Interval: Indonesian Journal of Mathematical Education
Vol. 2, No. 2, December 2024, pp. 132~140
ISSN: 3021-7857, DOI: 10.37251/ijome.v2i2.1343

The Correlation between Students' Problem-Solving Abilities and Their Mathematical Thinking in High School Mathematics Education

Edwar Firmansyah[1], Ines Buissa Baluta[2], Khaled Elfaituri[3]
[1]Betung 1 State Senior High School, Sumatera Selatan, Indonesia
[2]Department of Mathematics Teaching and Research, Universidade 11 de Novembro, Cabinda, Angola
[3]Department of Mathematics, Faculty of Science, University of Tripoli, Tripoli, Libya

Article Info

Article history:

Received Sep 9, 2024
Revised Oct 11, 2024
Accepted Nov 9, 2024
Online First Dec 12, 2024

Keywords:

Ability
Learning
Mathematical Thinking
Mathematics
Problem Solving

ABSTRACT

Purpose of the study: The aim of this study is to explore the relationship between students' problem-solving abilities and mathematical thinking, and to identify how these two abilities can support each other in the development of holistic mathematical skills in secondary education.

Methodology: This study uses quantitative methods with correlational and survey designs. The instrument used is a written test, consisting of story questions and multiple choices. Data collection is done through structured observation and documentation. The software used for data analysis is SPSS, with descriptive and inferential statistical analysis techniques, including the Pearson correlation test and simple linear regression test.

Main Findings: The results of the study showed that there was a strong and significant relationship between problem-solving ability and mathematical thinking of students in grades 11.F1 ($r = 0.74$, $p = 0.001$) and 11.F3 ($r = 0.68$, $p = 0.003$). Problem-solving ability was also shown to predict mathematical thinking with a significant effect ($R^2 = 0.55$, $p = 0.001$). The problem-solving factor can explain 55% of the variance in students' mathematical thinking.

Novelty/Originality of this study: This study shows a strong correlation between secondary school pupils' mathematical thinking and problem-solving skills, particularly when it comes to number-related content. The study's originality is the finding that students' problem-solving skills can anticipate how their mathematical thinking will evolve, offering fresh perspectives for creating learning models that would simultaneously improve both abilities.

Corresponding Author:
Edwar Firmansyah,
Betung 1 State Senior High School,
JL. Penghulu Ali Basir Lingkar 1 Betung, Rimba Asam, Kec. Betung, Kab. Banyuasin, Sumatera Selatan
Email: edwarfirnansyah01@gmail.com

1. INTRODUCTION

Mathematics learning in secondary schools plays an important role in shaping students' cognitive abilities to solve problems and think critically. Along with the development of technology and the demands of globalization, mathematics education must be able to face new challenges by introducing innovative approaches that can stimulate students' thinking power [1]-[3]. Basically, mathematics is one of the subjects that makes a major contribution to the development of logical and analytical skills, which are very necessary in various fields of life [4]-[6]. Therefore, it is important for mathematics teaching to facilitate students in understanding mathematical concepts in depth, and to be able to connect theory with applications in everyday life [7]-[9]. Thus, effective mathematics learning must emphasize the development of higher mathematical thinking skills [9]-[11].

Students' mathematical ability is the main indicator in determining the extent to which students can understand and apply the mathematical concepts that have been learned. This ability covers various aspects, including problem solving, conceptual understanding, and mathematical communication skills [12]-[14]. Good mathematical ability is not only important for students' academic success, but also for their ability to face life's challenges that require critical and analytical thinking [15]-[17]. In the context of education, mathematical ability can be divided into basic abilities and advanced abilities, all of which function to support the development of students' competencies in dealing with more complex problems in the real world [18]-[20]. Therefore, the development of continuous mathematical abilities becomes the main focus in mathematics learning at the secondary school level.

Mathematical problem-solving ability is one of the most important aspects in mathematics education, because through problem-solving students can practice critical, creative, and logical thinking skills. Problem-solving not only requires students to find the correct solution, but also involves complex thinking processes, including analysis, evaluation, and synthesis of information [21], [22]. This ability is key in helping students understand and master more abstract mathematical concepts [23]-[25]. Furthermore, problem-solving ability provides students with the opportunity to learn how to face various challenges and find efficient solutions in various contexts [26], [27]. Therefore, it is important to cultivate and improve problem-solving abilities in every mathematics learning activity [28]-[30].

Mathematical thinking is the ability to think logically and systematically in solving mathematical problems. This includes the ability to understand and construct arguments based on mathematical principles, as well as formulate and solve problems in a structured way [31]-[33]. Good mathematical thinking requires a deep understanding of mathematical concepts, as well as the ability to apply these concepts in different contexts [34], [35]. In addition, mathematical thinking is also closely related to students' ability to generalize, analyze, and synthesize in the context of mathematical problems [36], [37]. This thinking is very important in mathematics learning, because it will help students to develop the skills needed to face more complex challenges.

