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Project-Based Learning in Mathematics Classrooms: How It Improves Students' Problem-Solving Skills

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Abstract

The aim of this research is to determine whether Project-Based Learning (PjBL) affects middle school students' ability to solve mathematical problems during the learning process. This research is mix-method research with explanatory sequential design, namely the data is analyzed quantitatively first and continued with descriptive qualitative analysis. The results of the test indicated a t-value of 2.7354 with a p-value of 0.007751 (which is less than 0.05), signifying a significant difference of the experimental group and the control group after the treatment was applied. PjBL has an influence in improving problem solving of middle school students. Students can identify important elements in a problem, create appropriate problem representations, use relevant knowledge and skills to solve problems, and are able to interpret relevant results and conclusions. This study suggests that PjBL provides an impact on meaningful learning experiences and in-depth learning.

Keywords: *classroom activity; mathematics; problem-solving; project-based learning*

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INTRODUCTION

Project-Based Learning (PjBL) is an educational method that focuses on engaging students in authentic projects that relate to their daily lives. In the realm of mathematics education, PjBL plays a crucial role as it aids students in grasping mathematical concepts in a more comprehensive and applicable manner. By participating in projects, students gain not only theoretical knowledge but also insights into how to utilize mathematical principles in real-world scenarios (Rehman et al., 2024; Cruz et al., 2022). This approach can enhance student motivation, as they recognize the immediate connection between their studies and the surrounding environment (Kokotsaki et al., 2016; Zhang & Ma, 2023). PjBL encourages students to think both critically and creatively. They are required to plan, organize, and execute projects that frequently necessitate collaboration with their peers. This experience not only deepens their understanding of mathematical ideas but also hones their problem-solving abilities (Rehman et al., 2023). In mathematics learning, these skills are essential as many mathematical problems require discussion and cooperation to find effective solutions (Asmi et al., 2022).

Furthermore, PjBL offers students the chance to learn from their errors. While engaging in the project, students might face obstacles or challenges that compel them to explore various strategies before arriving at the correct answer. This experience teaches them that setbacks are a natural aspect of the learning journey and that persistence is crucial for tackling mathematical problems (Astuti et al., 2024). Consequently, PjBL can foster a positive attitude toward learning mathematics.

The ability to solve mathematical problems is a key indicator of students' comprehension of the material being taught. In the framework of PjBL, studies indicate that students participating in project-based learning often achieve higher academic success compared to those in traditional learning environments (Guo et al., 2020). This improvement is attributed to the active learning approach inherent in PjBL, where students are not merely passive recipients of information but also active seekers of knowledge through hands-on experiences (Adinda et al., 2023; Markula & Aksela, 2022; Septian et al., 2020). PjBL enables students to delve deeply into mathematical concepts and relate them to various other fields. As a result, they gain not only theoretical knowledge of mathematics but also an understanding of its application in real-world situations.

In more detail, success in the project can boost students' self-confidence. When they successfully complete the project and see the results of their hard work, it can provide a motivational boost to continue learning and perform better in math. This success can foster a positive learning atmosphere in which students feel more at ease asking questions and engaging in discussions about challenging mathematical concepts (Chang et al., 2024; Purnomo et al., 2023). Ultimately, the use of project-based learning in mathematics improves students' academic achievement while equipping them with critical life skills. By understanding the importance of applying mathematical concepts in real-life situations, students will be better prepared to face future challenges and be able to use their mathematical knowledge effectively in various aspects of their lives. A significant benefit of PjBL in mathematics education is enhanced student involvement. When students engage in engaging and meaningful projects, they often exhibit greater enthusiasm and motivation to learn. This engagement includes not only their attention during the learning process but also active participation in discussion, collaboration and exploration of new ideas (Crestani & Machado, 2023; Muslim et al., 2024).

