International Journal of Educational Research Excellence (IJERE)
https://ejournal.ipinternasional.com/index.php/ijere

Volume 03, Issue 02, July-December 2024
e-ISSN: 2830-7933
DOI: 10.55299/ijere.v3i2.1085

Enhancing Critical Thinking Skills in Mathematics Education: Integrating Problem-Based Learning in Seconday Schools

Baso Intang Sappaile[1*], Sayida Khoiratun Nisak [2], Ahmad Afandi[3], Sofiyatul Anshoriyah[4], Mardiati[5],

[1] Universitas Negeri Makassar, Indonesia
[2] Institut Islam Al-Mujaddid Sabak, Indonesia
[3] Universitas PGRI Argopuro Jember, Indonesia
[4] Universitas Panca Sakti Bekasi, Indonesia
[5] STKIP Budidaya, Indonesia
Corresponding Authors: baso.sappaile@unm.ac.id

Article history: received September 08, 2024; revised September 27, 2024; accepted September 28, 2024

Abstract. Mathematics has an instrumental function in enhancing the quality of Indonesian citizens. However, as science and technology progress and the digital age intensifies, it has become imperative to modify the mathematical learning paradigm to align it with the demands of the 21st century. The research objectives were to ascertain the following: The study sought to answer three research questions(1) the difference in the improvement of mathematical critical thinking ability of students who are given problem-based learning with students who are given direct learning; (2) the interaction of learning with initial mathematics ability on the improvement of students' mathematical critical thinking ability; (3) the difference in the improvement of learning independence of students who are given problem-based learning with students who are given direct learning. The findings of the study can be summarized as follows: (1) students who received problem-based learning exhibited a greater improvement in their mathematical critical thinking abilities than those who received direct learning; (2) there was no interaction between learning and initial mathematical ability on the improvement of mathematical critical thinking abilities; (3) students who received problem-based learning demonstrated a greater improvement in their learning independence than those who received direct learning.

Keywords: Put your keywords here, keywords separated by semicolons

I. INTRODUCTION

Mathematics is a field of study that plays an integral role in the educational curriculum. This is particularly evident in the context of school lessons, in comparison to other subjects. Furthermore, the content standards for primary and secondary education units in mathematics, as set forth by the Ministry of National Education in 2006, stipulate that mathematics should be made available to all students from the elementary level onward. This is with a view to equipping them with the capacity to think logically, analytically, systematically, critically, and creatively, as well as with the skill set needed to work together. It is anticipated that by engaging with the subject of mathematics, students will develop the aforementioned cognitive abilities, particularly those that facilitate the attainment of mathematical critical thinking skills.

Mathematical critical thinking represents the foundation of the cognitive process through which arguments are analyzed and ideas are interpreted to foster logical reasoning. Additionally, (Sutarni & Gatiniggsih, 2022) posits that mathematical critical thinking is a process that culminates in the formulation of beliefs and the determination of subsequent actions. As defined by (Ulya, 2023), mathematical critical thinking is an act of reflection and analysis concerning the ideas and concepts associated with a given problem or issue.

Meanwhile, (Hartawan et al., 2024) defines mathematical critical thinking as a cognitive process aimed at making sound judgments about the veracity of a proposition and the efficacy of a course of action. In light of the aforementioned expert opinions, it can be posited that mathematical critical thinking is an efficacious cognitive ability, enabling an individual to formulate, assess, and make judgments regarding beliefs and actions. The indicators of mathematical critical thinking skills utilized in this study encompass the capacity to identify, generalize, analyze algorithms, and solve problems.

Mathematical critical thinking skills are of great importance for students, as they facilitate the ability to reason rationally and select the optimal course of action. Moreover, it is imperative to inculcate the habit of mathematical critical thinking in students so that they can examine the myriad of problems that arise in their daily lives (Susandi & Widyawati, 2022).