Previous research conducted by Jailani et al., [38] obtained the main findings indicating that most students had difficulties in various aspects of mathematical connections, such as different representations, part-whole relationships, connections between mathematical concepts, and relationships between mathematical procedures. Then the research conducted by Malangtupthong et al., [39] found that teacher teaching and attitudes toward mathematics have a positive influence on mathematical problem solving competence. Previous research conducted by Inweregbuh et al., [40] found that students' achievement in creative thinking is still below average, one way to encourage students' creativity is by giving students the opportunity to solve open and less structured mathematical problems. The gaps in the three studies indicate that there has been no comprehensive study linking students' problem-solving abilities with mathematical thinking, especially in the context of mathematics education at the secondary school level. To fill this gap by exploring the relationship between the two core abilities.

Although research has shown the importance of these two abilities, there is still a significant gap in the mastery of problem solving and mathematical thinking among students in secondary schools. Several studies have shown that many students still have difficulty in applying mathematical concepts in solving more complex problems [37], [41]. In addition, although the importance of these two abilities has been recognized, existing teaching methods often do not effectively integrate the development of problem solving and mathematical thinking in every aspect of learning.

This study aims to explore the relationship between students' problem solving and mathematical thinking abilities in secondary schools, and to identify how both can support each other in the development of overall mathematical skills. The novelty of this study lies in the approach that examines both aspects comprehensively in the context of mathematics learning in Indonesia. The urgency of this research is very high, considering the importance of mastering these two abilities to prepare students to face global challenges in the future. With this research, it is hoped that it can provide new insights into how these two skills can be developed optimally in mathematics learning, so that it can improve the quality of mathematics education in high schools.

2. RESEARCH METHOD

This study uses a quantitative approach with a survey method. The quantitative approach was chosen because this study aims to measure the relationship between problem-solving abilities and mathematical thinking of high school students objectively, using numerical data that is analyzed statistically.

2.1 Research Design

This study uses a quantitative method with a correlational design to test the relationship between students' problem-solving abilities and mathematical thinking in mathematics learning in high school. This study focuses on number material. The correlational design was chosen because this study aims to identify the level of relationship between two variables without giving special treatment to the research subjects. This study was conducted cross-sectionally, where data was collected at a certain time to provide an overview of the relationship

between students' problem-solving abilities and mathematical thinking. Mathematical problem-solving abilities (independent variable). Students' mathematical thinking (dependent variable).

2.2 Population and Sample

The population in this study was all students of State Senior High School 1 Betung who were actively participating in mathematics learning during the academic year of the study. The research sample consisted of students in phase F, namely classes 11.F1 and 11.F3, at State Senior High School 1 Betung. The sampling technique used simple random sampling, where classes F1 and F3 were selected because they were representations of phase F that were relevant to the research objectives. The number of samples will be adjusted based on the number of students in both classes to ensure adequate representation.

2.3 Data Collection Techniques

Research data were collected through written tests specifically designed to measure students' problem-solving and mathematical thinking abilities. This test was conducted in the form of:

Problem-solving ability questions: Using essay-style story questions to evaluate students' abilities in analyzing, evaluating, and solving complex problems.

Mathematical thinking questions: Using a combination of multiple-choice and short essay questions to measure students' abilities in generalization, pattern recognition, and logical argumentation

During the test, structured observations were conducted to ensure that students completed the test independently and according to instructions. These observations were also used to record non-technical factors that could affect test results, such as students' concentration levels and environmental conditions. Documentation in the form of student attendance lists, answer sheets, and observation notes were used to complete the research data. All of these documents were archived for further analysis. The instruments in this study were valid and reliable with a Cronbach alpha value of 0.70. The outline of this research instrument is as follows:

Table 1. Grid of problem-solving ability research instruments

No	Indicators	Type of Question	Question Form	Number of Items	Cognitive Level (Bloom's Taxonomy)
1	Analyze problems from story problems (identify data, information, and solution needs).	Essay	About the story	2	C4 (Analysis)
2	Determine appropriate problem-solving strategies.	Essay	About the story	2	C5 (Evaluation)
3	Carry out solution steps until a solution is found.	Essay	About the story	3	C3 (Application)
4	Evaluate the solution obtained to ensure its correctness.	Essay	About the story	2	C5 (Evaluation)

The grid for the student's mathematical thinking instrument is presented in Table 2..

