

Mathematical Open Task Design to Explore Strategic Flexibility of College Student

Rezky Ramadhona¹, Manuharawati², Atik Wintarti³

¹ Raja Ali Haji Maritime University, Tanjungpinang, Indonesia;
State University of Surabaya, Surabaya, Indonesia
E-mail: ramadhona@umrah.ac.id
ORCID: <https://orcid.org/0009-0000-8408-5491>

² State University of Surabaya, Surabaya, Indonesia
E-mail: manuharawati@unesa.ac.id
ORCID: <https://orcid.org/0000-0003-1030-7295>

³ State University of Surabaya, Surabaya, Indonesia
E-mail: atikwintarti@unesa.ac.id
ORCID: <https://orcid.org/0000-0001-6514-1881>

DOI: 10.26907/esd.21.1.04

EDN: LJMVAE

Submitted: 19 July 2024; Accepted: 17 February 2026

Abstract

Flexibility is essential to face the rapidly changing times. This study aims to develop an open-ended mathematics task that can enhance students' strategic flexibility. This research was conducted in two main stages: preparation and evaluation. The preparation stages are formulating indicators, involving the preparation of task grids, and designing tasks. The stages in evaluation are testing the validity and practicality of the task. This study produced a mathematical task instrument that has been validated by experts and is able to reveal indicators of students' strategic flexibility. Students used various strategies to solve the given problems. The strategies used by students in completing these tasks included making logical deductions, making analogies with simpler numbers, using diagrams, and utilizing the GeoGebra application. Although they were able to verify the correctness of their initial solution, they did not try other different strategies to find a solution. Therefore, this open-ended mathematics task can serve as an effective tool to investigate students' strategic flexibility.

Keywords: college students, open-ended mathematical task, students' strategic flexibility, design research.

Разработка открытой задачи по математике для изучения стратегической гибкости студента колледжа

Резки Рамадона¹, Манухаравати², Атик Винтarti³

¹ Морской университет Раджи Али Хаджи, Танджунгпинанг, Индонезия;
Государственный университет Сурабая, Сурабая, Индонезия
E-mail: ramadhona@umrah.ac.id
ORCID: <https://orcid.org/0009-0000-8408-5491>

² Государственный университет Сурабая, Сурабая, Индонезия
E-mail: manuharawati@unesa.ac.id
ORCID: <https://orcid.org/0000-0003-1030-7295>

³ Государственный университет Сурабая, Сурабая, Индонезия
E-mail: atikwintarti@unesa.ac.id
ORCID: <https://orcid.org/0000-0001-6514-1881>

DOI: 10.26907/esd.21.1.04

EDN: LJMVAE

Дата поступления: 19 июля 2024; Дата принятия в печать: 17 февраля 2026

Аннотация

Стратегическая гибкость необходима для того, чтобы человек мог адекватно реагировать на непрерывные жизненные перемены. Цель данного исследования – разработать математическое задание открытого типа, способное повысить стратегическую гибкость учащихся. Исследование проводилось в два основных этапа: подготовка и оценка. Этап подготовки включал формулирование показателей, составление таблиц заданий и разработку самих заданий. Этап оценки – проверку достоверности и эффективности задания. В результате было разработано математическое задание, прошедшее экспертную проверку, которая подтвердила: задания данного типа способны выявить уровень стратегической гибкости учащихся. Учащиеся использовали различные стратегии для решения предложенных задач: логические выводы, аналогии с более простыми числами, использование диаграмм и приложения GeoGebra. Студенты могли проверить правильность своего первоначального решения, но не обращались к другим стратегиям поиска решения. Таким образом, предлагаемое математическое задание открытого типа может служить эффективным инструментом для совершенствования стратегической гибкости учащихся.

Ключевые слова: студенты колледжа, открытая задача по математике, стратегическая гибкость студентов, проектное исследование.

Introduction

Problem-solving strategies are crucial in solving mathematical problems. However, the use of a particular strategy does not guarantee that a solution is correct. Egodawatte and Stoilescu (2015) argue that students often struggle when they are unable to select appropriate strategies. To verify the accuracy of a solution, it is frequently necessary to apply alternative approaches. Commonly used strategies include identifying patterns, drawing diagrams, simplifying problems, guessing and checking, working backward, and manipulating structures (Celebioglu et al., 2010). Non-algebraic strategies, which are widely used, include guessing and checking, working backward, making drawings, and manipulating structures (Öçal et al., 2020). Therefore, the strategies available for problem-solving can be categorized into algebraic and non-algebraic strategies.

Previous studies indicate that high-achieving or gifted students tend to select more effective strategies (Avcu & Avcu, 2010; Koç Koca & Gürbüz, 2021). The strategies they frequently employ include making and drawing, finding a pattern, and logical reasoning. A less commonly used strategy is forming equations. That mean mastery of problem-solving strategies was still limited (Avcu & Avcu, 2010). Fazio et al. (2016) said that students with lower mathematical abilities often use the wrong strategies, and rarely switch to the correct strategies. Therefore, having a variety of problem-solving strategies is very effective in solving math problems.