In addition to the examination of mathematical critical thinking skills, a further research focus concerns the affective aspects of the learning process, namely the development of independence. The term "learning independence" refers to a learning skill in which the individual assumes responsibility for regulating, controlling, and assessing their own learning process (Saif et al., 2024). Consequently, students regulate their own learning by activating their cognitive, affective, and behavioral abilities in order to

Volume 03, Issue 02, July-December 2024
e-ISSN: 2830-7933
DOI: 10.55299/ijere.v3i2.1085

achieve the desired learning outcomes. There are a number of indicators that can be employed in order to measure learning independence. These include: The following indicators can be used to measure learning independence:

1) Learning initiative
2) Diagnosing learning needs
3) Setting learning targets and goals
4) Monitoring, regulating, and controlling learning progress
5) Viewing difficulties as a challenge
6) Utilizing the learning process as a challenge Seven additional factors were identified as contributing to the development of learning independence: (7) the ability to choose and apply learning strategies, (8) the capacity to evaluate the learning process and results, and (9) the presence of a self-concept (Mukhlisa et al., 2021).

The necessity of fostering learning independence in individuals engaged in mathematical studies is corroborated by a multitude of empirical findings. These include the observation that individuals exhibiting high levels of learning independence tend to demonstrate superior learning outcomes, proficiency in monitoring, evaluating, and organizing their learning, the capacity to save time in completing their assignments, effective organization of learning and time management, and the attainment of higher scores in science lessons (Mukhlisa et al., 2021). However, the current reality is that the concept of learning independence has not been adequately socialized and developed among students. There is a tendency for students to assume that the teacher is the sole source of knowledge, which ultimately leads to a reliance on others, particularly on the teacher.

Furthermore, knowledge can be obtained from a multitude of sources, including physical locations, specialized facilities, and the surrounding environment. These sources may include libraries, laboratories, and the Internet (Gnawali, 2024). This phenomenon is also observed in the context of Muhammdiyah 2 Junior High School, where students tend to exhibit passive behavior and rely predominantly on the teacher as the primary source of information and direction. It is uncommon for students to inquire about the material presented, and they frequently encounter difficulties in problem-solving due to a lack of self-belief, which ultimately contributes to the low level of learning independence observed among students.

The development of students' mathematical critical thinking skills and learning independence is hindered by a number of factors, including the manner in which learning is conducted by the teacher. It has been observed that teachers may not employ the most effective learning models to enhance students' mathematical critical thinking abilities and promote learning independence. The students' lack of mathematical critical thinking skills and learning independence is the result of a number of factors, including the manner in which the teacher conducts the learning process. Thus far, the teacher has not demonstrated an ability to select and utilize an appropriate learning model for the delivery of material and learning objectives. In the context of mathematics education, direct learning is a predominant pedagogical approach. The results of (Aswandi et al., 2024) research survey in several schools indicate that a significant proportion of mathematics teachers at all school levels, including elementary, junior high, and high school, continue to employ direct learning or teacher-centered learning.

Direct learning is a pedagogical approach wherein the teacher assumes the role of a leader and facilitator, while students are regarded as individuals engaged in the learning process. This approach may result in a learning environment that is dominated by the teacher or centered around the teacher (Griffee & Gorsuch, 2023). In direct learning, students are provided with information directly by the teacher pertaining to the material they are studying. They are not afforded the opportunity to construct their own knowledge, resulting in a lack of engagement in the learning process. This ultimately leads to the maintenance of low levels of mathematical critical thinking skills and learning independence.

In light of the aforementioned evidence, it is imperative that educators select an efficacious learning model to enhance students' mathematical critical thinking abilities and promote autonomous learning. One such model is problem-based learning. Problem-based learning is a method of instruction that encompasses the following steps: (1) Orienting students to the problem, (2) Organizing students to learn, (3) Guiding individual and group investigations, (4) Developing and presenting work, and (5) Analyzing and evaluating the problem-solving process. Problem-based learning is a student-centered approach that begins with the presentation of a problem as a starting point for the acquisition and integration of new knowledge (Griffee & Gorsuch, 2023). By presenting problems at the outset of the study, students are prompted to employ analytical, critical, and deductive reasoning to solve these problems, thereby developing their mathematical critical thinking skills. It is thus anticipated that the implementation of problem-based learning in the classroom will facilitate the enhancement of students' critical thinking abilities.