The urgency of this research lies in the increasing demand for educational approaches that not only improve academic outcomes but also equip students with essential 21st-century skills such as critical thinking, creativity, and collaboration. Mathematics, as a foundational subject, plays a pivotal role in developing these competencies. Implementing PjBL effectively can transform mathematics education by making it more relevant and engaging, thus potentially reducing student anxiety and dropout rates in STEM fields. The findings of this study are expected to inform educators, curriculum developers, and policymakers about best practices for integrating PjBL in mathematics classrooms. Moreover, by identifying specific challenges and proposing targeted solutions, this research can enhance the quality of mathematics instruction, ultimately leading to improved student performance and better preparation for real-world problem-solving beyond the classroom.

Previous research has extensively documented the positive effects of PjBL on student engagement and academic performance in mathematics (Guo et al., 2020; Ndiung & Menggo, 2024). For instance, Guo et al. (2020) demonstrated that students exposed to PjBL showed significant improvement in problem-solving tests compared to those in traditional classrooms. Similarly, Ndiung & Menggo (2024) highlighted the role of PjBL in fostering creative thinking and mathematical problem-solving skills in primary education. However, these studies often focus on overall achievement without delving deeply into the specific problem-solving processes or the difficulties students encounter during PjBL implementation. This creates a research gap concerning the nuanced understanding of how PjBL influences problem-solving strategies and where students struggle most. This study aims to fill this gap by providing detailed qualitative and quantitative evidence on the interplay between PjBL and mathematical problem-solving challenges, thereby contributing novel insights to the field.

Despite the growing adoption of Project-Based Learning (PjBL) in mathematics education, there remains a lack of clarity regarding the specific challenges students face when engaging with PjBL, particularly in relation to their problem-solving skills. Many studies have highlighted the benefits of PjBL in enhancing student engagement and academic achievement; however, few have explicitly identified the persistent difficulties or obstacles that hinder optimal learning outcomes in this context. This research aims to address this gap by investigating the particular problem-solving challenges encountered by ninth-grade students during PjBL activities in mathematics. Understanding these challenges is crucial to refining instructional strategies and ensuring that PjBL fulfills its potential as an effective pedagogical approach.

The main objective of this study is to examine the impact of Project-Based Learning on students' mathematical problem-solving abilities in this learning model. Specifically, this study seeks to answer the following questions: (1) How does PjBL affect students' problem-solving skills in mathematics? (2) What are the main challenges faced by high and low-ability students when solving mathematical problems in PjBL?

RESEARCH METHODOLOGY

This research is mix-method research with explanatory sequential design, namely the data is analyzed quantitatively first and continued with descriptive qualitative analysis. The data was analyzed quantitatively first by analyzing the comparison of problem-solving test results in classes using PjBL with control classes that did not use PjBL. The focus of the observation was the influence of the treatment on students' abilities to solve problems (Zhang & Ma, 2023). This research was conducted on the research population, namely 9th grade students of one of the Middle Schools Students in Probolinggo, East Java. The sample consisted of two classes that were chosen randomly through the cluster random sampling method. Before the sample was determined, the data before the treatment came from students' daily exam scores which were then carried out through normality tests, homogeneity tests, and average equality tests.

The test instruments used in this study were carefully developed and validated through multiple stages to ensure their accuracy and reliability. Initially, the instruments underwent content validity testing conducted by two expert validators, both of whom were lecturers with expertise in the subject matter. This step ensured that the test items adequately covered the intended content and learning objectives. Following this, the instruments were subjected to empirical validity testing by administering them to a pilot group of students who were not part of the experimental or control classes. The empirical validity was assessed using the Pearson Product Moment correlation formula, which measured the correlation between each test item and the overall test score. To evaluate the consistency of the instrument, reliability testing was performed using Cronbach's Alpha formula. The pilot test involved 32 respondents, and the results showed a Cronbach's Alpha value of 0.56, indicating moderate reliability. All test items were found to be valid and suitable for use in the main study.

The quantitative phase employed a posttest instrument designed to measure students' problem-solving abilities in mathematics. The test consisted of five descriptive questions focused on the topic of the area and volume of cubes and cuboids. These questions were aligned with four key indicators of problem-solving skills based on Polya's framework (1973): (1) Identifying important elements in the problem, (2) Creating a mathematical model or appropriate representation of the problem, (3) Applying relevant knowledge and skills to solve the problem, (4) Interpreting the results and drawing meaningful conclusions.