Table 2. Grid of mathematical thinking research instruments

No	Indicators	Question Type	Question Type	Number of Items	Cognitive Level (Bloom's Taxonomy)
1	Generalize patterns from numerical data or images.	Multiple Choice	Numerical/picture pattern	3	C4 (Analysis)
2	Make logical arguments based on specific data or mathematical principles.	Short Description	Logical explanation	2	C5 (Evaluation)
3	Connect mathematical concepts to real-life applications.	Multiple Choice and Essay	Contextual questions	3	C3 (Application)
4	Generalize more abstract mathematical concepts.	Short Description	Abstract concepts	2	C6 (Creation)

The maximum score of this research test instrument is 100. The categories for problem solving and mathematical thinking skills in the research are presented in Table 3 below:

Table 3. Research instrument categories

Score Interval	Category
85 - 100	Excellent
70 - 84	Good
55 - 69	Fair
< 55	Poor

2.4 Data Analysis Techniques

Data analysis in this study used descriptive statistics and inferential statistics. Descriptive statistics are used to describe the profile of students' problem-solving and mathematical thinking abilities, such as average, median, and standard deviation. The inferential statistics used are the Pearson correlation test used to determine the level and direction of the relationship between students' problem-solving and mathematical thinking abilities. And a simple linear regression test to determine the magnitude of the influence of variable X on variable Y [42]. This test was chosen because both variables have an interval or ratio data scale. Before the correlation analysis was carried out, prerequisite tests were carried out in the form of normality tests and linearity tests to ensure that the data met the assumptions of parametric statistics.

3. RESULTS AND DISCUSSION

This study aims to analyze the relationship between problem-solving ability and mathematical thinking of high school students in the context of mathematics learning. A quantitative approach with a correlational design is used to describe the relationship between the two variables objectively, based on empirical data collected through standardized test instruments. This study focuses on number material, as one of the basic topics that has high relevance in mathematics learning at the secondary school level.

The results of the study presented in this section aim to answer the research questions related to the level of relationship between problem-solving ability and mathematical thinking. Data analysis was carried out through inferential statistical tests, including Pearson's correlation test and simple linear regression, to identify the strength and direction of the relationship between the two variables. In addition, descriptive data on student ability profiles are also presented to provide a more detailed picture of student achievement in the aspects measured.

This section will also discuss the implications of the research findings for mathematics learning theory and classroom teaching practices. A comprehensive discussion is designed to explain the significance of the findings in the context of mathematics education, as well as provide recommendations for the development of more effective learning models in improving both abilities. The findings of this study are expected to make a real contribution to improving the quality of mathematics learning at the secondary school level. The results of descriptive statistics on students' problem-solving and mathematical thinking abilities in learning mathematics on number material are presented in Table 6.

Table 6. Description of students' problem solving abilities

Class	Category	Interval	F	%	Mean	Med	Min	Max
11.F1	Poor	< 55	0	0	71.2	72	58	90
	Fair	55 - 69	14	46.7%				
	Good	70 - 84	14	46.7%				
	Excellent	85 - 100	2	6.6%				
11.F3	Poor	< 55	1	3.3%	70.1	71	52	83
	Fair	55 - 69	15	50%				
	Good	70 - 84	14	46.7%				
	Excellent	85 - 100	0	0				

The results of the descriptive analysis show the profile of students' problem-solving abilities in two research classes, namely classes 11.F1 and 11.F3. In class 11.F1, there are no students in the Poor category (<55), as many as 46.7% of students are in the Fair category (55 – 69), 46.7% of students are in the Good category (70 – 84), and only 6.6% of students reach the Excellent category (85 – 100), with an average score (Mean) of 71.2, a middle score (Median) of 72, a minimum score (Min) of 58, and a maximum score (Max) of 90. Meanwhile, in class 11.F3, there are 3.3% of students in the Poor category (<55), 50% of students are in the Fair category (55 – 69), 46.7% of students are in the Good category (70 – 84), and no students reach the Excellent category (85 – 100), with an average score (Mean) of 70.1, a middle score (Median) of 71, a minimum score (Min) of 52, and a maximum score (Max) of 90. (Max) 83. This finding shows that there is variation in problem-solving ability between classes 11.F1 and 11.F3. Factors such as teaching strategies, learning motivation, and classroom conditions can be determinants of the differences in these results. This result provides insight for mathematics

teachers to focus more on learning approaches that support the improvement of students' problem-solving abilities, especially in the Fair and Poor categories.