Strategic flexibility is knowledge of various strategies and being able to switch from one strategy to another to find the right solution. This aligns with the findings of Gavaz et al. (2021), said that strategic flexibility is a skill that includes not only knowledge of various strategies but also being able to choose the best strategy and switch between them effectively. Additionally, Xu et al. (2017) emphasizes that strategic flexibility is knowledge of various strategies for problem solving and the ability to apply innovative approaches to specific situations. Therefore, as a future mathematics teacher, it is necessary to develop strategic flexibility so that you can teach it to your students later.

Several previous studies have conducted research related to flexibility in learning. Star et al. (2022) this study examines the relationship between students' accuracy in using strategies and their flexible application to solve linear equation problems in three countries. In a different study, Friesen and Knox (2022) investigated pre-service teachers in analyzing problem-solving strategies used by students through cartoons. Additionally, Newton et al. (2020) highlighted that those with lower prior knowledge needed more time to develop their flexibility.

An assessment of participants' flexibility can be conducted by analyzing the variety of strategies they employ and identifying any unique strategies they develop (Hong et al., 2023; Shaw et al., 2020). The flexibility assessment consists of three phases: In the first phase, Participants answered questions according to their initial abilities. In the second phase, participants worked again using a different method than before. Finally, in the third phase, they evaluate the methods that have been used and choose the best one (Xu et al., 2017).

Although several studies have examined flexibility in algebra (Newton et al., 2020; Star et al., 2022), fewer studies have explored the role of open mathematical tasks in promoting strategic flexibility, particularly in geometry. Open problems allow for multiple solution paths and outcomes (Jerry & Judith, 2006; Munroe, 2015) making them suitable tools for examining flexibility.

Accordingly, this study aimed to develop an open mathematical task capable of exploring students' strategic flexibility. The research questions were:

- 1) What task criteria can effectively explore students' strategic flexibility?
- 2) What percentage of students used more than one strategy, regardless of correctness?
- 3) How is students' strategic flexibility manifested when completing the task?

Literature review

Open Problem

Problem characteristics influence the strategies used to solve them. Well-structured problems typically guide students toward a single solution, whereas open problems allow multiple approaches and outcomes (Aljaberi & Gheith, 2016). Pehkonen (1997) classified problems into four types based on whether their initial and goal situations are open or closed. In this study, the task was designed with an open situation and an open goal, allowing for diverse assumptions and multiple valid solutions. Open problems encourage students to explore different approaches and strategies (Wijaya, 2018).

Each approaches problem-solving differently, influenced by the type of problem they encounter. The strategy one chooses depends on both the characteristics of the problem and those of the learner (Fazio et al., 2016). Problem-solving is a complex process that requires the integration of various skills. The process involves understanding the problem, selecting relevant information from the available options, converting that information into mathematical symbols, and arriving at a solution by performing the necessary operations (Saygılı, 2017).

Mihajlović and Dejić (2015) highlight that one of the benefits of giving students open-ended problems is that they can express their unique ideas for solving the problem. Open-ended problems provide students with the opportunity to practice their ability to use innovative problem-solving strategies. This study's tasks are designed to start from an open situation and culminate in an open-ended goal. Currently, students are typically accustomed to solving closed-type mathematical problems, which limits their creativity and flexibility in developing ideas. While there are studies on flexibility, few focus on using open tasks to explore strategic flexibility in geometry among college students. Therefore, this study addresses a significant gap by introducing a novel task designed explicitly.

Strategic Flexibility

Mathematical problems can be solved effectively when one has a clear strategy. Thus, a strategy encompasses logical actions in planning, implementation, and evaluation to arrive at a solution. Everyone approaches problem-solving differently, and no single strategy is inherently superior to another. However, some strategies may lead to better solutions than others (Krulik & Rudnick, 1988). This highlights that problem-solving methods can vary based on the individual and the problem. A person's ability to adapt their behavior to suit different situations is known as flexibility.

Some researchers define flexibility in mathematical terms as generating different strategies and selecting the most appropriate one for a specific problem (Arnal-Palacián, 2020; Hong et al., 2023). Others refer to this concept as strategic flexibility. Gavaz et al. (2021) explain that strategic flexibility is our sensitivity in choosing the most appropriate strategy for the situation at hand. Star et al. (2022) describe this as procedural flexibility, which is the ability to choose appropriate strategies based on an understanding of various problem-solving approaches. Verschaffel (2024) refers to it as strategic flexibility, which involves knowledge of diverse strategies and the inclination to select the most suitable one. In this study, the researcher defines flexibility as strategic flexibility, which is the ability to generate various strategies and switch to appropriate alternative strategies to solve a problem. Although different terms are used to describe flexibility, they all share a common characteristic: the use of multiple strategies.