After the instructional treatments were completed, the posttest was administered to both the experimental and control groups. This assessment aimed to evaluate the effectiveness of the different teaching methods on students' problem-solving skills. The data collected from the posttest scores served as the primary quantitative data for analysis. The quantitative phase of the study was guided by the hypothesis that there would be a significant difference in problem-solving abilities between students who experienced Project-Based Learning (PjBL) and those who received conventional instruction. Specifically, it was hypothesized that the experimental group (PjBL) would demonstrate superior problem-solving skills compared to the control group.

The posttest data were first subjected to normality tests to verify that the data distribution met the assumptions required for parametric testing. Subsequently, homogeneity tests were conducted to ensure that the variances between the two groups were comparable. Once these criteria were met, an independent t-test was conducted to assess if the disparity in average scores between the experimental and control groups was statistically meaningful. The findings from these evaluations laid the groundwork for understanding the influence of the teaching techniques on students' problem-solving skills.

In the qualitative stage, data were collected through observations designed to complement the quantitative findings. The instruments and indicators used in the qualitative stage were consistent with the instruments and indicators in the quantitative stage, with a focus on the problem-solving process and student behavior during learning activities. Qualitative instruments also underwent validity and reliability checks to ensure the data were reliable, although the specific methods for these checks were aligned with qualitative research standards such as triangulation and member checking. Qualitative data were analyzed through thematic or content analysis, which aimed to provide deeper insights into how students engaged in the learning process and the strategies they used to solve problems. This analysis helped contextualize and explain the quantitative results, offering a comprehensive understanding of the effectiveness of Project-Based Learning in improving mathematical problem-solving skills.

RESULTS AND DISCUSSION

This research was conducted with 9th grade students at a public junior high school in Probolinggo, East Java. Two classes were selected as research samples: the experimental class that utilized Project-Based Learning (PjBL) and the control class that followed an other teaching methods. The aim of this study was to assess the impact of PjBL on students' mathematical problem-solving abilities and to evaluate the extent of that influence.

Random sampling was performed by analyzing daily test score data collected prior to the treatment. The results of the normality test, homogeneity test, and average similarity test conducted on the daily test scores indicated that all data were normally distributed, homogeneous, and had averages that were not significantly different. Consequently, two classes were randomly chosen to serve as the experimental and control groups. The experimental class comprised 38 students who engaged in PjBL, while the control class included 38 students who experienced other than PjBL learning. The posttest results, which reflect the students' mathematical problem-solving abilities, were then analyzed.

In this study, the experimental class engaged in Project-Based Learning (PjBL), which involved a series of structured and interactive activities designed to deepen students' understanding of mathematical concepts through real-world applications. The learning process began with students planning their projects, where they identified objectives and outlined the steps necessary to complete their tasks. Collaboration was a key component, as students worked in groups to share ideas, discuss problems, and collectively develop solutions. The projects were carefully designed to encourage the application of mathematical concepts in practical contexts, helping students connect theory with real-life situations. Upon completing their projects, students reflected on their learning experiences and presented their findings and solutions to the class. Throughout this process, the teacher acted as a facilitator, providing guidance, feedback, and support to ensure students stayed on track and overcame any challenges.

In contrast, the control class followed a conventional teaching approach characterized by direct instruction. The teacher primarily delivered lessons through lectures, explaining mathematical concepts and demonstrating problem-solving techniques. Students practiced individually by working on exercises and problems assigned by the teacher. Interaction among students was limited, typically occurring only during question-and-answer sessions or when students were asked to explain their answers. Assessment in the control class was conducted through written tests aimed at measuring students' understanding of the material taught. This clear distinction in instructional methods provides a foundation for understanding the differences in students' mathematical problem-solving abilities observed in the posttest results. The experimental class's active, collaborative, and contextualized learning environment contrasts with the more passive and individual-focused learning in the control class, which is expected to influence the effectiveness of each approach in enhancing problem-solving skills.

