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Students' Creative Thinking in Solving Open-Ended Problems in Geometry Transformation Material

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ABSTRACT

This study aims to describe students' creative thinking abilities in solving open-ended problems in geometry transformation material. The problem used in this study was designed as a multiple solution task (MST) because it provides students with opportunities to generate more than one strategy or solution. This study employed a descriptive qualitative approach involving 27 students of Class XII-B at a Catholic senior high school in Surabaya. Data were collected through a written test and interviews and were then analyzed based on the indicators of fluency, flexibility, and novelty. The findings show that students were classified into three creativity groups. S1 represented the high-creativity group and demonstrated novelty through a non-routine strategy and by rechecking the solution. S2 represented the moderate-creativity group and demonstrated fluency and flexibility by producing more than one form of solution and using several methods, although the variation remained limited. S3 represented the low-creativity group and did not yet demonstrate fluency or flexibility because the student used only one method and produced a single answer. These findings indicate that open-ended problems in the form of MST can reveal differences in students' creative thinking abilities in geometry transformation material.

Keywords: creative thinking; open-ended; transformation geometry

INTRODUCTION

Mathematical creative thinking is an important ability that needs to be developed in senior high school mathematics learning (Kadir et al., 2022; Setiana et al., 2021). Mathematics learning is not only intended to help students master concepts but also to engage them in an active and meaningful learning process (Vale & Barbosa, 2023). In addition, *mathematics* learning aims to enable students to understand and solve problems effectively (Ariawan et al., 2024; Cuong et al., 2025).

Creative thinking in mathematics is closely related to problem solving (Leikin & Elgrably, 2022; Subanji et al., 2023; Yayuk et al., 2020). This relationship is also supported by Septian et al (2019), who found that learning through Creative Problem Solving could improve students' mathematical creative thinking ability because students were encouraged to engage actively in solving mathematical problems. Problem solving provides students with opportunities to understand a situation, select appropriate strategies, construct solution steps, and evaluate the results of their wor (Lu & Kaiser, 2022; Säfström et al., 2024). Jäder et al. (2025) explained that the problem-solving process does not only focus on the final answer but also on how students gradually construct their understanding. These findings indicate that students' creative thinking can be identified through the strategies, representations, and solution processes that emerge during mathematical problem solving. (Leikin & Pitta-Pantazi, 2013; Sipahi & Bahar, 2025).

One area of mathematics that supports the development of creativity is geometry (Apriliani & Lisnawati, 2025; de Vink et al., 2023). Geometry is part of the space and shape domain, which is related to forms, positions, and relationships among objects in space (NCTM, 2000; OECD, 2022). Geometry encourages students to think abstractly and understand objects spatially (Musa et al., 2025; Serin, 2018). Rahmadani & Rahmadani (2025) also showed that students may experience conceptual, procedural, and technical difficulties when solving geometry word problems, indicating that geometry requires strong conceptual understanding and systematic solution processes. The visual and spatial characteristics of geometry allow students to explore various strategies through representation and visualization (Žakelj & Klančar, 2022). Therefore, geometry is a relevant context for examining students' creative thinking abilities.

Geometry includes various topics that provide opportunities for students to develop diverse ways of thinking in solving problems (Schoevers et al., 2022). One topic in geometry that requires students to compare an original object and its image is geometric transformation (Götz & Gasteiger, 2022). Geometric transformation refers to the mapping of a point or object to its image on the same plane (Musser et al., 2008). This topic includes translation, reflection, rotation, and dilation (Dahal et al., 2022). Turgut (2022) stated that this material provides opportunities for students to use various strategies to solve problems, thereby potentially revealing their creative thinking abilities.

Creative thinking abilities in mathematics can be understood from several perspectives. Silver (1997) explained that creative thinking in mathematical problem solving includes three main indicators: fluency, flexibility, and novelty. Fluency refers to students' abilities to generate several relevant ideas or answers; flexibility is reflected in the use of more than one method to solve a problem; and novelty is indicated by the emergence of unique solutions that differ from commonly used approaches (Lu et al., 2025; Silver, 1997). In line with this view, Subanji et al. (2021) stated that students' mathematical creativity develops through three levels: imitation, modification, and construction. Imitation refers to students' abilities to reproduce existing solution procedures, modification refers to students' abilities to adapt or adjust strategies to make them more effective, and construction refers to students' abilities to develop new strategies that are appropriate to the demands of the problem. This study uses Silver's (1997) indicators because fluency, flexibility, and novelty are better suited for analyzing variations in students' answers, strategies, and the originality of solutions to open-ended problems. These indicators and levels tend to emerge when students are faced with open tasks that allow exploration of various possible answers or strategies (Levenson & Dasuqi, 2025; Markovitz et al., 2025).