Furthermore, the description of students' mathematical thinking in mathematics learning on number material is presented in the following table 7:

Table 7. Descriptive statistical results of students' mathematical thinking

Class	Category	Interval	F	%	Mean	Med	Min	Max
11.F1	Poor	< 55	1	3.3%	70.2	71	54	90
	Fair	55 - 69	14	46.7%				
	Good	70 - 84	13	43.3%				
	Excellent	85 - 100	2	6.7%				
11.F3	Poor	< 55	2	6.7%	70.1	71	52	86
	Fair	55 - 69	15	50%				
	Good	70 - 84	12	40%				
	Excellent	85 - 100	1	3.3%				

The results of the descriptive analysis show the profile of students' mathematical thinking abilities in two research classes, namely classes 11.F1 and 11.F3. In class 11.F1, 3.3% of students are in the Poor category (<55), 46.7% of students are in the Fair category (55 – 69), 43.3% of students are in the Good category (70 – 84), and 6.7% of students reach the Excellent category (85 – 100), with an average score (Mean) of 70.2, a middle score (Median) of 71, a minimum score (Min) of 54, and a maximum score (Max) of 90. Meanwhile, in class 11.F3, there are 6.7% of students in the Poor category (<55), 50% of students are in the Fair category (55 – 69), 40% of students are in the Good category (70 – 84), and 3.3% of students reach the Excellent category (85 – 100), with an average score (Mean) of 70.1, a middle score (Median) of 71, a minimum score (Min) of 52, and a maximum score (Max) of 90. maximum (Max) 86.

Before the inferential analysis was carried out, the data were tested with prerequisite tests including normality tests and linearity tests. The normality test was carried out using the Kolmogorov-Smirnov test to ensure that the data were normally distributed. The results of the normality test showed that the significance value of the problem-solving ability data in class 11.F1 was 0.123 and in class 11.F3 was 0.089. Meanwhile, the significance value of the mathematical thinking data in class 11.F1 was 0.076 and in class 11.F3 was 0.054. Since all significance values were greater than 0.05, it can be concluded that the data were normally distributed. The linearity test was carried out to ensure that the relationship between problem-solving ability and mathematical thinking was linear. The results of the linearity test showed that the significance value of the relationship between the two variables in class 11.F1 was 0.001 and in class 11.F3 was 0.003. Since the significance value was less than 0.05, it can be concluded that there is a linear relationship between the two variables. The results of this prerequisite test show that the data meets the parametric statistical assumptions so that it can be continued with inferential analysis..

Table 8. Results of the Pearson correlation test of problem solving ability and mathematical thinking

Class	Pearson Correlation Value (r)	Significance Value (p)	Interpretation
11.F1	0.74	0.001	Strong and significant relationship
11.F3	0.68	0.003	Strong and significant relationship

The positive and significant correlation values in both classes indicate a strong relationship between students' problem-solving abilities and mathematical thinking. The higher the students' problem-solving abilities, the higher their mathematical thinking abilities. With a significance value of less than 0.05, it can be concluded that the relationship between the two variables in both classes is significant. Furthermore, a simple linear regression test was used to determine whether problem-solving abilities can predict students' mathematical thinking. The regression model used is as follows:

Table 9. Results of simple linear regression test of problem solving and mathematical thinking abilities

Regression Equation	R^2	Significance Value (p) Interpretation	Significance Value (p) Interpretation
Y=0.45X+29.6Y	0.55	0.001	Problem solving ability significantly predicts mathematical thinking

The results of the simple linear regression test show that problem-solving ability has a significant effect on students' mathematical thinking. The regression equation obtained is Y = 0.45X + 29.6Y, where Y represents mathematical thinking and X represents problem-solving ability. The regression coefficient of 0.45 indicates that every 1 point increase in problem-solving ability will increase mathematical thinking by 0.45 points. The R2 value

of 0.55 indicates that 55% of the variance in mathematical thinking can be explained by the problem-solving ability variable. This shows a fairly large influence of problem-solving ability on mathematical thinking, although there are other factors that also influence it. In addition, the significance value ($p = 0.001$) which is smaller than 0.05 indicates that the relationship between the two variables is significant, meaning that problem-solving ability can predict students' mathematical thinking with a high level of confidence. These findings provide strong evidence that the development of problem-solving skills can be an important factor in improving students' mathematical thinking abilities. These results lead to the conclusion that improving problem-solving skills not only affects students' ability to solve mathematical problems, but also in developing deeper mathematical thinking. Therefore, mathematics learning that integrates more complex and contextual problem-solving exercises is needed to help students achieve higher mathematical thinking, as well as prepare them for further academic challenges.

The results of the current study are in line with previous studies in terms of focusing on developing problem-solving skills as a primary skill in mathematics learning. Previous studies have shown that approaches such as Problem-Based Learning (PBL) can effectively improve students' problem-solving skills, which also have implications for critical thinking skills [43]. The results of the current study show alignment with previous studies in terms of focusing on the development of students' mathematical thinking skills as a key component in mathematics learning. The results show that the higher the level of students' mathematical abilities, the more diverse the thinking patterns they use in solving problems, especially related to algebraic functions [44], [45]. This confirms the importance of mathematical thinking skills in influencing how students understand and solve problems. Thus, both previous and current research support the view that students' mathematical thinking skills are influenced not only by the learning approach but also by their ability to solve complex mathematical problems. The current study extends previous findings by quantitatively exploring the relationship between problem-solving skills and mathematical thinking, providing new insights for developing more integrated and effective learning strategies.