Problem-based learning was selected for its student-centered approach and emphasis on fostering independent learning (Rodrigues, 2023). The implementation of problem-based learning typically commences with the instructor presenting a problem to the students, thereby motivating them to engage in learning. Subsequently, the students will identify their learning requirements, both individually and in groups. Subsequently, students access learning resources, thereby facilitating the assimilation of cognitive structures. It is anticipated that, through a series of activities, children will develop greater learning independence (Alfanisa Dwi Pramudia Wardani et al., 2024). It is therefore anticipated that the implementation of problem-based learning will enhance students' autonomy in their learning processes.

In addition to mathematical critical thinking skills and student learning independence, teachers must consider the initial mathematical ability of their students. Initial mathematical ability refers to the skill set possessed by students prior to the commencement of the mathematics learning process (Wijayanti et al., 2021). Additionally, students exhibit considerable variation in their initial abilities, with some demonstrating high levels of proficiency, others exhibiting medium levels, and still others

Volume 03, Issue 02, July-December 2024
e-ISSN: 2830-7933
DOI: 10.55299/ijere.v3i2.1085

exhibiting low levels. Students' initial mathematical ability has a significant impact on their subsequent mathematical learning achievement.

It is imperative that teachers consider their students' initial mathematical abilities before commencing a learning session. This is due to the hierarchical nature of mathematics, which necessitates the mastery of previous material before progressing to new concepts (Samura et al., 2022). Nevertheless, it is evident that educators seldom prioritize the consideration of students' initial abilities. As (Hanafi, 2024) notes, the effectiveness of mathematics learning is often limited by a lack of attention paid by teachers to students' initial abilities. It is therefore incumbent upon the teacher to be aware of the students' initial mathematical abilities in order to minimise the likelihood of difficulties being encountered by the students in understanding the material to be taught. Furthermore, by understanding the diverse initial abilities of students, educators can select an appropriate learning model for the classroom, thereby ensuring effective learning outcomes.

II. METHODS

This study employs a quasi-experimental design with the objective of elucidating the enhancement of mathematical critical thinking abilities and students' autonomy in learning through problem-based instruction. The research was conducted at Muhammadiyah 2 Junior High School, located at Jogjakarta, during the even semester of the 2024/2025 academic year. The population of this study was comprised of all students at Muhammadiyah 2 Junior High School. The sample for this research was drawn from the eighth-grade students at the aforementioned school. Two classes of 60 students were selected through sampling, with 30 students in each class. The students in class VIII-A were assigned to the experimental class, while the students in class VIII-B were assigned to the control class.

This study employs a quasi-experimental design to assess the impact of two instructional approaches on students' mathematical critical thinking abilities and learning independence. The independent variables are problem-based learning and direct learning. The dependent variables are students' mathematical critical thinking abilities and learning independence. The control variable is the initial mathematics ability of students within the group, which was classified as low, medium, or high based on their pretest scores.

This study employed a pre-test-post test control group design as its research design. The instruments utilized to gather data in this study include an initial mathematics ability test, a mathematical critical thinking ability test, and a learning independence scale. The latter will undergo assessment by duly qualified validators, including lecturers and mathematics teachers at the school, and will be tested on respondents outside the sample class. The data set comprises normality testing, homogeneity testing, mean difference testing, gain index calculation, and hypothesis testing. The two-way ANOVA method was employed in testing all statistical hypotheses in this study.

III. RESULTS AND DISCUSSION

Following the testing of the prerequisites of data analysis, it was determined that the N-Gain of mathematical critical thinking and the N-Gain of learning independence exhibited a normal distribution and were homogeneous. Consequently, the analysis employed was parametric, utilizing two-way ANOVA. The results of the two-way ANOVA for the first and second hypotheses are presented in Table 4.1.