In mathematics learning, these characteristics can be found in open-ended problems that do not limit students to a single method or a single answer (Subanji et al., 2023; Suherman & Vidákovich, 2022). One form of open-ended problem is a multiple solution task (MST), which allows students to generate more than one solution and more than one problem-solving strategy (Sipahi & Bahar, 2025). Prambudi et al. (2025) also showed that open-ended mathematical problem solving can reveal students' creative models through the emergence of imitation, modification, and creation in their solution processes. MST problems provide opportunities for students to demonstrate fluency, flexibility, and novelty more optimally (Ardiansyah & Asikin, 2020; Matić & Sliško, 2022). In the topic of geometric transformations, the use of MST problems can help identify how students develop various strategies and solutions when solving problems (Pradiarti et al., 2024).

Several previous studies have examined mathematical creative thinking through problem solving, geometry learning, and open-ended tasks. However, studies that specifically investigate students' creative thinking when solving open-ended problems in geometric transformation material are still limited. Geometric transformations have visual, spatial, and strategic characteristics that enable students to develop a range of strategies and solutions. This condition underscores the need for a more in-depth study of students' creative thinking abilities in geometric transformation material. Therefore, this study focuses on students' creative thinking abilities in solving open-ended problems in geometric transformation materials.

RESEARCH METHODS

This study employed a descriptive qualitative approach to describe students' creative thinking abilities in solving open-ended problems in geometric transformation material. The participants of this study were 27 students of Class XII-B at a Catholic senior high school in Surabaya. Data was collected through a written test and interviews. The test instrument consisted of one multiple solution task (MST) problem that allowed students to generate more than one solution. The problem is presented in Figure 1 and was validated by a mathematics lecturer to ensure alignment with the study's objectives.

Students' creative thinking abilities were analyzed based on three indicators, namely fluency, flexibility, and novelty, as presented in Table 1. The students' written work was classified according to Siswono's (2008) levels of creative thinking abilities, ranging from Level 0 to Level 4, as shown in Table 2. This classification was then modified into three groups, namely high, moderate, and low, as presented in Table 3. This modification was conducted to obtain subjects who represented variations in students' creative thinking abilities while still adhering to the theoretical basis for the creative thinking abilities levels proposed by Siswono (2008). The subjects were selected through purposive sampling based on characteristics relevant to the study's objectives (Creswell, 2009). Based on this classification, one student was selected from each group, namely the high, moderate, and low groups, by considering the completeness of the answers and the representation of creative thinking indicators.

Tentukan berbagai transformasi yang dapat memetakan garis $g: 2x + y = 8$ menjadi garis $g': 2x + y = -4$

Figure 1. Geometric Transformation Problem

After the research subjects were determined, the researcher conducted guided interviews that allowed the subjects to explain their thinking processes in depth. The data, which consisted of written test results, interview results, and documentation, were analyzed using the Miles and Huberman (1994) model, which includes data reduction, data display, and conclusion drawing. The trustworthiness of the data was maintained through methodological triangulation, comparing written test results, interview results, and documentation.

Table 1. Indicators of Creative Thinking Abilities

Indicator	Description	Analysis Criteria
Fluency	The abilities to generate several ideas or solutions in solving a problem	Students are able to generate at least two correct solutions to the given problem. Each solution shows complete and logical solution steps.
Flexibility	The abilities to use different strategies or approaches	Students use at least two different solution strategies, such as a coordinate approach, direct transformation, or other geometric representations.
Novelty	The abilities to generate a unique or uncommon solution	Students produce a solution method that differs from the most commonly used strategies among other students or use a representation that is not directly visible in the problem.

Source: Adapted from (Levav-Waynberg & Leikin, 2012; Silver, 1997)

Table 2. Creativity Levels and Their Characteristics

Level	Characteristics
Level 4 (Very Creative)	Students are able to demonstrate fluency, flexibility, and novelty, or novelty and flexibility, in solving or posing problems.
Level 3 (Creative)	Students are able to demonstrate fluency and novelty, or fluency and flexibility, in solving or posing problems.
Level 2 (Fairly Creative)	Students are able to demonstrate novelty or flexibility in solving or posing problems.
Level 1 (Less Creative)	Students are able to demonstrate fluency in solving or posing problems.
Level 0 (Not Creative)	Students are not able to demonstrate any of the three indicators of creative thinking.

Source: Siswono (2008)

Table 3. Classification of Students' Creative Thinking Abilities

Group	Creative Thinking Abilities Level	Description
High	Level 4	Students demonstrate creative thinking indicators optimally.
Moderate	Level 2 and Level 3	Students demonstrate most of the creative thinking indicators.
Low	Level 0 and Level 1	Students demonstrate only a few indicators or do not yet demonstrate the indicators of creative thinking.