Descriptive Statistics

This section will present the problem-solving abilities of students in both the PjBL and control classes. The purpose of this comparison is to descriptively analyze the problem-solving skills of the two groups. According to Figure 1, the analysis revealed that the average score (mean) for the experimental group rose from the pre-test (66.8) to the post-test (77.1), whereas the control group only saw an increase from the pre-test (66.68) to the post-test (69.32). As illustrated in Figure 2, the average problem-solving score for the PjBL class is higher than that of the control class (77.1). In addition, the value of each statistical aspect of data distribution such as the minimum value (56>44); and the median (78>68); of the PjBL class are all greater than the control class.

	Kelompok	Tes	Mean	Median	SD	Min	Max	N
	<chr>	<chr>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<int>
1	Eksperimen	Post_Test	77.1	78	11.3	56	100	40
2	Eksperimen	Pre_Test	66.8	66	10.8	50	95	40
3	Kontrol	Post_Test	69.3	68	13.8	44	100	38
4	Kontrol	Pre_Test	66.7	67	11.2	50	95	38

Figure 1. Descriptive Statistics Result

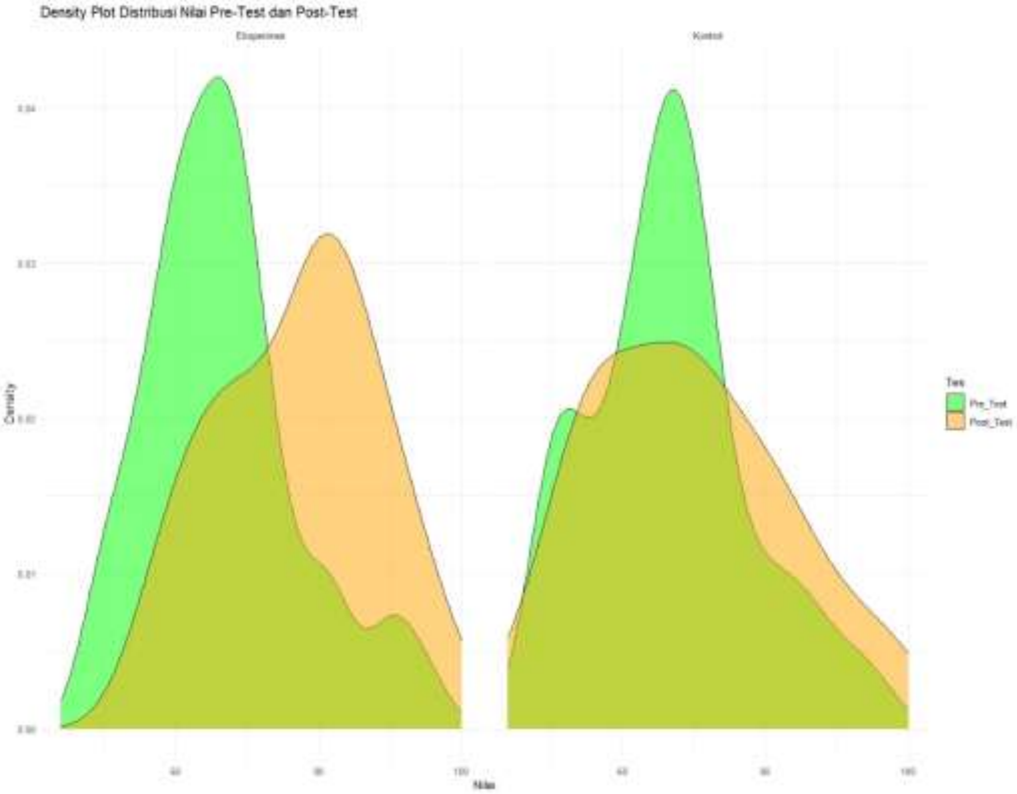

Figure 2. Density Plot of Experimental and Control Distribution

Furthermore, to see more specifically the comparison of the problem-solving abilities of the two classes, descriptive statistics will be shown in Figure 2. The distribution of the experimental group pre-test has a higher and more left peak, indicating that most students had lower scores during the pre-test. The distribution of the experimental group post-test shifts to the right, indicating an increase in scores after the intervention. The larger green area compared to the orange at the beginning indicates that many participants initially had low scores but decreased after the post-test. This suggests that the intervention implemented was effective in enhancing the scores of participants in the experimental group. In contrast, the distribution of the control group's pre-test and post-test scores exhibited a more similar pattern compared to the experimental group. Although there was a slight shift to the right in the post-test scores for the control group, it was not as pronounced as that of the experimental group. This indicates that while the control group did experience an increase in scores, it was not as substantial as that observed in the experimental group. The experimental group demonstrated a more significant rise in scores, as evidenced by the post-test distribution shifting further to the right compared to the pre-test. Although the control group also saw an increase, it was not as considerable as that of the experimental group. These findings indicate that the intervention provided to the experimental group had a positive impact on score improvement when compared to the control group. Therefore, it can be concluded from Figures 1 and 2 that the problem-solving abilities of the PjBL class are superior to those of the control class in a descriptive sense.

Test of Normality

In this section, a more detailed analysis will be performed to examine the differences in problem-solving abilities between the PjBL class and the control class. Prior