Table 1 presents the results of the first statistical hypothesis testing, which aimed to ascertain whether students taught with problem-based learning exhibited greater improvement in their mathematical critical thinking skills than those taught with direct learning. The results demonstrate that the F-value for the learning factor (problem-based learning and direct learning) is 114.94 with a significance value of 0.000, which is less than the significance level of 0.05. Consequently, the null hypothesis (Ho) is rejected. In other words, there is a discernible difference in the improvement of mathematical critical thinking skills between students who are provided with problem-based learning and those who are provided with direct learning.

Subsequently, an investigation was conducted to ascertain whether there was an interaction between students' initial mathematical abilities and learning on the improvement of students' mathematical critical thinking abilities. The results demonstrate that at the 5% significance level, the F value of 0.327 with a significance value of 0.722 is greater than the significance level of 0.05, indicating that the null hypothesis (H0) is accepted. It can thus be concluded that there is no interaction between learning (problem-based learning and direct learning) and students' mathematical initial ability (high, medium, and low) on the improvement of students' mathematical critical thinking skills.

Table 1. Summary Two-Way (ANOVA) test of gain in mathematical critical thinking.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1.290(a)	5	.258	33.521	.000
Intercept	10.608	1	10.608	1378.013	.000
Study	.885	1	.885	114.940	.000
Math Ability	.238	2	.119	15.466	.000
Study * Math Ability	.005	2	.003	.327	.722
Error	.416	54	.008		
Total	13.702	60			
Corrected Total	1.706	59			

Volume 03, Issue 02, July-December 2024
e-ISSN: 2830-7933
DOI: 10.55299/ijere.v3i2.1085

The mean enhancement in mathematical critical thinking capacity of students who underwent problem-based learning was observed to be 0.496 for the low Mathematical Analysis Ability category, 0.562 for the medium Mathematical Analysis Ability category, and 0.701 for the high Mathematical Analysis Ability category. While the mean increase in mathematical critical thinking ability of students who received direct learning was 0.248 (low Mathematical Analysis Ability category), 0.314 (medium Mathematical Analysis Ability category) and 0.409 (high Mathematical Analysis Ability category), respectively. Moreover, the mean difference in mathematical critical thinking ability between students who received problem-based learning and those who received direct learning was 0.248 for the low Mathematical Analysis Ability category, 0.248 for the medium Mathematical Analysis Ability category, and 0.292 for the high Mathematical Analysis Ability category. The statistical analysis of the difference in the average improvement for all categories of Mathematical Analysis Ability indicates that the difference is not significant. Therefore, it can be concluded that there is no interaction between learning and Mathematical Analysis Ability on improving students' mathematical critical thinking skills.

Table 2. Summary of Two-Way ANOVA Test of Gain in Learning Independence.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	(a)2.276	5	.455	244.046	.000
Intercept	7.258	1	7.258	3890.657	.000
Study	1.889	1	1.889	1012.456	.000
Math Ability	.037	2	.019	9.927	.000
Study * Math Ability	4.16E-006	2	2.08E-006	.001	.999
Error	.101	54	.002		
Total	10.755	60			
Corrected Total	2.377	59			

In addition, the third and fourth hypotheses will be tested. The results of the two-way ANOVA summary for testing the third and fourth hypotheses are presented in Table 2. The third statistical hypothesis was tested using the data in the table to determine whether students who were taught using a problem-based learning approach exhibited greater improvement in their learning independence than those taught using a direct learning approach. The results demonstrate that at the 5% significance level, the F-value for the learning factor (problem-based learning and direct learning) of 1012.456 with a p-value of 0.000 is less than the significance level of 0.05, indicating that the null hypothesis is rejected. In other words, there is a discernible discrepancy in the extent of the increase in learning independence between students who are provided with problem-based learning and those who are provided with direct learning.

