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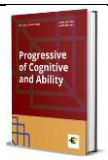

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Enhancing Problem-Solving and Self-Directed Learning in 8th-Grade Students through a Problem-Based Learning Approach

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Abstract

This research aims to assess the effect of the Problem-Based Learning (PBL) model on students' problem-solving abilities and learning independence. Motivated by the low problem-solving skills in mathematics caused by a lack of varied learning models and student inactivity, the study compares students receiving PBL treatment with those undergoing conventional learning. A quasi-experimental method involving a pretest, posttest, and learning independence questionnaire was used. The study was conducted in the 2023/2024 academic year with 8th-grade students from SMP PGRI Walantaka. Results show that students in the PBL group had significantly better problem-solving abilities compared to those in the conventional group, with a significance level of 0.000 ($p < 0.05$), indicating the effectiveness of PBL. Additionally, the average learning independence of students was 79%, categorised as good. The findings suggest that PBL can improve both problem-solving abilities and learning independence in mathematics education.

Keywords: Learning independence; Problem-solving abilities; Problem Based Learning (PBL)

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1. Introduction

Mathematics education plays a crucial role in developing critical thinking and problem-solving skills, which are essential for navigating modern society (Harahap, 2023). Problem-solving in mathematics involves various processes, including analysing, interpreting, reasoning, and reflecting (Anderson, 2009). It requires deep mathematical knowledge, general reasoning ability, and heuristic strategies for non-routine problems (Anderson, 2009). Mathematics education should focus on actively engaging students in the learning process, emphasising the process of learning over content memorisation (Peter, 2012). This approach can be achieved through project-based or collaborative activities that

encourage critical thinking development (Kania & Ratnawulan, 2022). Problem-solving skills developed through mathematics are applicable in various life situations and contribute to the advancement of theoretical mathematics and its practical applications (Palwa et al., 2024). By consistently training students in critical thinking and problem-solving through mathematics, educators can help develop these crucial skills for success in the information age (Susilo et al., 2023).

Problem-solving skills are essential in mathematics education, but Indonesian students often struggle in this area. (Mailisman et al., 2020). Studies have shown that students' problem-solving abilities vary based on their mathematical proficiency, with high-ability students demonstrating conceptual thinking and low-ability students relying on computational approaches. (Sanjaya et al., 2018). To address these challenges, problem-based learning (PBL) has been implemented in Indonesian curricula, proving effective in enhancing students' problem-solving skills and process abilities. (Wakit & Kusumodestoni, 2018). Research indicates that students' learning styles also influence their problem-solving capabilities, with visual, kinesthetic, and visual-kinesthetic learners showing different strengths and weaknesses in various problem-solving stages. (Febriyanti et al., 2024). Common difficulties faced by students include understanding the problem, creating mathematical models, and connecting mathematics to real-world situations. (Cahyani et al., 2024). These findings underscore the importance of tailoring teaching strategies to accommodate diverse learning styles and abilities in mathematics education.

Problem-based learning (PBL) has been shown to significantly enhance students' mathematical problem-solving abilities and learning independence across various educational levels. (Nisa' et al., 2023). PBL encourages active learning by engaging students in real-world problems, promoting critical thinking, collaboration, and motivation in mathematics (Kania et al., 2023). Studies have consistently demonstrated that students taught using PBL outperform those in conventional learning settings, regardless of their initial ability levels. (Hasan, 2023). Moreover, PBL has been found to positively impact students' interest in learning mathematics. (Prayogo, 2021). A meta-analysis of multiple studies revealed a high overall effect of PBL on mathematical problem-solving skills, with no significant differences based on educational level, class, sample size, or study year. (Kania et al., 2024). These findings underscore the effectiveness of PBL in enhancing mathematical competencies and fostering autonomous learning.

Problem-based learning (PBL) is a student-centred instructional method grounded in constructivist learning theory (Kemp, 2011; Loyens et al., 2019). It emphasises active learning through meaningful problems, fostering self-directed learning and problem-solving skills (Husain, 2011; Edens, 2000). The PBL process typically involves three phases: initial discussion, self-study, and reporting, guided by a tutor (Loyens et al., 2019). This approach incorporates key principles such as connecting to prior knowledge, collaborative learning, gradual development of autonomy, and focus on knowledge application (Loyens et al., 2019). While traditional curricula may yield better results in basic science knowledge assessments, PBL's benefits become more apparent over time (Loyens et al., 2019). Various PBL models exist, including full PBL programs and hybrid models combining lectures and problem-solving sessions (Husain, 2011). PBL has been implemented across multiple disciplines and educational levels, preparing students for real-world problem-solving (Edens, 2000).