Elia et al. (2009), classified strategic flexibility includes two main types. The first type: intra-task flexibility, refers to the ability to change strategies within the same problem. The second type: inter-task flexibility, refers to applying different strategies to solve different problems. According to Keleş and Yazgan (2022) indicators of intra-task strategic flexibility include the ability to change a strategy when it is ineffective, solving a problem again with a different strategy after the initial attempt, using multiple strategies simultaneously to tackle a problem, and verifying the correctness of a solution using an alternative strategy.

Based on the descriptions provided by previous researchers regarding their theoretical foundations and research findings, there are several ways to understand a person's strategic flexibility. Some researchers have mentioned variations in strategy and

variations in representation. In this study, the researchers collaborated and utilized the indicator for strategic flexibility proposed by Keleş and Yazgan (2022), as it represents an enhancement of the indicator initially developed by Elia et al. (2009).

Methodology

Procedure Research

This research aims to develop an open mathematical task that explores students' strategic flexibility. The development of these mathematical tasks follows two main stages: the preparation stage and the evaluation stage. During the preparation stage, we focus on determining indicators, compiling task grids, and designing the tasks. The evaluation stage involves expert reviews and the implementation of the tasks. According to the experts, a task is considered qualified if it is valid and the participants' responses reveal indicators of strategic flexibility.

Preparation Stage

In this stage, the first step is to formulate indicators. Determining these indicators begins with analyzing and synthesizing articles related to problem-solving strategies and their flexibility. Researchers identified four indicators to assess strategic flexibility in problem-solving: switching strategies when one does not work, trying a different strategy to solve the problem, employing multiple strategies simultaneously, and verifying the correctness of the solution using different strategies. The second step involves compiling task grids. To ensure that the designed tasks can effectively reveal strategic flexibility indicators, specific criteria or task grids are established. These criteria include presenting problems that relate to everyday life, ensuring that the problems have various ways of being solved, and that they offer multiple possible solutions. The final step is designing the tasks. The mathematical open task (as shown in Figure 1) focuses on geometry. To solve this problem, students must understand the concepts of flat area and the volume of three-dimensional space.

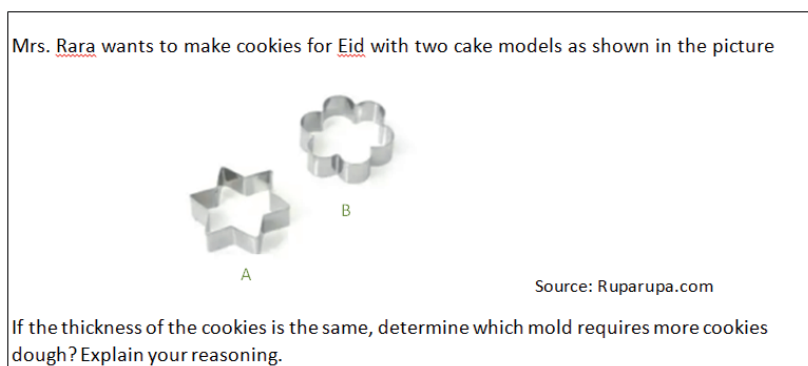


Figure 1. *Mathematical Open Task*

Evaluation stage

The evaluation stage aims to see whether the designed task is valid according to the expert and can be used to explore the strategic flexibility of college students. First, the designed task was reviewed by three expert validators lecturing in the Faculty of Mathematics and Natural Sciences at Surabaya State University. One of the validators

is a professor of Mathematics, the second validator is a lecturer in Mathematics whose research focuses on interactive learning media, and the third is a lecturer in Mathematics Education whose research focuses on geometry. Experts have declared the designed mathematical open task feasible and appropriate to the grid. The validation results can be seen in Table 1.

Table 1. *Expert Validation Results*

<i>Aspect</i>	<i>Indicator</i>	<i>Expert 1</i>	<i>Expert 2</i>	<i>Expert 3</i>
Content	The problem presented is an open problem	5	5	5
	The presented problem encourages students to use various strategies	5	5	5
	The problem of having multiple answers	4	5	5
Construction	Tasks designed according to the grid arranged	5	5	5
	Tasks can be solved with different strategies	4	3	5
	Tasks can bring up aspects of strategic flexibility	5	4	4
Language	Tasks use communicative, easy-to-understand language	5	5	5

Table 1 show that each validator assigned a minimum score of 3 for each indicator. This indicates that the mathematics task developed is valid in terms of content, construction, and language. An expert has confirmed that the designed mathematics task is valid.

Once the task has been validated, the researcher proceeds to select participants. The analysis of the readability test indicated that the designed task was understandable, which led the authors to implement this task for the participants. They were asked to solve open-ended mathematical problems presented online through a Google Form link. Subsequently, the results of the participants' work were analyzed using indicators of strategic flexibility.

Participants

The research was attended by 30 participants from several cities in Indonesia, who were chosen randomly. They have different levels of background and ability, but they have passed the Geometry subject. The information of the participants is shown in Table 2.