The fourth statistical hypothesis was tested to ascertain whether there was an interaction between students' initial mathematical abilities and their learning to become more independent learners. The results demonstrate that the F-value for the learning factor (problem-based learning and direct learning) is 0.001 with a significance value of 0.999. As the significance value exceeds the significant level value of 0.05, the null hypothesis (Ho) is accepted, indicating that there is no interaction between learning and students' initial mathematics ability on increasing students' learning independence.

The mean increase in learning independence of students utilizing problem-based learning is 0.534 for the low analytics mathematics category, 0.564 for the medium Mathematics Analysis Ability category, and 0.607 for the high category. In contrast, the mean increase in learning independence of students who received direct learning is 0.151 for the low Mathematics Analysis Ability category, 0.18 for the medium Mathematics Analysis Ability category, and 0.223 for the high Mathematics Analysis Ability category. Moreover, the mean difference in learning independence between students who received problem-based learning and those who received direct learning was 0.383 for the low Mathematics Analysis Ability category, 0.384 for the medium Mathematics Analysis Ability category, and 0.384 for the high Mathematics Analysis Ability category. The statistical analysis revealed that the observed improvement in learning independence was not significantly influenced by the students' Mathematical Analysis Ability, indicating a lack of interaction between learning and Mathematical Analysis Ability on increasing student learning independence. This finding was consistent across all levels of Mathematical Analysis Ability categories.

A. *Studying Factor*

The subsequent section will elucidate the factors associated with this phenomenon, including learning factors, mathematical critical thinking ability, learning independence, the interplay between the instructional approach utilized and the students' initial mathematical ability on enhancing mathematical critical thinking ability and student learning independence.

One of the most significant factors influencing the development of mathematical critical thinking skills and student learning autonomy is the learning process itself, particularly problem-based learning. Problem-based learning is conducted in five stages. In the initial stage, students are oriented to the problem they will be addressing. They are provided with a Student Activity Sheet containing a problem designed to be solved. At this juncture, students are instructed to engage in independent thinking and work, initially focusing on the problems posed by the instructor. This is inversely proportional to direct learning, in which the instructor presents problems after the material has been taught. Moreover, the students are not provided with the aforementioned Student Activity Sheets. The students are provided with problems that are typical of those found in textbooks.

Volume 03, Issue 02, July-December 2024
e-ISSN: 2830-7933
DOI: 10.55299/ijere.v3i2.1085

Moreover, in the second stage, namely the formation of learning groups, the teacher divides the students into several heterogeneous groups based on initial ability (as indicated by Mathematics Initial Ability scores), gender, and ethnicity, with each group comprising five individuals. In this stage, students appear to exert considerable effort to utilize their cognitive abilities to comprehend the problem at hand. In contrast, in a direct learning environment, the teacher seldom implements a group learning approach. Instead, they tend to present the learning material to the students in a more individualized manner.

In the third stage, the teacher facilitates group investigations. The instructor facilitates student engagement through the promotion of collaborative discourse within peer groups. Teachers may encounter challenges when multiple groups encounter difficulties in solving the problems presented in the Student Activity Sheet. The objective of the teacher is to facilitate students' ability to engage in collaborative learning by leveraging the resources available in existing reference materials. The teacher offers indirect assistance in the form of instructions, prompts, or information that can facilitate students' comprehension of the learning material. In contrast, direct learning entails the provision of direct assistance to students experiencing difficulties.

In the fourth stage, the teacher facilitates the development and presentation of the work, requesting that one of the groups present the results of their discussion in front of the class. In the fifth stage, the process of solving problems is analyzed and evaluated, with other groups offering responses to the presenting group. At this juncture, students are encouraged to engage in critical thinking, whereby they evaluate their group's work in comparison to the contributions of other groups and solicit feedback from the presenting group. Thus, students do not merely accept information from others. In direct learning, the teacher poses questions and then assigns some students to complete the exercise on the board, after which the teacher verifies the students' responses. Based on the aforementioned description, the two lessons differ in terms of the teacher's approach to knowledge formation. This distinction is believed to align with the findings of research indicating that problem-based learning is more effective than direct learning in enhancing students' mathematical critical thinking abilities and fostering learning autonomy.