The novelty of this research lies in a deeper understanding of the relationship between problem-solving skills and students' mathematical thinking in the context of mathematics learning at the secondary school level, especially in number material. The findings of this study reveal that problem-solving skills are not only related to the ability to solve mathematical problems, but also act as a significant predictor of the development of students' mathematical thinking [46], [47]. This study also shows that although other factors also influence, 55% of the variance in mathematical thinking can be explained by problem-solving skills, which provides strong empirical evidence of the importance of developing problem-solving skills in improving students' mathematical thinking. These findings are expected to be the basis for developing more effective learning models in improving both skills simultaneously in the classroom.

The implications of this study for the field of mathematics education are the importance of integrating problem-solving skills into mathematics learning to improve students' mathematical thinking. The findings of the study indicate that problem-solving skills have a significant influence on students' mathematical thinking skills, which means that mathematics teaching that emphasizes the development of these skills can have a positive impact on students' critical and analytical thinking skills in solving mathematical problems. Therefore, teachers need to design and implement learning strategies that focus on developing problem-solving skills, such as through a problem-based learning approach or contextual learning that challenges students to think creatively and logically [48]-[50].

The impact of the results of this study is its contribution to improving the quality of mathematics learning in secondary schools by providing insight into how problem-solving skills can be a key factor in developing students' mathematical thinking. The results of this study also provide valuable information for the development of a more effective mathematics curriculum, by considering the importance of balancing the mastery of basic mathematical concepts and the development of problem-solving skills. Thus, this study contributes to the development of better learning models and can improve students' achievement of mathematical competence, both in the context of exams and in everyday life applications. The limitations of this study lie in the sample being limited to two classes in one school, which may not represent the entire population of students at the secondary school level, as well as the focus only on number material.

4. CONCLUSION

This study concludes that there is a significant relationship between problem-solving ability and mathematical thinking of students at the secondary school level, especially in number material. The results of the analysis show that problem-solving ability has a significant positive effect on the development of students' mathematical thinking. This finding indicates that improving problem-solving skills can improve students' mathematical thinking, which is important in improving students' ability to solve more complex and contextual mathematical problems. Thus, the integration of challenging problem-solving exercises in mathematics learning is needed to support the development of students' mathematical thinking, as well as prepare them for higher academic challenges. This study provides an important contribution to the development of a more effective

mathematics learning model, which can improve students' problem-solving skills and mathematical thinking simultaneously. Recommendations for further research can expand the sample and learning materials to explore the relationship between students' problem-solving ability and mathematical thinking in various contexts and levels of education.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to all parties who have supported and contributed to the completion of this research. I appreciate the efforts of all parties who have helped in data collection and analysis.

REFERENCES

[1] P. Körtesi, Z. Simonka, Z. K. Szabo, J. Guncaga, and R. Neag, "Challenging Examples of the Wise Use of Computer Tools for the Sustainability of Knowledge and Developing Active and Innovative Methods in STEAM and Mathematics Education," *Sustain.*, vol. 14, no. 20, pp. 1–23, 2022, doi: 10.3390/su142012991.

[2] P. Yaniawati, R. Kariadinata, N. M. Sari, E. E. Pramiarsih, and M. Mariani, "Integration of e-learning for mathematics on resource-based learning: Increasing mathematical creative thinking and self-confidence," *Int. J. Emerg. Technol. Learn.*, vol. 15, no. 6, pp. 60–78, 2020, doi: 10.3991/ijet.v15i06.11915.

[3] Z. K. Szabo, P. Körtesi, J. Guncaga, D. Szabo, and R. Neag, "Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills," *Sustain.*, vol. 12, no. 23, pp. 1–28, 2020, doi: 10.3390/su122310113.

[4] T. S. Sheromova, A. N. Khuziakhmetov, V. A. Kazinets, Z. M. Sizova, S. I. Buslaev, and E. A. Borodianskaia, "Learning styles and development of cognitive skills in mathematics learning," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 16, no. 11, 2020, doi: 10.29333/EJMSTE/8538.

[5] B. H. Majeed and L. F. Jawad, "Tactical Thinking and its Relationship with Solving Mathematical Problems Among Mathematics Department Students Importance of Research," *iJET*, vol. 16, no. 09, pp. 247–262, 2021.

[6] L. F. Jawad, B. H. Majeed, and H. T. S. Alrikabi, "The Impact of Teaching by Using STEM Approach in The Development of Creative Thinking and Mathematical Achievement Among the Students of The Fourth Scientific Class," *Int. J. Interact. Mob. Technol.*, vol. 15, no. 13, pp. 172–188, 2021, doi: 10.3991/ijim.v15i13.24185.