Table 2. *Background of participants*

<i>Variabels</i>	<i>Sub-variabel</i>	<i>Number of Participants</i>
Gender	Male	6
	Female	24
Occupation	Pre-service mathematic teacher	4
	Student of mathematic education	26
University	State university	11
	Private university	19

The majority participants are female mathematics education students who are studying at private universities. All participants in this research are voluntary, and participants are free to withdraw from the study at any time.

Data Analysis

Data analysis was conducted by examining participants’ responses to open-ended mathematical problem-solving tasks. Both the written solutions and the interview transcripts were initially analyzed in Indonesian to preserve contextual meaning. Selected excerpts were then carefully translated into English for reporting purposes in this article. The qualitative analysis of participants’ work was guided by the strategic flexibility framework developed by Keleş and Yazgan (2022).

Results

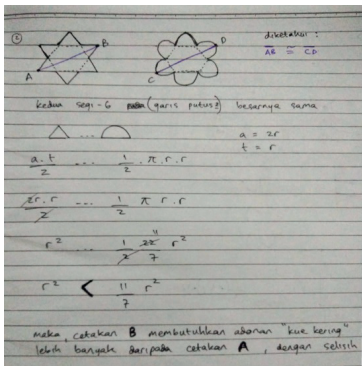
This section presents the results of the analysis of the potential of the developed open-ended mathematical tasks in exploring participants’ strategic flexibility. Students approached the open-ended tasks using a variety of strategies. Some students employed a single strategy, while others applied multiple strategies. A few students did not employ any identifiable strategy and therefore were unable to provide a solution. Additionally, some students used two strategies simultaneously to arrive at a solution. The details of percentages are summarized in the Table 3.

Table 3. The Percentage of Each Strategy

Number of Strategies	Quantity	Percentage (%)
0	0	0
1	14	46.67
2	16	53.33

As presented in Table 3, more students use two than one strategy to complete the given task. Of the 14 students who completed the task with a strategy, six still needed the correct solution. Meanwhile, of the 16 students who completed the task using more than one strategy, 11 people used two strategies simultaneously to get a solution, and five other students used a different strategy to check the correctness of the solution they got after successfully using the first strategy. The strategy that was produced can be seen in Table 4.

Table 4. Description of Strategy

Strategy Code	Description	Example
Logical reasoning	Using logical reasoning to guess at a solution.	Molds that require more dough are flower-shaped because they don’t have an angle
Mathematical calculation	Calculate area using variable	

Strategy Code	Description	Example
	Calculate area using simple numbers	
Technology	Using the Geogebra application	

The relationship between student strategies and strategic flexibility indicators is presented below.

Indicator 1

The success in finding a solution made the 30 students decide not to make any changes to their initial strategy. In this case, Student 1 (S1) made a simile by visualizing the circle's radius as equal to the triangle's height, namely 7. Next, S1 solves it using the concept of flat area. Assuming the area of the hexagons of both molds is the same, S1 said mold B requires more dough than mold A (Figure 2). Different strategies were given by Student 2 (S2). The strategy used by S2 in solving the problem is to use application assistance to determine the area of mold A (Figure 3a), then determine the area of mold B, and perform mathematical calculations using the concept of area to decide which mold needs more dough (Figure 3b). The technology that S2 used to help get the solution to the problem was the Geogebra application. By using Geogebra, S2 immediately finds out the area of mold A. To determine the area of mold B, S2 determines the area of the regular hexagon first via Geogebra and then calculates the overall mold area using simple algebra.

- let's say radius $r=7$

Area of 6 Half-circles $= 6 \cdot \frac{1}{2} \pi r^2$
 $= 3 \pi 7^2$
 $= 462$

Area of mold B = area of hexagon + 462

- Let's say the base is 14,

Area of 6 triangles $= 6 \cdot \frac{1}{2} \cdot 14 \cdot 7$
 $= 294$

area of mold A = area of hexagon + 294

if the area of the hexagon is assumed to be the same, the mold that requires more dough is mold B

Figure 2. S1s' Answer

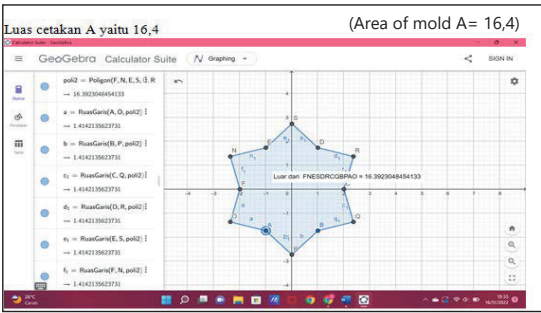
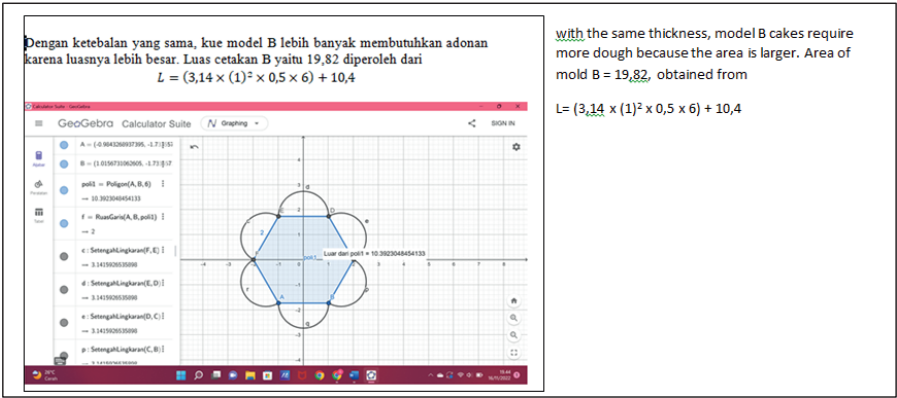