B. *Mathematical Critical Thinking Ability*

The objective of the experimental class is to enhance students' mathematical critical thinking abilities. To this end, problem-based learning is employed. In problem-based learning, the stage of the learning process that has the greatest impact on the development of students' critical thinking skills is the student orientation stage to the problem. This stage is characterised by the provision of problems contained in the Student Activity Sheet, which allows students to identify relevant information on the problem and to engage in the process of finding solutions to these problems. This prompts students to utilise their fundamental competencies to identify solutions to problems and also to develop new conceptual frameworks. This activity provides students with the opportunity to enhance their cognitive abilities.

Moreover, during the phase of developing and presenting work, students' mathematical critical thinking skills are also formed. This is an opportunity for students to engage in constructive criticism, ask questions, make suggestions, and provide an assessment of the work of the presenting group. Therefore, the problem-based learning stage has a considerable impact on enhancing students' mathematical critical thinking abilities.

The findings of the research indicated that all indicators of mathematical critical thinking skills exhibited an increase in both the experimental and control classes. However, the enhancement in mathematical critical thinking skills among students who received problem-based learning was more pronounced compared to those who underwent direct learning. The observed increase in students' mathematical critical thinking skills in both classes is still categorized as moderate. This is evidenced by the N-gain of students' mathematical critical thinking skills in the experimental class, which received problem-based learning, being 0.579, and in the control class, which received direct learning, being 0.3153. The enhancement of critical thinking skills observed in this study is more pronounced when compared to the findings of the research conducted by (Isnani, 2023). The findings underscore the importance of well- designed PBL activities and supportive learning environments in maximizing the development of critical thinking skills. Overall, this research contributes to the existing literature by providing insights into the effectiveness of PBL in promoting critical thinking skills among elementary school students.

C. *Independent Learning*

In the context of problem-based learning, the phases of the learning process that have a significant impact on students' capacity for self-directed learning are the initial orientation to the problem at hand and the subsequent guidance provided to facilitate individual and group investigations. During the orienting stage, students are encouraged to construct their own knowledge by independently identifying knowledge concepts from the problems presented by the instructor. Consequently, the instructor does not explicitly convey the concept of knowledge to the students.

Moreover, at the stage of guiding group investigations, the teacher oversees the progression of group discussions within the classroom setting and also facilitates students in gathering information from a multitude of sources. This enables students to become proficient in the role of active investigators, equipping them with the ability to utilise effective strategies in addressing the problems they will investigate. The teacher provides assistance only when it is truly required by the students. Therefore, students can learn to identify and resolve these issues independently, thereby developing a capacity for independent learning.

The results of the study indicated that all indicators of learning independence exhibited an increase in both the experimental and control groups. However, the rate of increase in learning independence was higher in the experimental group, who were engaged in problem-based learning, compared to the control group, who received direct instruction. The mean N-gain for student

Volume 03, Issue 02, July-December 2024
e-ISSN: 2830-7933
DOI: 10.55299/ijere.v3i2.1085

learning independence in the experimental class that received problem-based learning is still in the medium category, at 0.5669, while the mean N-gain for students in the control class is still in the low category, at 0.1805. In comparison to the outcomes observed by (Amirudin & Zanthy, 2024), which revealed the application of the problem solving approach in learning can improve students' mathematical communication skills and also student learning independence in terms of the results of post-test data analysis.

D. *Interaction between Learning and Students' Mathematics Initial Ability and Students' Learning Independence*

The researcher initially postulated that there was an interaction between students' initial mathematical ability, learning, and the improvement of students' mathematical critical thinking skills and independence. This was based on supporting theories and relevant research. However, the results of this study indicate that there is no statistically significant interaction between learning factors and students' initial mathematical ability factors in influencing the improvement of students' mathematical critical thinking skills and students' learning independence.