Source: Modified from Siswono (2008)

RESULTS AND DISCUSSION

Based on the analysis of students' written work on the given open-ended problem, students' mathematical creativity levels were classified into three groups, as presented in Table 4. The distribution indicates that most students were in the moderate creativity group, while only a small number of students reached the high creativity level. The high group consisted of 3 students who reached Level 4. The moderate group consisted of 16 students who were classified at Levels 2 and 3. Meanwhile, the low group consisted of 8 students who were classified at Levels 0 and 1. This distribution became the basis for selecting the research subjects for further analysis. From each group, one student was selected to represent the corresponding creativity level. Therefore, the selected research subjects were S1 (high group), S2 (moderate group), and S3 (low group).

Table 4. Distribution of Creativity Levels among Students of Class XII-B

Group	Creative Thinking Abilities Level	Number of Students
High	Level 4	3
Moderate	Level 2 and 3	16
Low	Level 0 and 1	8

Source: Adapted from Siswono (2008)

The research findings are further presented through an in-depth analysis of the three selected subjects. The analysis focuses on the achievement of mathematical creativity indicators proposed by Silver (1997): fluency, flexibility, and novelty. Data from students' written work and interviews were used to trace each subject's solution strategies, thinking processes, and forms of creativity that emerged during problem solving. This analysis was intended to describe how each subject demonstrated different characteristics of creative thinking based on the strategies used in solving the geometric transformation problem. Therefore, the comparison among S1, S2, and S3 provides a clearer understanding of the differences in students' mathematical creativity levels.

High Group

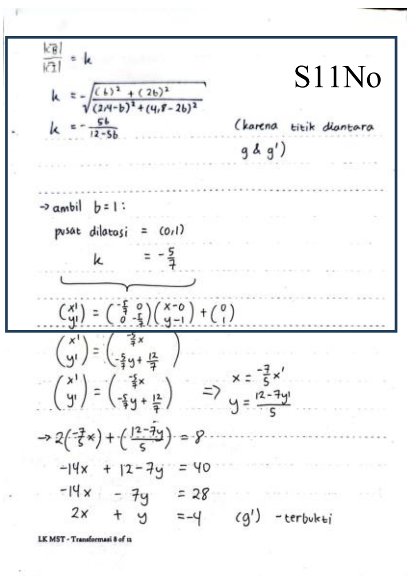

Figure 2. S1's Dilation Solution

In this study, novelty appeared when students were able to use an uncommon method that remained mathematically correct. Based on the analysis, S1 demonstrated novelty in solving the geometric transformation problem. This can be seen in section S11No, where S1 used a dilation approach with a general center at a point (a, b) and independently determined the scale factor k. This strategy shows that S1 did not directly use a particular center of dilation but first constructed the relationship between the original point and its image to obtain the value of k. The use of a general center (a, b) also indicates that S1 was able to develop a more open solution idea because the center of dilation was not determined at the beginning but was found through the mathematical relationship constructed during the solution process, as shown in Figure 2. This indicates that S1 was not merely applying a memorized formula but was able to build a mathematical relationship based on the structure of the problem. In addition, S1's strategy shows an abilities to move beyond routine procedures commonly used in solving transformation problems. Therefore, the use of a general dilation center became important evidence that S1's solution contained a novelty aspect. The novelty in S1's answer was also supported by the following interview excerpt.

W: "What makes you sure that the strategy is correct?"
S1: "Because when i tried using $b = 1$, The result became clear. I obtained the center $(0,1)$ and also the value of k."

The excerpt shows that S1 not only generated a strategy that differed from common procedures but also checked the consistency of the strategy used. The selection $b = 1$ became S1's way of transforming an initially general model into a more specific one, so that the correctness of the relationship between the center of dilation and the scale factor could be rechecked. Thus, the novelty shown by S1 appeared in the ability to construct a non-routine strategy, use a general center of dilation, independently determine the scale factor, and verify the solution through the substitution of a particular value. This finding aligns with studies indicating that novelty in mathematical creative thinking appears when students can produce non-routine strategies, construct relationships among concepts, and check the solutions obtained (Nuryah et al., 2025; Schoevers et al., 2022).