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to conducting hypothesis testing, a Shapiro-Wilk normality test will be carried out for both classes to identify the appropriate analysis method. Figure 3 below presents the results of the normality test for both groups.

```
[1] "Uji Normalitas (Shapiro-Wilk) untuk Pre-Test"
> print(shapiro_exp_pre)

        Shapiro-Wilk normality test

data:  data$Pre_Test_Eksperimen
W = 0.94643, p-value = 0.0572

> print(shapiro_ctrl_pre)

        Shapiro-Wilk normality test

data:  data$Pre_Test_Kontrol
W = 0.95564, p-value = 0.1366
```

```
[1] "Uji Normalitas (Shapiro-Wilk) untuk Post-Test"
> print(shapiro_exp_post)

        Shapiro-Wilk normality test

data:  data$Post_Test_Eksperimen
W = 0.975, p-value = 0.5101

> print(shapiro_ctrl_post)

        Shapiro-Wilk normality test

data:  data$Post_Test_Kontrol
W = 0.96734, p-value = 0.3252
```

Figure 3. Test of Normality Results

The normality test conducted using Shapiro-Wilk reveals that all groups (pre-test experimental, post-test experimental, pre-test control, and post-test control) have p-values exceeding 0.05. This indicates that the data across all groups are normally distributed, thereby satisfying the normality assumption.

Test of Homogeneity

Additionally, a homogeneity test was performed to assess whether the problem-solving data of students in both the experimental and control classes exhibited a homogeneous distribution. The results of the homogeneity test for students in both groups can be seen in Figure 4. The data from the problem-solving test results indicate that the scores are both normally and homogeneously distributed, which means they meet the criteria for further analysis.

```
Levene's Test for Homogeneity of Variance (center = median)
      Df F value Pr(>F)
group  1  0.0681 0.7948
      76
> print(levene_post_test)
Levene's Test for Homogeneity of Variance (center = median)
      Df F value Pr(>F)
group  1  1.3374 0.2511
      76
```

Figure 4. Test of Homogeneity Results

According to Figure 4, the homogeneity test conducted using Levene's Test for both the pre-test and post-test yielded p-values of 0.7948 and 0.2511, respectively, both of which exceed 0.05. This suggests that the variance between the experimental and control groups can be regarded as homogeneous, thereby satisfying the assumption of homogeneity.

Hypothesis Test

An independent t-test was A separate t-test was conducted to analyze the post-test results between the experimental group and the control group. As shown in Figure 5, the results indicated a t-value of 2.7354 with a p-value of 0.007751 (which is less than 0.05), signifying a significant difference between the two groups following the treatment. The 95% confidence interval for the mean difference ranges from 2.116401 to 13.452020, with the experimental group achieving a higher mean post-test score (77.1) compared to the control group (69.32). Therefore, it can be concluded that PjBL is effective in enhancing

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students' problem-solving abilities.

```
        Two Sample t-test

data:  data$Post_Test_Eksperimen and data$Post_Test_Kontrol
t = 2.7354, df = 76, p-value = 0.007751
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  2.116401 13.452020
sample estimates:
mean of x mean of y
 77.10000  69.31579
```