Figure 3a. S2s' Answer (The area of the mould A)



with the same thickness, model B cakes require more dough because the area is larger. Area of mold B = 19,82, obtained from $L = (3,14 \times (1)^2 \times 0,5 \times 6) + 10,4$

Figure 3b. S2s' Answer (The area of the mould B)

Based on the S1 and S2 answers, they did not try to use other strategies to solve the problem after they had a solution. After that, an interview was conducted with the students to determine whether they could find another way, and the students answered that it would take more time to get it. Apart from that, the task does not require multiple strategies. Participants who did not get the correct solution did not change their strategy to get another solution because they felt the solution they obtained needed to be corrected.

Indicator 2

In this context, 5 participants tried to solve the problem again using a different strategy after successfully using the first strategy, such as Student 3 (S3)'s answer (Figure 4).

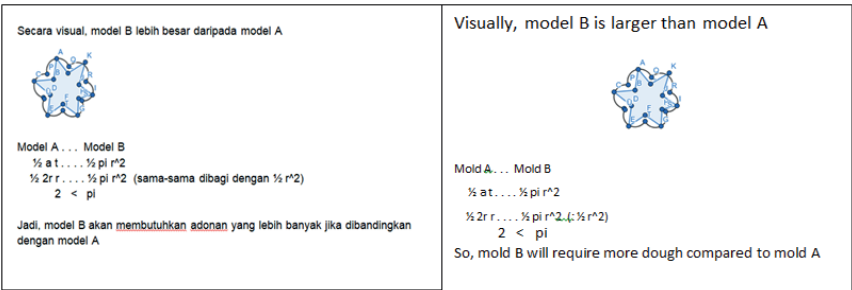


Figure 4. S3's Answer

S3 used the help of an application to describe the cake mold and can immediately decide visually that the mold that requires much dough is mold B. Next, to prove the truth, S3 tried to use mathematical calculations, proving that mold B is bigger than mold A. This finding indicates the use of a dual strategy by S3, namely, making a picture by application and mathematical calculation.

Indicator 3

Of the 16 participants who used more than two strategies, 11 used two simultaneously to get a solution. Student 4 (S4) determined the mold that needed more dough by the picture, and then S4 tried to use another strategy to prove it, namely by doing calculations (Figure 5). The calculation done by S4 was different from that done by S1. S4 used a variable, while S1 used an analogy of the radius value with a simple number.

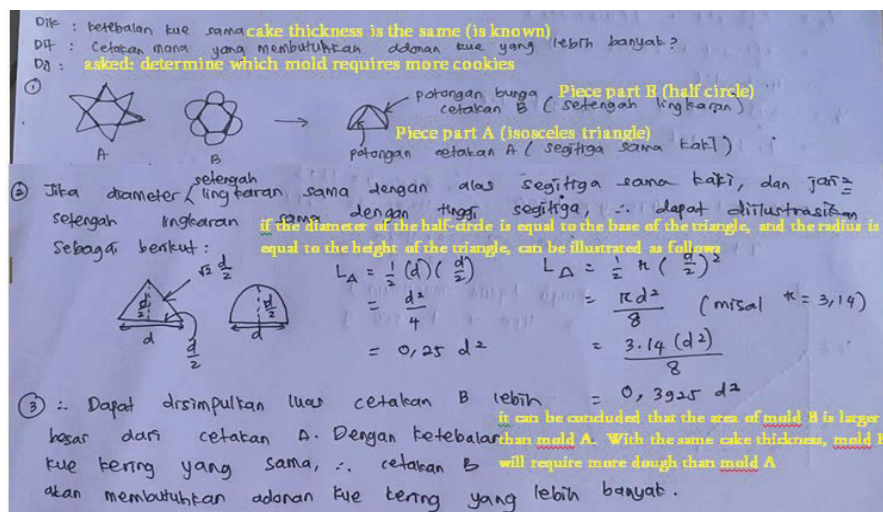


Figure 5. S4's Answer

Figure 5 shows that S4 integrates two methods at once, namely, drawings and calculations.

Indicator 4

In this case, it can be seen from Student 5 (S5) answered. S5 directly answered after the researcher presented the problem.

S5: (reading and understanding) I think the answer is B, Mrs

R: Can you prove the truth of your answer?