[7] S. Papadakis, M. Kalogiannakis, and N. Zaranis, "Teaching mathematics with mobile devices and the Realistic Mathematical Education (RME) approach in kindergarten," *Adv. Mob. Learn. Educ. Res.*, vol. 1, no. 1, pp. 5–18, 2021, doi: 10.25082/amler.2021.01.002.

[8] N. Maryani and D. B. Widjajanti, "Mathematical literacy: How to improve it using contextual teaching and learning method?," *J. Phys. Conf. Ser.*, vol. 1581, no. 1, 2020, doi: 10.1088/1742-6596/1581/1/012044.

[9] G. Greefrath, H. S. Siller, K. Vorhölter, and G. Kaiser, "Mathematical modelling and discrete mathematics: opportunities for modern mathematics teaching," *ZDM - Math. Educ.*, vol. 54, no. 4, pp. 865–879, 2022, doi: 10.1007/s11858-022-01339-5.

[10] E. Aldila Afriansyah, T. Herman, Turmudi, and J. Afgani Dahlan, "Critical thinking skills in mathematics," *J. Phys. Conf. Ser.*, vol. 1778, no. 1, 2021, doi: 10.1088/1742-6596/1778/1/012013.

[11] H. C. Çelik and F. Özdemir, "Mathematical thinking as a predictor of critical thinking dispositions of pre-service mathematics teachers," *Journal, Int. Educ.*, vol. 16, no. 4, pp. 0–3, 2020, doi: 10.29329/ijpe.2020.268.6.

[12] Y. Harisman, D. E. Mayani, Armiati, H. Syaputra, and M. H. Amiruddin, "Analysis of Student'S Ability To Solve Mathematical Literacy Problems in Junior High Schools in the City Area," *Infin. J.*, vol. 12, no. 1, pp. 55–68, 2023, doi: 10.22460/infinity.v12i1.p55-68.

[13] E. Ahdhianto, Marsigit, Haryanto, and N. N. Santi, "The effect of metacognitive-based contextual learning model on fifth-grade students' problem-solving and mathematical communication skills," *Eur. J. Educ. Res.*, vol. 9, no. 2, pp. 753–764, 2020, doi: 10.12973/eu-jer.9.2.753.

[14] M. Khalid, S. Saad, S. R. Abdul Hamid, M. Ridhuan Abdullah, H. Ibrahim, and M. Shahrill, "Enhancing creativity and problem solving skills through creative problem solving in teaching mathematics," *Creat. Stud.*, vol. 13, no. 2, pp. 270–291, 2020, doi: 10.3846/cs.2020.11027.

[15] B. Arisoy and B. Aybek, "The effects of subject-based critical thinking education in mathematics on students' critical thinking skills and virtues*," *Eurasian J. Educ. Res.*, vol. 2021, no. 92, pp. 99–120, 2021, doi: 10.14689/ejer.2021.92.6.

[16] S. Sachdeva and P.-O. Eggen, "Learners' Critical Thinking About Learning Mathematics," *Int. Electron. J. Math. Educ.*, vol. 16, no. 3, p. em0644, 2021, doi: 10.29333/iejme/11003.

[17] D. H. Tong, N. P. Loc, B. P. Uyen, and T. H. Son, "Enhancing creative and critical thinking skills of students in mathematics classrooms: An experimental study of teaching the inequality in high schools," *Univers. J. Educ. Res.*, vol. 8, no. 2, pp. 477–489, 2020, doi: 10.13189/ujer.2020.080219.

[18] V. Pina, V. M. Campello, K. Lekadir, S. Seguí, J. M. García-Santos, and L. J. Fuentes, "Mathematical Abilities in School-Aged Children: A Structural Magnetic Resonance Imaging Analysis With Radiomics," *Front. Neurosci.*, vol. 16, no. April, pp. 1–12, 2022, doi: 10.3389/fnins.2022.819069.

[19] A. A. Setiawan, A. Muhtadi, and J. Hukom, "Blended Learning and Student Mathematics Ability in Indonesia: A Meta-Analysis Study," *Int. J. Instr.*, vol. 15, no. 2, pp. 905–916, 2022, doi: 10.29333/iji.2022.15249a.

[20] F. Anam, J. R. Suteja, A. Septianto, A. Purnomo, and Y. P. Utami, "Improving the Numeracy Mathematics Ability: The Role of Abacus Learning Model," *J. Phys. Conf. Ser.*, vol. 1594, no. 1, 2020, doi: 10.1088/1742-6596/1594/1/012041.

