–40.
35. Yasemin C. G., Tenzin D. Strategic competence for multistep fraction word problems: an overlooked aspect of mathematical knowledge for teaching. *Educational Studies in Mathematics*, 2021. DOI: https://doi.org/10.1007/s10649-021-10028-1.
36. Stacy T. S., Anahit A. P., Gerardo R. The mathematical flexibility of college students: The role of cognitive and affective factors. *British Journal of Educational Psychology*, 2020, vol. 90, no. 4, pp. 981–996. DOI: 10.1111/bjep.12340.
37. Lisa K. F., Robert S. S. Strategy use and strategy choice in fraction magnitude comparison. *J. Exp. Psychol. Learn. Mem. Cogn.*, 2016, vol. 42, no. 1, pp. 1–16. DOI: 10.1037/xlm0000153.
38. Ann M. H., Tom J. C. Factors affecting the process of proficient mental addition and subtraction: Case studies of flexible and inflexible computers. *Journal of Mathematical Behavior,* 2004, vol. 23, no. 4, pp. 443–463. DOI: 10.1016/j.jmathb.2004.09.005

Authors

Rezky Ramadhona
(Surabaya, Indonesia)
Ph.D. Candidate, Department of Mathematics Education
Faculty of Mathematics and Natural Sciences
Universitas Negeri Surabaya
***
(Tanjungpinang, Indonesia)
Lecturer, Mathematics Education Study Program
Universitas Maritim Raja Ali Haji
Email: rezky.21031@mhs.unesa.ac.id
Scopus Author ID: 58796584600

Manuharawati
(Surabaya, Indonesia)
Professor in Department of Mathematics
Faculty of Mathematics and Natural Sciences
Universitas Negeri Surabaya
E-mail: manuharawati@unesa.ac.id
Scopus Author ID: 56520384900

Atik Wintarti
(Surabaya, Indonesia)
Lecturer in Department of Mathematics
Faculty of Mathematics and Natural Sciences
Universitas Negeri Surabaya
E-mail: atikwintarti@unesa.ac.id
Scopus Author ID: 57053275600

Author's contribution

Rezky Ramadhona: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Visualization, Project Administration, Funding acquisition
Manuharawati: Methodology, Validation, Writing - Review & Editing, Supervision
Atik Wintarti: Methodology, Validation, Writing - Review & Editing, Supervision

The author's declared no conficts of interest