Moderate Group

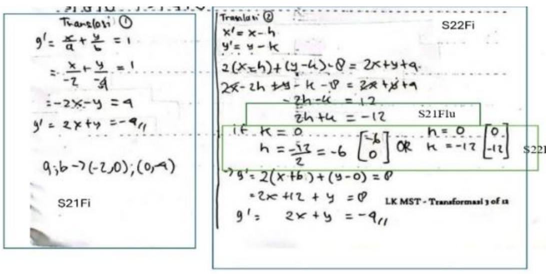

Figure 3. S2's Translation Solution

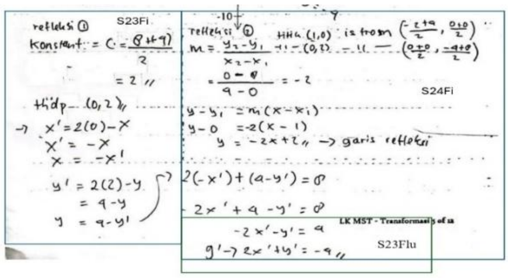

Figure 4. S2's Reflection Solution

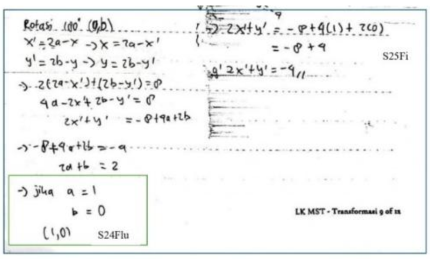

Figure 5. S2's Rotation Solution

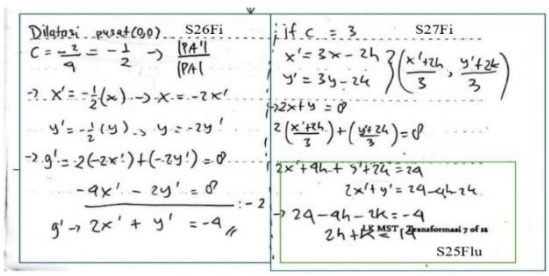

Figure 6. S2's Dilation Solution

Flexibity

S2's flexibility was clearly shown through the ability to use and shift among various approaches to solve geometric transformation problems. In the translation section, evidence of S2's flexibility is shown in Figure 3, particularly in the regions marked S21Fi and S22Fi. In this part, S2 used translation as the first strategy by combining a geometric approach via the intercept form with an algebraic approach via substitution into the general form of translation. This shift from a visual form to a symbolic form indicates that S2 was able to view the problem through different representations. This ability is an important characteristic of flexibility because students are not limited to a single solution method, but are able to adjust their strategies according to the needs of the problem (Leikin & Pitta-Pantazi, 2013).

Furthermore, in the reflection section, evidence of S2's flexibility can be seen in Figure 4, particularly in the sections marked S23Fi and S24Fi. In this part, S2 used two approaches: the midpoint approach and the line-gradient approach. These two approaches show that S2 was able to connect the concepts of geometric transformation and linear equations. In the rotation part, the evidence of S2's flexibility can be seen in Figure 5, particularly in the part marked S25Fi. In this part, S2 applied a coordinate transformation centered at and connected it with the equation of a line. This strategy indicates that S2 was able to generalize the concept of transformation and integrate it with algebra. This ability reflects cognitive flexibility because the student could connect several different concepts in a single solution process (Schoevers et al., 2022).

In the dilation part, the evidence of S2's flexibility can be seen in Figure 6, particularly in the parts marked S26Fi and S27Fi. In this part, S2 used two approaches, namely dilation centered at $(0,0)$. These results show that S2 demonstrated flexibility because the student was able to use and shift among different approaches in solving geometric transformation problems. S2 did not use only one method but applied translation, reflection, rotation, and dilation with different approaches according to the form of the problem. Therefore, S2 can be considered to have fulfilled the flexibility indicator because the student was able to select relevant strategies, change solution methods, and adjust approaches based on the structure of the problem. This finding is in line with studies stating that flexibility in mathematical thinking appears through the use of various strategies that are adjusted to the characteristics and structure of the problem (Nuryah et al., 2025; Wang & Star, 2023). This explanation is supported by the following interview excerpt.

> **W:** "Why did you use different methods here, such as reflection, rotation, or dilation?"
> **S2:** "Because I understood that the shape changed, so from that I chose the appropriate method to obtain its image."

Fluency

S2's fluency was shown through the ability to generate more than one correct idea or form of solution in solving the problem. In the translation part, the evidence of S2's fluency can be seen in Figure 3, particularly in the parts marked S21Flu and S22Flu. In this part, S2 used translation as the first method and was able to find more than one pair of values (h, k) that satisfied the given condition. This shows that S2 did not stop at one possible answer but was able to produce several results that were still relevant to the problem. These abilities indicate fluency in generating mathematical ideas because S2 could construct more than one correct answer within one type of transformation. Furthermore, in the reflection part, the evidence of S2's fluency can be seen in Figure 4, particularly in the part marked S23Flu. In this part, S2 was able to rewrite the result of the reflection into an equivalent equation. In the rotation part, the evidence of S2's fluency can be seen in Figure 5, particularly in the part marked S24Flu. In this part, S2 constructed several forms of equations step by step until obtaining the final result. In the dilation part, the evidence of S2's fluency can be seen in Figure 6, particularly in the part marked S25Flu. In this part, S2 generated several forms of equations from the approach used. This sequence of solutions shows that S2's fluency was not only reflected in the number of final answers but also in the ability to produce several correct forms of solution during the problem-solving process.

