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Effectiveness of Problem-Based Learning in Improving Elementary Students' Mathematics Achievement

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ABSTRACT

The low mathematics achievement of elementary school students remains a common problem in learning. Although the Problem-Based Learning (PBL) model has been widely studied at the secondary education level, studies on its effectiveness in mathematics learning at the Madrasah Ibtidaiyah level are still relatively limited. Therefore, this study was conducted to analyze the implementation and effectiveness of the Problem-Based Learning (PBL) model in improving the mathematics achievement of fourth-grade students at Madrasah Ibtidaiyah Hidayatul Ulum Tempel Krian Sidoarjo. The study used a quantitative approach with an experimental design involving 48 students, consisting of 24 students in the experimental class and 24 students in the control class. Data were collected through observation, tests, and documentation, then analyzed using Analysis of Covariance (ANCOVA). The results showed that the implementation of the PBL model had a significant effect on students' mathematics learning achievement, with a significance value of <0.001. The average posttest score of the experimental class was 82.08, higher than the control class's 65.83. The normalized gain value of 0.62 indicates a moderate improvement in learning outcomes. Furthermore, the ANCOVA results yielded a Partial Eta Squared value of 0.279, indicating that the PBL model had a 27.9% effect on the variation in students' mathematics learning achievement, falling within the moderate to large effect category. These findings confirm that PBL is effective in improving mathematics learning outcomes while simultaneously fostering students' critical thinking and problem-solving skills. The implication of this study is that the PBL model can be used as an effective alternative learning strategy for Madrasah Ibtidaiyah teachers to improve the quality of student-centered mathematics learning.

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1. INTRODUCTION

Mathematics is a core subject that plays a crucial role in developing logical and systematic thinking patterns in students. Good mathematical skills are essential not only in academic contexts but also in everyday life, which demands critical thinking and problem-solving skills (Harris 2019) (Zaynabjon Habibulla-qizi Madatova 2025). However, in real-world applications, mathematics learning is often perceived as difficult and abstract, resulting in low student achievement. One reason for low student achievement in mathematics is the inappropriate use of conventional, teacher-centered learning models.

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Suprijono states that a learning model is a pattern used as a guideline for planning classroom and tutorial learning. According to Arends, the learning model used includes the stages of learning activities and classroom management (Suprijono 2015). Learning using the lecture method tends to make students passive (Khudayberganova 2026) (Thwin dan Lwin 2018), lacking interest in the learning process, and providing them with fewer opportunities to develop their potential (Syahrir dkk. 2025) (Filgona dkk., 2020.) . As a result, understanding of mathematical concepts is less than optimal (Putri dkk. 2023) (Deviana dan Bagus Pramartha 2020) , especially in materials that require reasoning, such as number patterns (Salisa dan Rahaya 2023) (Arigawati dan Kusnandi 2021).

Problem-Based Learning (PBL) is a learning model that presents problems at the beginning of learning. This model is a student-centered learning model that presents students with various real-life problems, and students attempt to solve them (Meilasari dkk. 2020). In this model, lessons focus on a problem that must be solved by students, so students are responsible for analyzing and solving the problem on their own, while the educator's role is merely as a facilitator and provides guidance to students (Rachmawati dan Rosy 2021; Sirait 2016). This model aligns with constructivism theory, which assumes that knowledge is formed through experience and interaction with the learning environment.

Previous research has shown that the application of the Problem-Based Learning (PBL) model can improve learning motivation, critical thinking skills, and student learning outcomes, particularly in mathematics. However, the effectiveness of the PBL model can vary depending on student characteristics, school conditions, and teacher strategies. Therefore, further research is needed to examine the effectiveness of the PBL model in the context of mathematics learning in Islamic elementary schools.

This study aims to analyze the effectiveness of the Problem-Based Learning (PBL) model in improving the mathematics achievement of fourth-grade students at Madrasah Ibtidaiyah Hidayatul Ulum Tempel Krian Sidoarjo. This research is motivated by the persistently low mathematics achievement of students and the limited research examining the effectiveness of PBL at the Madrasah Ibtidaiyah level, particularly in mathematics learning. Therefore, this study is crucial to provide empirical evidence regarding the application of student-centered learning models in the context of Islamic elementary education. The study used a quantitative approach with an experimental design. The sample size was 48 students: 24 in the experimental class and 24 in the control class. Data collection techniques included observation, testing, and documentation. Data were analyzed using Analysis of Covariance (ANCOVA). The results showed that the implementation of the PBL model significantly impacted students' mathematics achievement, with a significance value of $p < 0.001$. The average posttest score for the experimental class was 82.08, higher than the average posttest score for the control class, which was 65.83. The normalized gain value of 0.62 indicates a moderate improvement in learning outcomes. Furthermore, the Partial Eta Squared value of 0.279 indicates that the PBL model has a 27.9% effect on the variation in student mathematics learning achievement, which falls into the moderate to large effect category. This finding indicates that the PBL model is effective in improving student mathematics learning outcomes. The implication of this study is that PBL can be

used as an alternative, innovative and contextual learning model for elementary school teachers in an effort to improve the quality of mathematics learning.