A number of factors may be responsible for this phenomenon, with the nature of the learning activities undertaken being a significant contributing factor. In particular, problem-based learning in experimental classes is likely to have a pronounced impact. Based on the results of observations of learning activities carried out by observers, it was found that the average teacher's ability to manage learning at the first meeting was 60 (75%), at the second meeting 61 (76.2%), at the third meeting 62 (77.5%), and at the fourth and fifth meetings 64 (78.7%). The mean score for the teachers' overall ability to manage learning was 61.8 (77.2%). The mean value of the observation of learning activities at each meeting is in the "good" category, and there is a consistent improvement between one meeting and the next. Moreover, the mean value of each indicator on the observation sheet of learning activities is 3 (good category) and 4 (very good category). The findings of the observational study indicate that learning has a substantial impact on the enhancement of students' mathematical critical thinking abilities and autonomy in learning. The impact of learning is purported to be more pronounced than that of initial mathematical ability. This is why there is no interaction between initial ability and learning on the improvement of students' mathematical critical thinking ability and learning independence.

Moreover, the data analysis revealed that the mean difference in the enhancement of mathematical critical thinking proficiency between students who received problem-based learning and direct learning and exhibited low, medium, and high initial mathematical abilities did not exhibit statistically significant discrepancies. Similarly, the same can be said of the average difference in the improvement of students' learning independence. Therefore, the findings of this study indicate that the presence of diverse learning approaches did not result in a discernible difference in the average enhancement of mathematical critical thinking abilities and student learning independence, which was observed to be more pronounced in one of the categories of Mathematics Initial Ability, irrespective of whether it was low, medium, or high.

IV. CONCLUSIONS

The findings of the research and the ensuing discussion allowed for the drawing of the following conclusions. (1) The enhancement of students' mathematical critical thinking abilities when engaged in problem-based learning is more pronounced than when they are taught directly; (2) There is no correlation between teaching methodology and students' initial mathematical abilities with regard to the improvement of students' mathematical critical thinking abilities; (3) The advancement of students' autonomy in learning when problem-based learning is employed is more pronounced than when direct learning is utilized; (4) There is no correlation between teaching methodology and students' initial mathematical abilities with regard to the advancement of students' autonomy in learning.

ACKNOWLEDGEMENTS

Author thanks to all people and institution which helped in most cases, sponsor and financial support acknowledgments.

REFERENCES

Alfanisa Dwi Pramudia Wardani, Wirawan Fadly, & Martinez David. (2024). IMPROVING CONTEXTUALIZED PROBLEM-SOLVING SKILLS IN 8TH GRADE STUDENTS THROUGH “DIGESTIVE SYSTEM” PROBLEM-ORIENTED LEARNING. *INSECTA: Integrative Science Education and Teaching Activity Journal*, *5*(1), 47–60. https://doi.org/10.21154/insecta.v5i1.8856

Amirudin, N. H., & Zanthy, L. S. (2024). The Development of Canva-Assisted Problem-Solving Approach Teaching Materials to Improve Students’ Mathematical Communication Ability on Vocational School based on Learning Independence. *(JIML) JOURNAL OF INNOVATIVE MATHEMATICS LEARNING*, *7*(2), 220–230. https://doi.org/10.22460/jiml.v7i2.19743

Aswandi, A., Lefrida, R., Pathuddin, P., & Alfisyahra, A. (2024). The Effect of Extracurricular Activities and Learning Motivation on the Students’ Mathematics Learning Achievement. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *12*(1), 98. https://doi.org/10.33394/j-ps.v12i1.10197

Gnawali, Y. P. (2024). Paradigm Shift in Mathematics Education. *Janajyoti Journal*, *2*(1), 29–47. https://doi.org/10.3126/jj.v2i1.68308