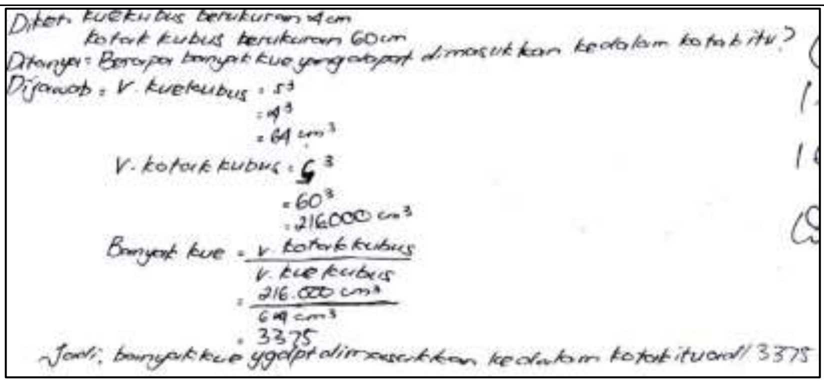
Figure 5. Hypothesis Test Results

Additionally, the observations reveal the mathematical problem-solving skills of students in both the control and experimental classes. The students' performance is highlighted when Project-Based Learning (PjBL) is implemented. There is a noticeable difference in the work produced by students with high problem-solving abilities (S1), which serves as an illustration of their activities within the PjBL framework. Conversely, the second set of work demonstrates the outcomes of students with lower problem-solving skills (S2). The following will be described in more detail from the work results of the two subjects on one of the essay questions. In this section, a description of student problem solving will be presented based on low and high categories.

Description of Subject with high problem-solving ability (S1)

Based on the results of subject with high problem-solving ability (S1) in Figure 6, it shows that S1 can identify important elements in the problem; able to create a mathematical model or appropriate problem representation; and use relevant knowledge and skills to solve the problem; and interpret the results and draw relevant conclusions. S1 has succeeded in identifying relevant information from the given problem, namely the size of the cube cake and the cube box. S1 explained that the cake has a side of 4 cm, and the box has a side of 60 cm, this demonstrates that S1 has a strong grasp of the problem's context. Based on this work, S1 can further understand what important information is needed to calculate the number of cakes that can be put into the box. Seeing the relationship between the size of the cake and the box strengthens S1's understanding of the problems faced from the work steps.

In the planning stage based on Figure 6, S1 shows the ability to formulate the right strategy using the cube volume formula. S1 calculates the volume of the cake and box correctly with an explanation of the calculation steps in more detail. S1 can show that the volume of the cake is calculated with $Vcake = Scake^3$ and the volume of the box with $Vbox = Sbox^3$. Furthermore, the formula is applied by S1 based on the concept understood. S1 successfully implements the plan by calculating the volume and getting the correct final answer, which is 3375 cakes. At the end of the solution, S1 considers re-checking the calculation steps and ensuring that all relevant information has been used.



Translated version:

known: cube cake measuring 4 cm
cube box measuring 60 cm
asked: how many cakes can be put into the box?
answered: V.cube cake $= S^3$
$= 4^3$
$= 64\ \text{cm}^3$
V.cube box $= S^3$
$= 60^3$
$= 216000\ \text{cm}^3$
number of cakes $= \frac{\text{V.cube box}}{\text{V.cube cake}}$
$= \frac{216000\ \text{cm}^3}{64\ \text{cm}^3}$
$= 3375$
So, the number of cakes that can be put into the box is 3375

Figure 6. Example of S1

Description of Subject with low problem-solving ability (S2)

According to the findings from the work of subject with low problem-solving ability (S2) presented in Figure 7, it shows that subject has not been optimal in identifying important elements in the problem; creating a mathematical model or appropriate problem representation; and using relevant knowledge and skills to solve the problem; and has not been able to interpret the results and draw relevant conclusions. S2 has succeeded in identifying relevant information from the given problem, namely the size of the cake and the size of the box. However, there is an error in stating the size of the cake as "cake size = 4 cm" without mentioning that the cake is in the form of a cube. In addition, S2 does not explicitly state that the box is also in the form of a cube, which can cause confusion. A deeper understanding of the context of the problem and a clearer explanation of the geometric shapes involved will help strengthen students' understanding of the problem at hand.