S5: (draw like Figure 6) Then, explain using algebra:

– In the star picture, one triangle is estimated to have a height of 1 cm and a base of 2 cm. Therefore, one triangle has an area of $1 \times 2 \times \frac{1}{2} = 1 \text{ cm}^2$. Since there are 12 triangles, $1 \times 12 = 12 \text{ cm}^2$

– Six semicircles and six triangles form the flower-shaped figure; if the base of the triangle is 2 cm, then the radius of the circle is 1 cm. So, the area of three circles is $3 \times 3.14 \times 1 \times 1 = 9.42 \text{ cm}^2$. Plus, six triangles whose sizes have been found are $6 \times 1 \text{ cm}^2 = 6 \text{ cm}^2$. Thus, the total area is $9.42 + 6 = 15.42 \text{ cm}^2$. So, mold B needs more dough than A.

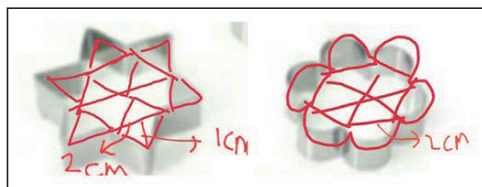


Figure 6. S5s' Answer

The interview results above show that strategy S5 is to guess directly by providing logical reasons. S5 spontaneously mentioned that mold B needed more dough. Then, using simple logic and algebra, S5 can prove the correctness of the solution. Then, S5 can provide different strategies to prove the correctness of the solution obtained after being asked to explain it.

Unlike the other students, Student 6 (S6) considered cake mold A to consist of equilateral triangles and hexagons, while mold B consisted of semicircles and hexagons. S6 assumed that the base of the triangle and the diameter of semicircle are the same, but the height of the triangle and the radius of the semicircle are different. Used the Pythagorean formula S6 obtains the height of the triangle, because the height of the triangle is greater than the radius of the circle, resulting in a larger area of mold A than mold B. So, S6 stated mold A requires more dough than mold B (Figure 7). S6 had a different answer from the other students because he had different assumptions about the height of the triangle in mold A and the radius of the half-circle in mold B. While the other students assumed it was the same. This indicates that the problem has more than one solution.

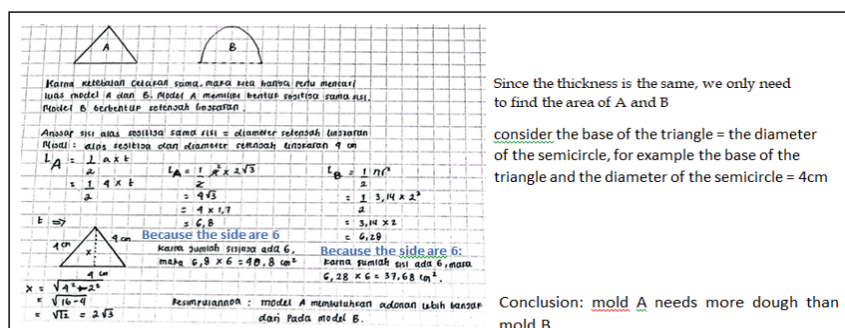


Figure 7. S6s' Answer

Discussion

The research findings indicate that mathematical open tasks allow students to demonstrate their skills. This aligns with the fundamental criteria for open problems outlined by Foong (2000), emphasizing that open-ended problems can provide opportunities for students to demonstrate their mathematical abilities, thereby fostering their strategic flexibility.

The potential mathematical open problem in facilitating the strategic flexibility of students to find solutions was discussed from two perspectives: student's strategies and students' actions in responding to problems. Students' strategies for completing the mathematical open task are different. First, students solved the problem using logical reasoning. Much of children's mathematical knowledge is based on their logical reasoning (Nunes et al., 2007). Logical reasoning is critical to develop in order to improve student's

critical thinking abilities. According to research results by Bronkhorst et al. (2020), logical reasoning can be used to complete formal and everyday reasoning tasks. Second, students used mathematical calculations with simple numbers and variables. Almost all students used calculations with simple numbers, and two students used variables. They think using simple numbers is more straightforward. Third, using technology to solve problems can help students find solutions quickly. Daher and Anabousy (2020) said that the technology used can facilitate the modification of the repeatability of certain conditions. So, technology plays a role in helping students get problem-solving solutions. Therefore, the findings of this study support previous research (Gavaz et al., 2021; Star et al., 2022) that open problems promote students' flexible thinking skills in mathematical problem-solving.

Students' actions in responding to problems can be viewed from several perspectives. First, students need to recognize when their initial solution is incorrect so that they can seek alternative solutions. Teachers need to intervene when students struggle to find a solution. Effective interventions include asking students to re-read the problem, providing clues or keywords, and allowing them time to think and resolve the issue. Zhang and Xin (2012) said that providing interventions to students in solving story problems can improve their understanding. Second, students do not switch to other strategies once they find the answer to the problem. Keleş and Yazgan (2022) showed that subjects did not try other strategies after successfully finding a solution with initial strategy. Third, students used multiple strategies simultaneously to solve a problem. This is in line with what Fazio et al. (2016) said that the same individual may use different problem-solving approach for the same problem. Lastly, students can validate the correctness of their solutions using alternative strategies once prompted to explain their thought processes. The outcomes of this research indicate that the problems presented in assignments can stimulate strategic flexibility among students.