Griffee, D. T., & Gorsuch, G. (2023). *Using Theories for Second Language Teaching and Learning*. Bloomsbury Publishing Plc. https://doi.org/10.5040/9781350258945

Hanafi, A. (2024). Examining the Impact of Family-based Anti-corruption Character Education on Adolescent Attitudes: A Case Study of SMA Negeri 12 Makassar. *South Asian Journal of Social Studies and Economics*, *21*(6), 121–125. https://doi.org/10.9734/sajsse/2024/v21i6837

Volume 03, Issue 02, July-December 2024
e-ISSN: 2830-7933
DOI: 10.55299/ijere.v3i2.1085

Hartawan, I. G. N. Y., Putri, L. H. A., & Mahayukti, G. A. (2024). Junior High School Student's Computational Thinking Ability in Solving Mathematical Problems. *Jurnal Pedagogi Dan Pembelajaran*, *7*(1), 124–133. https://doi.org/10.23887/jp2.v7i1.78001

Hasanah, S. N., Sunarno, W., & Prayitno, B. A. (2021). Improving Students' Critical Thinking Skills Trough Contextual Teaching and Learning Science Module. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, *6*(2), 106. https://doi.org/10.26737/jipf.v6i2.1828

Isnani, T. (2023). Implementation of Project-Based Learning Approach in Improving Critical Thinking Skills of Elementary School Students. *Jurnal Ar Ro'is Mandalika (Armada)*, *3*(1), 47–55. https://doi.org/10.59613/armada.v3i1.2844

Mukhlisa, R., Gani, A., Winarni, S., Khaldun, I., & Hanum, L. (2021). Independence of Learning and Achievement of Learners' Cognitive Abilities in Thermochemical Materials through the Application of Flipped Classroom. *Jurnal Penelitian Pendidikan IPA*, *7*(4), 523–530. https://doi.org/10.29303/jppipa.v7i4.674

Rodrigues, A. L. (2023). Innovative Hybrid Learning: A New Paradigm in Teacher Education for Transformative Learning. In *Active and Transformative Learning in STEAM Disciplines* (pp. 153–175). Emerald Publishing Limited. https://doi.org/10.1108/978-1-83753-618-420231008

Saif, A., Umar, I. N., Ghazal, S., & Aldowah, H. (2024). *The Problem-Based Learning Revolution: A Systematic Review Exploring Its Effect on Student Achievement and Self-regulated Learning* (pp. 196–205). https://doi.org/10.1007/978-3-031-59711-4_18

Samura, A. O., Darhim, Juandi, D., Said, A. Mhd., Nani, K. la, & Tamur, M. (2022). *Improving the critical thinking ability of junior high school students through realistic mathematics education innovation*. 020057. https://doi.org/10.1063/5.0096077

Susandi, A. D., & Widyawati, S. (2022). Implementation of realistic mathematic education (RME) learning model in improving critical thinking skills. *Al-Jabar : Jurnal Pendidikan Matematika*, *13*(2), 251–260. https://doi.org/10.24042/ajpm.v13i2.14996

Sutarni, S., & Gatiniggsih, R. (2022). Improving Mathematical Critical Thinking Ability Through Realistic Mathematics Learning In JHS Students. *Jurnal Riset Pendidikan Matematika*, *9*(1), 46–56. https://doi.org/10.21831/jrpm.v9i1.48750

Ulya, V. F. (2023). IMPLICATIONS OF BEHAVIORISTIC LEARNING THEORY IN PRIMARY SCHOOL LEVEL STUDENT LEARNING. *Journal of Islamic Elementary Education*, *1*(2), 12–32. https://doi.org/10.35896/jiee.v1i2.212

Wijayanti, K., Khasanah, A. F., Rizkiana, T., Mashuri, Dewi, N. R., & Budhiati, R. (2021). Mathematical creative thinking ability of students in treffinger and brain-based learning at junior high school. *Journal of Physics: Conference Series*, *1918*(4), 042085. https://doi.org/10.1088/1742-6596/1918/4/042085
.