[21] F. S. Fatimah, H. Asy'ari, A. Sandria, and J. A. Nasucha, "Learning Fiqh Based on the TAPPS (Think Aloud Pair Problem Solving) Method in Improving Student Learning Outcomes," *At-tadzkir Islam. Educ. J.*, vol. 2, no. 1, pp. 1–15, 2023, doi: 10.59373/attadzkir.v2i1.13.

[22] E. Xu, W. Wang, and Q. Wang, "The effectiveness of collaborative problem solving in promoting students' critical thinking: A meta-analysis based on empirical literature," *Humanit. Soc. Sci. Commun.*, vol. 10, no. 1, pp. 1–11, 2023, doi: 10.1057/s41599-023-01508-1.

[23] J. F. P. Luzano, "The Interplay of Conceptual Understanding and Problem-Solving Competence in Mathematics," *Int. J. Multidiscip. Approach Stud.*, vol. 10, no. 2, 2023.

[24] F. Del Cerro Velázquez and G. M. Méndez, "Application in augmented reality for learning mathematical functions: A study for the development of spatial intelligence in secondary education students," *Mathematics*, vol. 9, no. 4, pp. 1–19, 2021, doi: 10.3390/math9040369.

[25] M. Öztürk, Y. Akkan, and A. Kaplan, "Reading comprehension, Mathematics self-efficacy perception, and Mathematics attitude as correlates of students' non-routine Mathematics problem-solving skills in Turkey," *Int. J. Math. Educ. Sci. Technol.*, vol. 51, no. 7, pp. 1042–1058, 2020, doi: 10.1080/0020739X.2019.1648893.

[26] N. Pongsakdi, A. Kajamies, K. Veermans, K. Lertola, M. Vauras, and E. Lehtinen, "What makes mathematical word problem solving challenging? Exploring the roles of word problem characteristics, text comprehension, and arithmetic skills," *ZDM - Math. Educ.*, vol. 52, no. 1, pp. 33–44, 2020, doi: 10.1007/s11858-019-01118-9.

[27] Y. Wardat, M. A. Tashtoush, R. AlAli, and A. M. Jarrah, "ChatGPT: A revolutionary tool for teaching and learning mathematics," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 19, no. 7, 2023, doi: 10.29333/ejmste/13272.

[28] F. Ukobizaba, G. Nizeyimana, and A. Mukuka, "Assessment Strategies for Enhancing Students' Mathematical Problem-solving Skills: A Review of Literature," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 17, no. 3, pp. 1–10, 2021, doi: 10.29333/ejmste/9728.

[29] Muhtarom, M. S. Zuhri, and B. A. Herlambang, "Analysis of Mathematics Problem-Solving Ability of Junior High School Students in terms of Learning Independence," *AIP Conf. Proc.*, vol. 3046, no. 1, pp. 149–161, 2024, doi: 10.1063/5.0194547.

[30] H. Fitriana and A. N. Waswa, "The Influence of a Realistic Mathematics Education Approach on Students' Mathematical Problem Solving Ability," *Interval Indones. J. Math. Educ.*, vol. 2, no. 1, pp. 28–33, 2024, doi: 10.37251/ijome.v2i1.979.

[31] R. Purwitaningrum and R. C. I. Prahmana, "Developing instructional materials on mathematics logical thinking through the Indonesian realistic mathematics education approach," *Int. J. Educ. Learn.*, vol. 3, no. 1, pp. 13–19, 2021, doi: 10.31763/ijele.v3i1.178.

[32] J. Hwang and Y. Ham, "Relationship between mathematical literacy and opportunity to learn with different types of mathematical tasks," *J. Math. Educ.*, vol. 12, no. 2, pp. 199–222, 2021, doi: 10.22342/JME.12.2.13625.199-222.

[33] E. Yayuk, Purwanto, A. R. As'Ari, and Subanji, "Primary school students' creative thinking skills in mathematics problem solving," *Eur. J. Educ. Res.*, vol. 9, no. 3, pp. 1281–1295, 2020, doi: 10.12973/eu-jer.9.3.1281.

[34] E. Nurlinda, Z. Azis, and M. Doly Nasution, "Students' Mathematical Reasoning Ability and Self-Efficacy Viewed from the Application of Problem Based Learning and Contextual Teaching and Learning Models Assisted," *J. Math. Educ. Appl.*, vol. 3, no. 2, pp. 54–61, 2024, [Online]. Available: https://doi.org/10.30596/jmea.v3i2.20329

[35] D. Hurrell, "Conceptual Knowledge OR Procedural Knowledge or Conceptual Knowledge AND Procedural Knowledge: Why the Conjunction is Important to Teachers," *Aust. J. Teach. Educ.*, vol. 46, no. 2, pp. 57–71, 2021, doi: 10.14221/ajte.2021v46n2.4.