Conclusion

Strategic flexibility must be cultivated so that students can adapt to the changes they encounter in life. One effective way to achieve this is by familiarizing students with various problem-solving strategies. The criteria for the tasks designed to explore students' strategic flexibility are as follows: 1) The problem is related to everyday life, 2) The problem can be solved using various strategies, 3) There are various possible solutions, and 4) The problem requires students to solve it using different approaches. Regarding results, 53.3% of the sample used more than one strategy to arrive at a correct solution, while 36.67% employed a mix of strategies to reach a correct answer. The developed open-ended mathematics problem can explore students' strategic flexibility, as they allow them to use various strategies to find solutions. Furthermore, students can choose the most appropriate strategy and validate the correctness of the solution using different strategies. Therefore, the designed mathematics problem instrument can develop students' strategic flexibility in solving open-ended mathematics problem.

This study still has limitations, particularly the lack of adequate instructions, that could have helped students find solutions using various strategies. Consequently, some participants did not try alternative strategies after successfully finding a solution. Another limitation of this study is that it did not consider other factors that could influence it, such as the participants' cognitive abilities or the educational background. Despite these limitations, the findings provide valuable insights for researchers and educators regarding the development of tasks that encourage students' strategic flexibility in solving open-ended mathematical problems.

Future research could implement this task after students have completed formal instruction in geometry across different educational levels. Further studies may also examine students' strategic flexibility in relation to cognitive ability, gender, and varying levels of task difficulty.

Conclusion of the Ethics Committee

The study was conducted in accordance with the articles of the Rector's Regulation of State University of Surabaya Number 32 of 2022 Concerning the Code of Ethics for Lecturers, Educational Personnel, And Students.

There is no conflict of interest.

Acknowledgements

The authors thanks to the Center for Higher Education Funding and Assessment (PPAPT) under the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia and the Indonesia Endowment Fund for Education (LPDP) for the financial support provided for this research.

References

- Aljaberi, N. M., & Gheith, E. (2016). Pre-Service Class Teacher' Ability in Solving Mathematical Problems and Skills in Solving Daily Problems. *Higher Education Studies*, 6(3), 32–47. <https://doi.org/10.5539/hes.v6n3p32>
- Arnal-Palacián, M. (2020). Mathematical flexibility of degree of primary education students in solving an area problem: Pick's theorem. *Mathematics Teaching-Research Journal*, 12(4), 21–35.
- Avcu, S., & Avcu, R. (2010). Pre-service elementary mathematics teachers' use of strategies in mathematical problem solving. *Procedia - Social and Behavioral Sciences*, 9, 1282–1286. <https://doi.org/10.1016/j.sbspro.2010.12.321>
- Bronkhorst, H., Roorda, G., Suhre, C., & Goedhart, M. (2020). Logical Reasoning in Formal and Everyday Reasoning Tasks. *International Journal of Science and Mathematics Education*, 18, 1673–1694. <https://doi.org/10.1007/s10763-019-10039-8>
- Celebioglu, B., Yazgan, Y., & Ezentaş, R. (2010). Usage of non-routine problem-solving strategies at first grade level. *Procedia - Social and Behavioral Sciences*, 2(2), 2968–2974. <https://doi.org/10.1016/j.sbspro.2010.03.449>
- Daher, W., & Anabousy, A. (2020). Flexibility Processes of Pre-service Teachers in Problem Solving with Technology. *International Journal of Technology in Education and Science*, 4(3), 247–255. <https://doi.org/10.46328/ijtes.v4i3.96>
- Egodawatte, G., & Stoilescu, D. (2015). Grade 11 students'interconnected use of conceptual knowledge, procedural skills, and strategic competence in algebra: a mixed method study of error analysis. *European Journal of Science and Mathematics Education*, 3(3), 289–305. <https://doi.org/10.30935/scimath/9438>
- Elia, I., van den Heuvel-Panhuizen, M., & Kolovou, A. (2009). Exploring strategy use and strategy flexibility in non-routine problem solving by primary school high achievers in mathematics. *ZDM - Mathematics Education*, 41, 605–618. <https://doi.org/10.1007/s11858-009-0184-6>
- Fazio, L. K., DeWolf, M., & Siegler, R. S. (2016). Strategy use and strategy choice in fraction magnitude comparison. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 42(1), 1–16. <https://doi.org/10.1037/xlm0000153>
- Foong, P. Y. (2000). Open-ended problems for higher-order thinking in mathematics. *Teaching and Learning*, 20(2), 49–57.
- Friesen, M., & Knox, A. (2022). Pre-service teachers learn to analyse students'problem-solving strategies with cartoon vignettes. *Twelfth Congress of the European Society for Research in Mathematics Education (CERME12)*, Bozen-Bolzano, Italy. <https://hal.science/hal-03745715v1>