Based on this explanation, S2 can be considered to have fulfilled the fluency indicator because the student was able to generate more than one correct answer or form of solution. However, S2's fluency was still categorized as moderate because the number of ideas produced was not extensive, and the variation was not highly diverse. S2 was indeed able to produce several forms of solution, but most of them were still developments of similar methods rather than meaningfully different solutions. This finding is in line with recent studies stating that fluency in mathematical creative thinking appears when students are able to generate several correct ideas or answers, whereas stronger fluency is indicated by a larger number of correct, diverse solutions that do not merely repeat the same form of solution (Pradiarti et al., 2024; Purwati et al., 2025).

Low Group

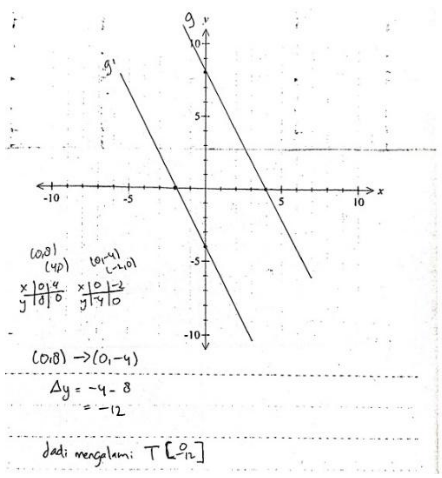

Figure 7. S3's Translation Solution

S3's creative thinking abilities had not yet shown the achievement of the flexibility and fluency indicators. The evidence of S3's solution process can be seen in Figure 7. In the figure, S3 used only one simple approach, namely by taking one point on each line and then comparing the change in the coordinate values to determine the type of transformation that occurred. S3 determined the point $(0,8)$ on the initial line and the point $(0,-4)$ on the resulting line, and then concluded that a translation of $T\binom{0}{-12}$ had occured.

This process shows that S3 followed only one procedure without attempting other possible methods to solve the same problem, such as reflection, rotation, or dilation. Therefore, S3 had not yet demonstrated the flexibility indicator because the student was unable to use or shift to other strategies to solve the problem. In addition, S3 also did not demonstrate the fluency indicator because the student produced only one answer without exploring other possible correct solutions.

This condition indicates that S3's creative thinking abilities were still at a low level because the student had not been able to demonstrate more than one creativity indicator simultaneously. This finding is in line with recent studies stating that students with low creativity levels tend to use only one solution method and are not able to generate various answers or different strategies (Ardiansyah et al., 2025; Purwati & Alberida, 2022). This finding is supported by the following brief excerpt from an interview.

W : "Why did you choose the translation method??"
S3 : "Because I saw that the line only moved downward."
W : "Is there another method or transformation?"
S3 : "I think there is, Miss, but I only remember the translation method."

The interview excerpt shows that S3 chose translation because the student only observed the direct change in the position of the line, not because the student considered several possible transformations. S3's response also indicates that the student had not yet been able to generate alternative strategies. This strengthens the result of the written work, which shows that S3 had not fulfilled the fluency and flexibility indicators. This condition is in line with Putra et al. (2024), who showed that students at low creativity levels had not fully achieved the fluency and flexibility indicators. This finding is also supported by Abdussakir et al. (2024), who stated that mathematical creative thinking abilities can be viewed from the achievement of fluency, flexibility, and novelty indicators. Therefore, low creativity is reflected when students are not yet able to generate many ideas and are not yet able to use various strategies.

Based on the overall findings, each group showed different characteristic of mathematical creativity. S1, who represented the high group, demonstrated novelty through a non-routine strategy and by rechecking the solution. This finding is in line with Schoevers et al. (2022), who stated that mathematical creativity emerges when students are able to construct meaningful ideas and do not merely follow routine procedures. S2, who represented the moderate group, demonstrated flexibility and fluency through the use of several methods and more than one form of solution. Wang and Star (2023) explained that flexibility appears when students are able to select and use different strategies according to the problems they face. S3, who represented the low group, used only one method and produced one answer, so the students had not yet fulfilled the fluency and flexibility indicators. Leikin and Pitta-Pantazi (2013) emphasized that differences in mathematical creativity abilities can be seen from the number of ideas, the diversity of strategies, and the novelty of the solutions produced.

CONCLUSION

This study shows that students' creative thinking abilities in solving open-ended problems in geometric transformation material varied across creativity groups. Students in the high-creativity group demonstrated novelty through the use of non-routine strategies, while students in the moderate-creativity group demonstrated flexibility and fluency through several solution methods. Students in the low-creativity group used only one solution method, indicating that the fluency and flexibility indicators had not yet been achieved. These findings confirm that creativity is not only reflected in the final answer but also in the process of exploring ideas and solution strategies.