Furthermore, based on Figure 7, S2 tries to use the cube volume formula, but there is an error in the calculation. S2 calculates the volume of the cake correctly using the formula $V = S \times S \times S$, but the result should be 64 cm^3, not 48 cm^3. In addition, S2 uses the wrong formula to calculate the volume of the box, namely $V = 5 \times S2$. This error shows that S2 has not been careful in applying the correct formula and does not understand the basic concept of the volume of a cube. S2 continues by adding the volume of the cake and the volume of the box, but the result obtained, which is 18048, does not reflect the number of cakes that can be put into the box. S2 does not divide the volume of the box by the volume of the cake to get the number of cakes that can be accommodated. The rechecking

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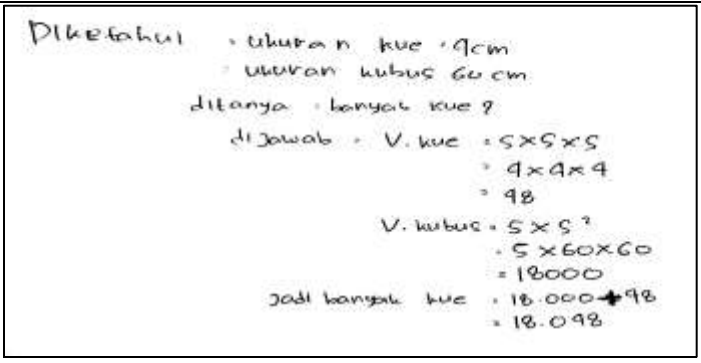
process is also not done properly, because S2 does not evaluate the steps of its calculation to ensure the accuracy of the results.


Diketahui : ukuran kue : 4cm
ukuran kubus 60 cm
ditanya : banyak kue ?
di jawab : V. kue : 5x5x5
: 4x4x4
: 48
V. kubus : 5x5²
: 5x60x60
: 18000
Jadi banyak kue : 18.000+48
: 18.048

Translated version:

known: cake size = 4 cm
cube size = 60 cm
asked: number of cakes .....?
answered: V. cake = SxSxS
= 4x4x4
= 48
V.cube = $5xS^2$
= 5x60x60
= 18000
So, the number of cakes 18000+48 = 18048

Figure 7. Example of S2

Based on the findings derived from both quantitative and qualitative analyses, Project-Based Learning (PjBL) has proven to be effective in enhancing students' problem-solving capabilities. Furthermore, a comparative examination of the average and other statistical measures of problem-solving performance indicates that students in the PjBL environment outperformed their counterparts in the control group descriptively. This observation aligns with the research conducted by Prabawa and Zaenuri (2017), which affirms the efficacy of PjBL in fostering problem-solving skills. Students exhibiting a Field Independent cognitive style demonstrate superior problem-solving abilities compared to those with a field dependent cognitive style. Specifically, field dependent students may grasp the problem at hand but often struggle with devising a solution plan, executing it, and conducting subsequent evaluations. Conversely, Field Dependent Knowledge students can comprehend the problem and formulate a solution plan, yet they face challenges in implementing the plan and performing re-evaluations. Field Independent Learning students are capable of understanding the problem, planning a solution, and executing the plan, although they may find re-evaluation to be a challenge. In contrast, Field Independent Knowledge students excel in all aspects: they understand the problem, devise a solution, implement the plan, and conduct thorough re-checks (Prabawa and Zaenuri, 2017).

These findings suggest that PjBL not only enhances academic performance but also cultivates critical thinking skills among students through collaborative group work. Additionally, research conducted by Almulla (2020) and Yu (2024) corroborates that PjBL offers a more meaningful and engaging learning experience for students. In this framework, students are afforded the opportunity to explore real-world problems, which not only deepens their comprehension of the subject matter but also fosters effective collaboration and communication skills. This study illustrates that the implementation of PjBL enables

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students to cultivate essential problem-solving skills, thereby facilitating the achievement of learning objectives in an effective manner.