Recent studies have demonstrated the effectiveness of Problem-Based Learning (PBL) in enhancing students' mathematical problem-solving abilities and engagement. aaaa found that PBL significantly improved students' problem-solving skills and interest in learning mathematics. Similarly, Karan Brown (2022) reported higher grades and increased confidence in problem-solving among students exposed to PBL strategies. A meta-analysis by Suparman et al. (2021) revealed a medium positive effect of PBL on mathematical problem-solving skills among Indonesian junior high school students. While these studies focused on general mathematics, Ihsan & Elizar (2024) specifically

examined the application of Inquiry-Based Mathematics Education (IBME) with Mathigon in teaching Cartesian coordinates, finding significant improvements in problem-solving abilities and engagement compared to traditional approaches. These findings collectively support the implementation of PBL and related approaches to enhance students' mathematical problem-solving skills and engagement.

This study aims to explore the impact of the Problem-Based Learning model on students' problem-solving skills and learning independence, particularly in the context of Cartesian coordinate geometry. By addressing this gap, the study contributes to the growing body of research on effective mathematics instruction, providing insights into how PBL can be leveraged to improve students' engagement and performance in mathematics.

2. Methods

This research is quantitative research using a quasi-experimental method. The type of experimental research is experimental research, where experimental research conducts experiment on experimental groups. The method used is the quasi-experimental method, known as a pseudo-experiment. The stages carried out in this research are: (1) providing treatment with the application of Problem-Based Learning (PBL), (2) conducting a posttest, and (3) concluding. The following is the design of this research in Table 1.

Table 1- Non-Equivalent Control Group Design

Group	Pretest	Treatment	Posstes
Experiment	T	X	T
Control	T	O	T

Description:
X: Learning using the Problem-Based Learning (PBL) learning model
O: Learning with a conventional model
T: Final test in the form of a problem-solving ability test and a student learning independence questionnaire

This research was conducted in classes VIII A and VIII B in the odd semester of 2023/2024. The research sample consisted of 50 students. The independent variable in this study is the Problem-Based Learning (PBL) learning model. The dependent variable is the problem-solving ability and learning independence of students. In this study, data was collected by giving tests and questionnaires. The instruments used were the problem-solving ability test instrument for Cartesian coordinate material containing five descriptive questions and the non-test instrument for student learning independence containing a questionnaire of 20 statements.

The data analysis techniques in this study were descriptive analysis (mean, standard deviation, highest and lowest values), instrument validity test, normality test, homogeneity test, paired sample t-test and independent sample t-test. The analysis was carried out using Microsoft Excel and SPSS. The value of the t-test interprets the increase in problem-solving ability and the student's learning independence questionnaire. The t-test is calculated with the following calculation:

If the P value > 0.05, then $H0$ is accepted, and $H1$ is rejected
If the P value < 0.05, then $H0$ is rejected, and $H1$ is accepted

3. Results and Discussion

3.1. Results

Quantitative data were generated from the results of the posttest and questionnaire conducted in classes VIII A and VIII B. The posttest is a problem-solving ability test given after learning that applies the Problem-Based Learning (PBL) learning model. The posttest consists of 5 descriptive questions on the Cartesian coordinate material, and the questionnaire is a statement of student learning

independence that applies the Problem-Based Learning (PBL) learning model. This questionnaire consists of 20 short statements. The test and questionnaire function to see the extent to which students' problem-solving abilities and learning independence have increased before and after the implementation of learning. The following are the descriptive results of the posttest in Table 2 and Table 3.

Table 2 - Descriptive Analysis of the Posttest

Group	N	Minimum	Maximum	Mean	Std. Deviation
Experiment	25	85	96	89,96	2,896
Control	25	53	85	64,04	6,541

Table 2. shows the average value of the problem-solving ability posttest, namely 89.96 and 64.04. By using the t-test calculation. From this, it can be concluded that the average value of students' problem-solving abilities has increased significantly. This means that there is an increase in problem-solving abilities after implementing Problem-Based Learning (PBL).