Overall, open-ended problems in the form of Multiple Solution Tasks (MST) can be used to reveal various aspects of students' mathematical creativity, particularly in geometric transformation material. These tasks provide students with opportunities to develop various solutions and select strategies based on their understanding. The findings offer insights for teachers to develop more flexible and innovative mathematics learning that is not limited to a single solution procedure.

However, this study was limited to one class and focused only on geometric transformation material. Future research may involve more participants from various creativity levels and expand the scope of mathematical material to obtain more comprehensive findings. In addition, further studies may also explore external factors, such as learning methods and classroom environments, that may influence students' creativity in solving mathematical problems.

REFERENCES

Abdussakir, A., Chabibah, R., Yahya, F. H., & Ali, F. (2024). Between gender and academic achievement: Creative thinking in mathematics problem solving among junior high school students. *Beta: Jurnal Tadris Matematika*, *17*(2), 205–222. https://doi.org/10.20414/betajtm.v17i2.667

Apriliani, M., & Lisnawati, D. (2025). Analisis kemampuan berpikir kreatif matematika siswa kelas VII SMP Al Farabi pada materi geometri. *Aljabar : Jurnal Ilmuan Pendidikan, Matematika dan Kebumian*, *1*(3), 103–113. https://doi.org/10.62383/aljabar.v1i3.661

Ardiansyah, A. S., & Asikin, M. (2020). Challenging students to improve their mathematical creativity in solving multiple solution task on challenge based learning class. *Journal of Physics: Conference Series*, *1567*(2), 022088. https://doi.org/10.1088/1742-6596/1567/2/022088

Ardiansyah, D., Siswono, T. Y. E., Harini, N. V., & Heng, L. (2025). Creative thinking ability of junior high school students in solving open-ended problems on plane geometry. *Journal of the Indonesian Mathematics Education Society*, *3*(2), 88. https://doi.org/https://doi.org/10.26740/jimes.v3n2.p88-96

Ariawan, R., Leonardus Sukestiyarno, Y., Pujiastuti, E., Sugiman, S., & Zafrullah, Z. (2024). Trends in the use of critical thinking as mathematics learning over the last 20 years: analysis bibliometric. *Jurnal Pendidikan MIPA*, *25*(2), 637–658. https://doi.org/10.23960/jpmipa/v25i2.pp637-658

Creswell, J. W. (2009). *Research design (qualitative, quantitative, and mixed methods approaches)* (Third Edit). Sage Publication.

Cuong, L. M., Tien-Trung, N., Ngu, P. N. H., Vangchia, V., Thao, N. P., & Thao, T. T. P.

(2025). Mathematics problem-solving research in high school education: trends and insights from the scopus database (1983–2023). *European Journal of Science and Mathematics Education*, *13*(2), 77–89. https://doi.org/10.30935/scimath/16038

Dahal, N., Pant, B. P., Shrestha, I. M., & Manandhar, N. K. (2022). Use of geogebra in teaching and learning geometric transformation in school mathematics. *International Journal of Interactive Mobile Technologies (iJIM)*, *16*(08), 65–78. https://doi.org/10.3991/ijim.v16i08.29575

de Vink, I. C., Willemsen, R. H., Keijzer, R., Lazonder, A. W., & Kroesbergen, E. H. (2023). Supporting creative problem solving in primary geometry education. *Thinking Skills and Creativity*, *48*(May), 101307. https://doi.org/10.1016/j.tsc.2023.101307

Götz, D., & Gasteiger, H. (2022). Reflecting geometrical shapes: approaches of primary students to reflection tasks and relations to typical error patterns. *Educational Studies in Mathematics*, *111*(1), 47–71. https://doi.org/10.1007/s10649-022-10145-5

Jäder, J., & Johansson, H. (2025). Exploring students' conceptual understanding through mathematical problem solving: students' use of and shift between different representations of rational numbers. *Research in Mathematics Education*, *1*(1), 1–18. https://doi.org/10.1080/14794802.2025.2456840

Kadir, I. A., Machmud, T., Usman, K., & Katili, N. (2022). Analisis kemampuan berpikir kreatif matematis siswa pada materi segitiga. *Jambura Journal of Mathematics Education*, *3*(2), 128–138. https://doi.org/10.34312/jmathedu.v3i2.16388

Leikin, R., & Elgrably, H. (2022). Strategy creativity and outcome creativity when solving open tasks: focusing on problem posing through investigations. *ZDM – Mathematics Education*, *54*(1), 35–49. https://doi.org/10.1007/s11858-021-01319-1