The implementation of the Project-Based Learning (PjBL) model in middle school mathematics education has been demonstrated to be effective in enhancing students' problem-solving skills. According to the research conducted by Hardiningsih et al. (2023), the findings from Cycle I indicated that students' problem-solving abilities were categorized as sufficient, achieving a score of 50%. In contrast, observations of student engagement during this cycle were rated as very good, with an achievement level of 88.57%. In Cycle II, the study revealed that students' problem-solving abilities improved to a very good category, attaining a score of 83.3%. Additionally, the observations of student activities continued to reflect a very good rating, maintaining an achievement level of 88.57%. Consequently, it can be concluded that the PjBL learning model is effective in enhancing students' problem-solving capabilities.

Moreover, PjBL fosters greater student engagement in the learning process, thereby boosting their motivation and comprehension of the material (Rakhmawati et al., 2024). In a broader educational context, this model promotes the development of collaborative and communication skills among students, which are essential for their preparedness to tackle real-world challenges (Guo et al., 2020). Further studies indicate that PjBL can alleviate student boredom in mathematics learning while simultaneously increasing both teacher and student participation during the educational process. Therefore, the implementation of PjBL not only enhances academic outcomes but also cultivates a more dynamic and enjoyable learning environment for students (Hapsari & Airlanda, 2018; Lase & Mendrofa, 2023).

Project-Based Learning (PjBL) also fosters the development of robust problem-solving skills among students. Throughout various projects, students encounter challenges that necessitate the application of diverse mathematical strategies to derive solutions. This process encompasses data analysis, decision-making, and result evaluation, all of which are critical competencies in the field of mathematics (Serin, 2023). By engaging in the resolution of real-world problems, students not only acquire the ability to perform calculations and apply formulas but also enhance their logical and critical thinking skills when confronted with complex scenarios. Ultimately, the integration of PjBL in mathematics education equips students to face future challenges effectively.

CONCLUSION AND SUGGESTIONS

The results of this research show that Project-Based Learning (PjBL) greatly affects the improvement of problem-solving skills in students at the middle school level. PjBL has proven to be effective in promoting student engagement in problem-solving activities. This instructional method facilitates substantial improvements in students' problem-solving skills by encouraging them to participate in real-world projects that necessitate the application of their knowledge and skills in relevant contexts. Through the PjBL approach, students are able to identify key components of a problem, develop appropriate representations of the issues at hand, utilize pertinent knowledge and skills to devise solutions, and interpret relevant results and conclusions. By immersing students in scenarios that demand critical and analytical thinking, PjBL not only enhances their problem-solving capabilities but also boosts their motivation and involvement in the learning process. This methodology equips students to confront real-world challenges in a more organized and meaningful manner.

However, this study has several limitations that should be considered. First, the sample size was limited to a specific group of middle school students in a particular region, which may affect the generalizability of the findings to other populations or educational contexts. Second, the duration of the intervention was relatively short, which might not fully capture the long-term effects of PjBL on problem-solving skills. Third, the study primarily relied on quantitative measures of problem-solving ability, potentially overlooking qualitative aspects such as students' attitudes, creativity, and collaboration dynamics during the projects. Lastly, external factors such as teacher expertise, classroom environment, and students' prior knowledge were not extensively controlled, which could influence the outcomes.

Based on these limitations, several suggestions for future research are proposed. Future studies should include a larger and more diverse sample across different regions and educational levels to enhance the generalizability of the results. Longitudinal research designs are recommended to examine the sustained impact of PjBL on students' problem-solving abilities and other related competencies over time. Incorporating mixed-method approaches that combine quantitative and qualitative data can provide a more comprehensive understanding of how PjBL affects various dimensions of student learning, including motivation, creativity, and teamwork. Further investigation into the role of teacher training, classroom environment, and student background factors will help clarify how these variables interact with PjBL implementation and influence student outcomes.

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