[36] J. Medová, K. O. Bulková, and S. Čeretková, "Relations between generalization, reasoning and combinatorial thinking in solving mathematical open-ended problems within mathematical contest," *Mathematics*, vol. 8, no. 12, pp. 1–20, 2020, doi: 10.3390/math8122257.

[37] M. Goos and S. Kaya, "Understanding and promoting students' mathematical thinking: a review of research published in ESM," *Educ. Stud. Math.*, vol. 103, no. 1, pp. 7–25, 2020, doi: 10.1007/s10649-019-09921-7.

[38] Jailani, H. Retnawati, E. Apino, and A. Santoso, "High school students' difficulties in making mathematical connections when solving problems," *Int. J. Learn. Teach. Educ. Res.*, vol. 19, no. 8, pp. 255–277, 2020, doi: 10.26803/ijlter.19.8.14.

[39] P. Malangtupthong, W. Nurittamont, and B. Phayaphrom, "Factors Influencing Mathematical Problem-Solving Competency: A Case Study on High School Students," *SSRN Electron. J.*, vol. 11, no. June, pp. 1–18, 2023, doi: 10.2139/ssrn.4522267.

[40] O. C. Inweregbuh, I. J. Osakwe, C. C. Ugwuanyi, and O. J. Agugoesi, "Assessment of Students' Creative Thinking Ability in Mathematical Tasks at Senior Secondary School Level," *Int. J. Curric. Instr.*, vol. 12, no. 2, pp. 494–506, 2020.

[41] B. Usodo *et al.*, "Fragmentation of thinking structure and its impact to students' algebraic concept construction and problem solving," *J. Phys. Conf. Ser.*, vol. 1567, no. 3, 2020, doi: 10.1088/1742-6596/1567/3/032006.

[42] R. Susanto, "Pemetaan Kompetensi Pedagogik dalam Keterkaitan Dimensi Pengetahuan Pedagogik dan Profil Karakteristik Awal (Mapping Pedagogical Competencies in the Relationship between Pedagogical Knowledge Dimensions and Initial Characteristic Profiles)," *JPPI (Jurnal Penelit. Pendidik. Indones.*, vol. 7, no. 1, pp. 164–171, 2021.

[43] E. Ahdhianto, Marsigit, Haryanto, and Y. Nurfauzi, "Improving fifth-grade students' mathematical problem-solving and critical thinking skills using problem-based learning," *Univers. J. Educ. Res.*, vol. 8, no. 5, pp. 2012–2021, 2020, doi: 10.13189/ujer.2020.080539.

[44] Marzuki, Wahyudin, E. Cahya, and D. Juandi, "Students' critical thinking skills in solving mathematical problems; a systematic procedure of grounded theory study," *Int. J. Instr.*, vol. 14, no. 4, pp. 529–548, 2021, doi: 10.29333/iji.2021.14431a.

[45] I. R. Sibgatullin, A. V. Korzhuev, E. R. Khairullina, A. R. Sadykova, R. V. Baturina, and V. Chauzova, "A Systematic Review on Algebraic Thinking in Education," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 18, no. 1, pp. 1–15, 2022, doi: 10.29333/EJMSTE/11486.

[46] I. Polo-Blanco, P. Suárez-Pinilla, J. Goñi-Cervera, M. Suárez-Pinilla, and B. Payá, "Comparison of Mathematics Problem-Solving Abilities in Autistic and Non-autistic Children: the Influence of Cognitive Profile," *J. Autism Dev. Disord.*, vol. 54, no. 1, pp. 353–365, 2024, doi: 10.1007/s10803-022-05802-w.

[47] W. R. Tumangger, I. A. Khalil, and R. C. I. Prahmana, "The Impact of Realistic Mathematics Education-based Student Worksheet for Improving Students' Mathematical Problem-Solving Skills," *IndoMath Indones. Math. Educ.*, vol. 7, no. 2, p. 196, 2024, doi: 10.30738/indomath.v7i2.122.

[48] J. Nilimaa, "New Examination Approach for Real-World Creativity and Problem-Solving Skills in Mathematics," *Trends High. Educ.*, vol. 2, no. 3, pp. 477–495, 2023, doi: 10.3390/higheredu2030028.

[49] R. Ramadansur, A. K. Sembiring, R. Rizky, and N. Nelvariza, "Promoting Critical Thinking Skills through Contextual Teaching and Learning," *Lect. J. Pendidik.*, vol. 14, no. 2, pp. 340–351, 2023, doi: 10.31849/lectura.v14i2.15030.

[50] P. M. Papilaya and P. M. J. Tuapattinaya, "Problem-Based Learning dan Creative Thinking Skills Students Based on Local Wisdom in Maluku," *AL-ISHLAH J. Pendidik.*, vol. 14, no. 1, pp. 429–444, 2022, doi: 10.35445/alishlah.v14i1.1406.