Table 3 - Descriptive Analysis of Questionnaire

Group	N	Minimum	Maximum	Mean	Std. Deviation
Experiment	25	54	70	61,52	3,980
Control	25	65	75	70,36	2,596

Table 3 shows the average value of the student learning independence questionnaire, namely 61.52 and 70.36. Using the t-test calculation. From this, it can be concluded that the average value of student learning independence has increased significantly. This means that there has been an increase in student learning independence after implementing Problem-Based Learning (PBL) learning.

Furthermore, a paired sample t-test was conducted, which functions to analyse the effect of using the Problem-Based Learning (PBL) learning model on students' problem-solving abilities and learning independence. Before that, a Normality test was carried out to determine whether the data was normally distributed. The results of the normality test of the problem-solving ability post-test are in Table 4, and the normality test of the student learning independence questionnaire is in Table 5.

Table 4 - Posttest Normality Test

		Kolmogorov-Smirnova			Shapiro-Wilk		
	Kelas	Statistic	df	Sig.	Statistic	df	Sig.
Hasil Belajar	Posttest Eksperimen	.231	25	.001	.893	25	.013
	Posttest Kontrol	.262	25	.000	.850	25	.002

a. Lilliefors Significance Correction

Table 4 shows the significant value of the post-test is > 0.13. From here, it can be concluded that the data from the problem-solving ability is normally distributed. So, it is continued with the independent sample t-test. The purpose of the independent sample t-test is to see if there is a difference between the average score of problem-solving ability before and after being treated. The results of the independent sample t-test are shown in Table 6

Table 5 - Questionnaire Normality Test

N		25
Normal Parametersa,b	Mean	.0000000
	Std. Deviation	2.53311403
Most Extreme Differences	Absolute	.134
	Positive	.134
	Negative	-.094
Test Statistic		.134
Asymp. Sig. (2-tailed)		.200

Table 5 shows the significant value of the questionnaire is > 0.200. From here, it can be concluded that the data from student learning independence is normally distributed. So, it is continued with the independent sample t-test. The purpose of the independent sample t-test is to see if there is a difference between the average score of student learning independence before and after being treated. The results of the independent sample t-test are shown in Table 7.

Table 6 - Independent Sample t-test

Class	Sig. (2-tailed)	Decision
Experiment and Control	0.000	H_0 is rejected

Table 6 shows that the significance is 0.00 < 0.05, so $H0$ is rejected. This means that there is a significant difference in the post-test results. From here, it can be concluded that Problem-Based Learning (PBL) learning affects problem-solving abilities.

Table 7 - Independent Sample t-test

Class	Sig. (2-tailed)	Decision
Experiment and Control	0.000	H_0 is rejected

Table 7 shows that the significance is 0.00 < 0.05, so $H0$ is rejected. This means that there is a significant difference in the questionnaire. From here, it can be concluded that Problem-Based Learning (PBL) learning affects student learning independence.

3.2. Discussion

The Problem-Based Learning (PBL) model has demonstrated significant effectiveness in enhancing students' mathematical abilities and learning outcomes. Multiple studies have shown that PBL improves problem-solving skills, critical thinking, and mathematical reasoning compared to conventional teaching methods. (Magdalena et al., 2023). PBL fosters deeper understanding by engaging students in real-world problems, promoting active learning, and encouraging independent exploration (Asri et al., 2024). Research indicates that PBL significantly improves students' interest in learning mathematics and their ability to apply mathematical concepts effectively. (Saputri & Kesumawardani, 2021). Furthermore, PBL has been shown to enhance learning independence and collaborative skills across various student ability levels. (Angraini & Abdurrahman, 2024). These findings suggest that implementing PBL in mathematics education can lead to more competent and enthusiastic learners.

Research consistently demonstrates that problem-based learning (PBL) enhances students' self-directed learning (SDL) abilities and learner autonomy. PBL interventions have been shown to significantly increase intrinsic motivation, critical thinking, and metacognitive self-regulation in students (Nasrullah et al., 2024). Studies indicate that PBL fosters the development of SDL attributes, including self-management in learning, independent pursuit of learning, and learner control of instruction (Nur & Pratiwi, 2024). The PBL approach promotes learner-centred education, encouraging students to

take initiative in their learning processes and improve self-regulation (Martin, 2008). Furthermore, PBL has been found to develop key employability skills alongside content knowledge application (Abraham et al., 2016). These findings suggest that PBL is an effective pedagogical approach for cultivating SDL abilities and learner autonomy, which are crucial for lifelong learning and professional development in various fields, including engineering and medical education.