Leikin, R., & Pitta-Pantazi, D. (2013). Creativity and mathematics education: the state of the art. *ZDM – Mathematics Education*, *45*(2), 159–166. https://doi.org/10.1007/s11858-012-0459-1

Levav-Waynberg, A., & Leikin, R. (2012). The role of multiple solution tasks in developing knowledge and creativity in geometry. *The Journal of Mathematical Behavior*, *31*(1), 73–90. https://doi.org/10.1016/j.jmathb.2011.11.001

Levenson, E. S., & Dasuqi, A. (2025). Exploring group work on open-ended geometrical tasks: face-to-face and online. *International Journal of Science and Mathematics Education*, *23*(6), 1629–1650. https://doi.org/10.1007/s10763-024-10532-9

Lu, X., & Kaiser, G. (2022). Can mathematical modelling work as a creativity-demanding activity? An empirical study in China. *ZDM - Mathematics Education*, *54*(1), 67–81. https://doi.org/10.1007/s11858-021-01316-4

Lu, X., Kaiser, G., Zhu, Y., Ma, H., & Yan, Y. (2025). Mathematical creativity in modelling: further development of the construct, its measurement, and its empirical implementation. *ZDM – Mathematics Education*, *57*(2–3), 365–379. https://doi.org/10.1007/s11858-025-01652-9

Markovitz, L. M., Leikin, R., & Landau, G. M. (2025). Who succeeds in STEM studies? following the funnel. *International Journal of Science and Mathematics Education*, *23*(6), 1981–2007. https://doi.org/10.1007/s10763-025-10594-3

Matić, L. J., & Sliško, J. (2022). An empirical study of mathematical creativity and students' opinions on multiple solution tasks. *International Journal of Mathematical Education in Science and Technology*, *55*(9), 2170–2190. https://doi.org/10.1080/0020739X.2022.2129496

Miles, M. B., & Huberman Michael, A. (1994). Qualitative data analysis. In *Qualitative Data Analysis second edition* (2 ed., hal. 1–354). Sage Publication.

Musa, L. A. D., Munir, N. P., Muhammad Ikram, Javier Garcia Garcia, & Camilo Andres Rodriguez-Nieto. (2025). Students' problem-solving skills in HOTS geometry tasks: A

case study of spatial ability. *Al-Jabar : Jurnal Pendidikan Matematika*, *16*(2), 597–614. https://doi.org/10.24042/ajpm.v16i2.28482
Musser, G. L., Trimpe, L. E., & Maurer, V. R. (2008). *A problem-solving approach with applications* (P. Recter (ed.); 2nd ed.). Pearson Prentice Hall.
NCTM. (2000). Principles and Standarts for School Mathematis. In *Jurnal Sains dan Seni ITS* (Vol. 6, Nomor 1). http://repositorio.unan.edu.ni/2986/1/5624.pdf%0Ahttp://fiskal.kemenkeu.go.id/ejournal%0Ahttp://dx.doi.org/10.1016/j.cirp.2016.06.001%0Ahttp://dx.doi.org/10.1016/j.powtec.2016.12.055%0Ahttps://doi.org/10.1016/j.ijfatigue.2019.02.006%0Ahttps://doi.org/10.1
Nuryah, L., Mufidah, R., Budayasa, I. K., & Lukito, A. (2025). Exploring gender differences in middle school students ' creative approaches to open-ended geometry problems. *Jurnal Riset Pendidikan dan Inovasi Pembelajaran Matematika*, *9*(1), 77–87. https://doi.org/https://doi.org/10.26740/jrpipm.v9n1.p77-87
OECD. (2022). *Insights and interpretastions*. Programme for International Student Assessment (PISA) 2022.
Pradiarti, R. A., Sudirman, S., & Sisworo, S. (2024). Students' creative thinking process in solving multiple solution tasks on geometry material. *Jurnal Pendidikan MIPA*, *25*(1), 248–263. https://doi.org/10.23960/jpmipa/v25i1.pp248-263
Prambudi, S. A., Susanto, H., & Purwanto, P. (2025). Creative models of junior high school students in solving open ended mathematical problems on keirsey personality types. *PRISMA*, *14*(1), 34. https://doi.org/10.35194/jp.v14i1.4773
Purwati, P., Wulandari, T. C., & Soemantri, S. (2025). Creative problem-solving tasks and mathematical creativity: a second-order construct approach. *Journal of Honai Math*, *8*(2), 197–210. https://doi.org/10.30862/jhm.v8i2.944
Purwati, S., & Alberida, H. (2022). Profile of students' creative thinking skills in high school. *Thinking Skills and Creativity Journal*, *5*(1), 22–27. https://doi.org/10.23887/tscj.v5i1.45432
Putra, Y. Y., AB, J. S., & Fitri Rahmadi, I. (2024). Level of creative thinking ability of students in solving numeracy problems. *Journal of Research and Advances in Mathematics Education*, *9*(2), 66–74. https://doi.org/10.23917/jramathedu.v9i2.10453
Rahmadani, A. S., & Rahmadani, D. (2025). Analisis kesalahan siswa dalam menyelesaikan soal cerita teorema pythagoras berdasarkan teori kastolan. *Primatika: Jurnal Pendidikan Matematika*, *14*(2), 309–322. https://doi.org/https://doi.org/10.30872/primatika.v14i2.5653
Säfström, A. I., Lithner, J., Palm, T., Palmberg, B., Sidenvall, J., Andersson, C., Boström, E., & Granberg, C. (2024). Developing a diagnostic framework for primary and secondary students' reasoning difficulties during mathematical problem solving. *Educational Studies in Mathematics*, *115*(2), 125–149. https://doi.org/10.1007/s10649-023-10278-1
Schoevers, E. M., Kroesbergen, E. H., Moerbeek, M., & Leseman, P. P. M. (2022). The relation between creativity and students' performance on different types of geometrical problems in elementary education. *ZDM – Mathematics Education*, *54*(1), 133–147. https://doi.org/10.1007/s11858-021-01315-5
Septian, A., Komala, E., & Komara, K. A. (2019). Pembelajaran dengan model creative problem solving (CPS) untuk meningkatkan kemampuan berpikir kreatif matematis siswa. *PRISMA*, *8*(2), 182–190. https://doi.org/https://doi.org/10.35194/jp.v8i2.376
Serin, H. (2018). Perspectives on the teaching of geometry: teaching and learning methods. *Journal of Education and Training*, *5*(1), 1. https://doi.org/10.5296/jet.v5i1.12115
Setiana, D. S., Purwoko, R. Y., & Sugiman, S. (2021). The application of mathematics