- Gavaz, H. O., Yazgan, Y., & Arslan, Ç. (2021). Non-routine problem solving and strategy flexibility: A quasi-experimental study. *Journal of Pedagogical Research*, 5(3), 40–54. <https://doi.org/10.33902/jpr.2021370581>
- Hong, W., Star, J. R., Liu, R., Jiang, R., & Fu, X. (2023). A Systematic Review of Mathematical Flexibility: Concepts, Measurements, and Related Research. *Educational Psychology Review*, 35, 104. <https://doi.org/10.1007/s10648-023-09825-2>
- Jerry, P., & Judith, E. (2006). The “Open Approach” to Teaching School Mathematics. *Research in Mathematical Education*, 10(3), 151–167.
- Keleş, T., & Yazgan, Y. (2022). Indicators of gifted students’ strategic flexibility in non-routine problem solving. *International Journal of Mathematical Education in Science and Technology*, 53(10), 2797–2818. <https://doi.org/10.1080/0020739X.2022.2105760>
- Koç Koca, A., & Gürbüz, R. (2021). Problem Solving Strategies Used by Gifted Secondary School Students to Solve Math Problems. *Bolu Abant İzzet Baysal University Journal of Faculty of Education*, 21(1), 348–359. <https://doi.org/10.17240/AIBUEFD.2021.21.60703-862916>
- Krulik, S., & Rudnick, J. A. (1988). *Problem Solving: A Handbook for Elementary School Teachers*. Allyn and Bacon.
- Mihajlović, A., & Dejić, M. (2015). Using Open-Ended Problems and Problem Posing Activities in Elementary Mathematics Classroom. In *Proceedings of the 9th International MCG Conference* (pp. 34–40). Sinaia, Romania.
- Munroe, L. (2015). The Open-Ended Approach Framework. *European Journal of Educational Research*, 4(3), 97–104. <https://doi.org/10.12973/eu-jer.4.3.97>
- Newton, K. J., Lange, K., & Booth, J. L. (2020). Mathematical Flexibility: Aspects of a Continuum and the Role of Prior Knowledge. *The Journal of Experimental Education*, 88(4), 503–515. <https://doi.org/10.1080/00220973.2019.1586629>
- Nunes, T., Bryant, P., Evans, D., Bell, D., Gardner, S., Gardner, A., & Carraher, J. N. (2007). The contribution of logical reasoning to the learning of mathematics in primary school. *British Journal of Developmental Psychology*, 25(1), 147–166. <https://doi.org/10.1348/026151006X153127>
- Öçal, M. F., Şen, C., Güler, G., & Kar, T. (2020). The investigation of prospective mathematics teachers’ non-algebraic solution strategies for word problems. *International Journal of Mathematical Education in Science and Technology*, 51(4), 563–584. <https://doi.org/10.1080/0020739X.2019.1597936>
- Pehkonen, E. (1997). Introduction to the concept “open-ended problem”. In E. Pehkonen (Ed.), *Use of Open-Ended Problems in Mathematics Classroom* (pp. 7–11).
- Saygılı, S. (2017). Examining The Problem-Solving Skills and The Strategies Used by High School Students in Solving Non-routine Problems. *E-International Journal of Educational Research*, 8(2), 91–114.
- Shaw, S. T., Pogossian, A. A., & Ramirez, G. (2020). The mathematical flexibility of college students: The role of cognitive and affective factors. *British Journal of Educational Psychology*, 90(4), 981–996. <https://doi.org/10.1111/bjep.12340>
- Star, J. R., Tuomela, D., Joglar-Prieto, N., Hästö, P., Palkki, R., Abánades, M. Á., Pejlare, J., Jiang, R. H., Li, L., & Liu, R. (2022). Exploring students’ procedural flexibility in three countries. *International Journal of STEM Education*, 9(1), 4. <https://doi.org/10.1186/s40594-021-00322-y>
- Verschaffel, L. (2024). Strategy flexibility in mathematics. *ZDM - Mathematics Education*, 56, 115–126. <https://doi.org/10.1007/s11858-023-01491-6>
- Wijaya, A. (2018). How do open-ended problems promote mathematical creativity? A reflection of bare mathematics problem and contextual problem. *Journal of Physics: Conference Series*, 983, 012114. <https://doi.org/10.1088/1742-6596/983/1/012114>
- Xu, L., Liu, R., Star, J. R., Wang, J., Liu, Y., & Zhen, R. (2017). Measures of potential flexibility and practical flexibility in equation solving. *Frontiers in Psychology*, 8, 1368. <https://doi.org/10.3389/fpsyg.2017.01368>
- Zhang, D., & Xin, Y. P. (2012). A follow-up meta-analysis for word-problem-solving interventions for students with mathematics difficulties. *The Journal of Educational Research*, 105(5), 303–318. <https://doi.org/10.1080/00220671.2011.627397>