The research papers collectively demonstrate the effectiveness of various educational interventions in enhancing students' learning outcomes. Statistical tests, including normality tests, homogeneity tests, and t-tests, were consistently employed to validate the findings. (Maura et al., 2025). These studies revealed significant improvements in students' learning independence. (Fauzi et al., 2025), problem-solving abilities (Suherman et al., 2024), and critical thinking skills (Ekaputra, 2023). The interventions examined included digital literacy programs. (Brown & Usoro, 2023), team games tournaments with the Quizizz application (Rokayah, 2023), Whole Brain Teaching method (Merdeka, 2023), and interactive learning media (Arni et al., 2024). The use of experimental and quasi-experimental designs, along with pre-test and post-test comparisons, strengthened the validity of the findings. These studies underscore the importance of innovative teaching methods and digital tools in enhancing various aspects of student learning and independence.

Problem-Based Learning (PBL) is an effective approach for enhancing mathematics education and student engagement. Studies have shown that PBL significantly improves mathematics learning outcomes compared to conventional teaching methods. (Magdalena et al., 2023). This learner-centred approach engages students in real-world problem-solving, fostering critical thinking, collaboration, and motivation. (Serin, 2019). PBL has been found to increase students' active involvement, motivation, and learning outcomes in mathematical problem-solving (Sari et al., 2019). The effectiveness of PBL extends beyond mathematics, promoting collaborative learning, disciplinary subject learning, iterative learning, and authentic learning across various subjects. (Patria & Salamah, 2022). By incorporating real-life scenarios and encouraging peer interaction, PBL makes learning more relevant and meaningful for students. This approach not only improves problem-solving abilities but also nurtures learning independence as students take on more responsibility for their education.

Recent studies highlight the effectiveness of Problem-Based Learning (PBL) in enhancing mathematics education and developing 21st-century skills. PBL has been shown to significantly improve mathematics learning outcomes, critical thinking, and problem-solving skills compared to conventional teaching methods (Angraini et al., 2024). A meta-analysis of 20 studies revealed that PBL has a highly significant effect on developing 4C skills (Critical Thinking, Creativity, Collaboration, Communication), with an average effect size of 1.72 (Efendi1 & Suastra, 2023). In teacher education, PBL implementation has been found to strengthen mathematical competencies and favour collaborative problem-solving activities. (Ainah, 2023). However, successful PBL implementation requires effective professional development for teachers to overcome barriers in K-12 classrooms. (Soesanto et al., 2022). These findings underscore the importance of integrating PBL into mathematics curricula and providing adequate teacher training to promote essential 21st-century skills among students.

Project-based learning (PBL) is an active, student-centred approach that promotes critical thinking, collaboration, and real-world connections (Tahiri, 2024). While PBL has shown benefits in various educational contexts, including high school science (Goodnough & Cashion, 2006), its implementation faces challenges. These include limited teacher training, parental, and the need for effective scaffolding and support from teachers (Kokotsaki et al., 2016). The teacher's role in PBL is flexible and requires adaptation from traditional teaching methods (Hung et al., 2019). Studies on PBL's effectiveness often lack randomised control groups, making it difficult to establish causal links between PBL and positive student outcomes. Successful PBL implementation depends on factors such as modern digital technology, high-quality group processes, and well-aligned assessment (Kania & Juandi,

2023). Further research is needed to deepen understanding and inform evidence-based practices in educational settings.

4. Conclusions

Based on the research that has been conducted, it is concluded that there is a significant influence of the problem-solving ability and learning independence of students who receive the Problem-Based Learning (PBL) learning model better than the conventional learning model the problem-solving ability of students who receive conventional learning treatment. This is indicated by the average value of students who receive the Problem-Based Learning (PBL) learning model treatment, which is 89.96, better than students who receive the conventional model treatment, which is 64.04. So, the initial assumption stating that there is an influence of the Problem-Based Learning (PBL) learning model on students' problem-solving ability and learning independence is proven. Suggestions for further research based on the results of this research are: (1) Based on the results of the study that learning using the Problem-Based Learning (PBL) learning model is better than the conventional learning model so that the Problem-Based Learning (PBL) learning model can be used as a reference in improving and improving the quality of learning in schools and (2) Further research is needed to examine the influence of the Problem-Based Learning (PBL) learning model at different levels.

Conflict of Interest

The authors declare no conflicts of interest

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