learning model to stimulate mathematical critical thinking skills of senior high school students. *European Journal of Educational Research*, *volume-10*-(volume-10-issue-1-january-2021), 509–523. https://doi.org/10.12973/eu-jer.10.1.509

Silver, E. A. (1997). Fostering creativity through instruction rich in mathematical problem solving and problem posing. *Zentralblatt für Didaktik der Mathematik*, *29*(3), 75–80. https://doi.org/10.1007/s11858-997-0003-x

Sipahi, Y., & Bahar, A. K. (2025). Mathematical creativity: a systematic review of definitions, frameworks, and assessment practices. *Education Sciences*, *15*(10), 1348. https://doi.org/10.3390/educsci15101348

Siswono, T. Y. E. (2008). Proses berpikir kreatif siswa dalam memecahkan dan mengajukan masalah matematika. *Jurnal Ilmu Pendidikan*, *15*(1), 60–68.

Subanji, S., Nusantara, T., Rahmatina, D., & Purnomo, H. (2021). The statistical creative framework in descriptive statistics activities. *International Journal of Instruction*, *14*(2), 591–608. https://doi.org/10.29333/iji.2021.14233a

Subanji, S., Nusantara, T., Sukoriyanto, S., & Atmaja, S. A. A. (2023). Student's creative model in solving mathematics controversial problems. *Jurnal Cakrawala Pendidikan*, *42*(2), 310–326. https://doi.org/10.21831/cp.v42i2.55979

Suherman, S., & Vidákovich, T. (2022). Assessment of mathematical creative thinking: A systematic review. *Thinking Skills and Creativity*, *44*(January), 101019. https://doi.org/10.1016/j.tsc.2022.101019

Turgut, M. (2022). Reinventing geometric linear transformations in a dynamic geometry environment: multimodal analysis of student reasoning. *International Journal of Science and Mathematics Education*, *20*(6), 1203–1223. https://doi.org/10.1007/s10763-021-10185-y

Vale, I., & Barbosa, A. (2023). Active learning strategies for an effective mathematics teaching and learning. *European Journal of Science and Mathematics Education*, *11*(3), 573–588. https://doi.org/10.30935/scimath/13135

Wang, H., & Star, J. R. (2023). Investigating algorithm-oriented flexibility and structure-informed flexibility in mathematics learning. *Asian Journal for Mathematics Education*, *2*(1), 16–41. https://doi.org/10.1177/27527263231163593

Yayuk, E., Purwanto, P., As'ari, A. R., & Subanji, S. (2020). Primary school students' ceative thinking skills in mathematics problem solving. *European Journal of Educational Research*, *volume-9-2*(volume-9-issue-3-july-2020), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281

Žakelj, A., & Klančar, A. (2022). The role of visual representations in geometry learning. *European Journal of Educational Research*, *11*(3), 1393–1411. https://doi.org/10.12973/eu-jer.11.3.1393