2. METHOD

This research used a quantitative approach with an experimental method. Quantitative research uses numerical data and statistical analysis. Experimental research, on the other hand, is a research method used to determine the effect of a particular treatment. Experimentation refers to a deliberate attempt to modify the conditions that determine the occurrence of an event, observing and interpreting the changes that occur in a controlled manner (Sugiyono, 2019). The quasi-experimental design used was the Nonequivalent Control Group Design with O1 X O2, O3 - O4. This design, also included in the quasi-experimental design, is considered a quasi-experiment because many designs constructed according to the experimental design model are considered by many to lack the characteristics of a true experimental design. The variables that should be controlled cannot be controlled, thus rendering the validity insufficient to be considered a true experiment (Suryabrata, 2016).

The subjects of this study were 48 fourth-grade students of Madrasah Ibtidaiyah Hidayatul Ulum Tempel Krian Sidoarjo, aged 9–10 years. The sample consisted of 24 students in the experimental class and 24 students in the control class, with the composition of the experimental class: 13 males and 11 females. The control class: 12 males and 12 females. Class selection was carried out using a purposive sampling technique based on the consideration that both classes have relatively homogeneous characteristics, such as the level of academic ability, the same learning materials, similar social backgrounds, and are taught by teachers with equivalent qualifications. The experimental class was given treatment in the form of the application of the Problem Based Learning (PBL) model, while the control class used a conventional learning model. Students' initial knowledge was measured through a pretest before the treatment was given. After the learning process took place, a posttest was carried out to measure the improvement in students' mathematics learning achievement. Thus, the differences in learning outcomes obtained can be analyzed to determine the effectiveness of the application of the Problem Based Learning (PBL) model. Purposive sampling is a sampling technique carried out based on certain considerations that are in accordance with the research objectives so that the selected sample is considered capable of providing relevant and representative data. Data collection techniques in this study included observation, testing, and documentation. A test is a set of questions or exercises or other tools used to measure the skills, knowledge, intelligence, abilities, or talents of an individual or group (Nasution 2016). The test was used to measure students' mathematics achievement through pretests and posttests. Data analysis was conducted using ANCOVA to determine the effect of the PBL learning model on students' mathematics achievement. The number of questions used is 10 questions in essay form. In the N-Gain Test, the application of the Problem Based Learning learning model is in the moderate category with an average normalized gain of 0.62, which means it is included in the moderate category. The results of the normality test showed a Sig α value for the class taught using the Problem-Based Learning model of 0.062, which is greater than the α value (0.062 > 0.05). Meanwhile, the Sig α value for the class using the conventional learning model was 0.258, which is greater than the α

value (0.258 > 0.05). This means that the posttest for both the experimental and control classes was normally distributed. The results of the homogeneity test "Test of Homogeneity of Variances" obtained a significance value (Sig.) of the experimental and control class learning outcome variables for students at Madrasah Ibtidaiyah Hidayatul Ulum Tempel Sidoarjo of 0.423. Because the Sig. value of 0.423 > 0.05, as the basis for decision making in the homogeneity test above, it can be interpreted that the variance of the experimental and control class learning achievement data for class IV students at Madrasah Ibtidaiyah Hidayatul Ulum Tempel Sidoarjo is homogeneous.

The validity test in this study used the Pearson Product Moment correlation technique, which is by correlating the score of each question item with the total score of all questions. The number of respondents in this validity test was 48 students, so the r table value at a significance level of 5% was 0.291. The highest rxy value was found in question number 9, at 0.776, indicating that the question was very effective in measuring student learning outcomes. Meanwhile, the lowest rxy value was found in question number 4, at 0.405, but it still met the validity criteria.

The reliability statistics for all post-test items showed a Cronbach's Alpha value above 0.6, indicating that each item was considered reliable. The highest value was found in question 9 (0.818), while the lowest value was found in question 2 (0.775). The total Cronbach's Alpha value was 0.816, indicating that the post-test instrument was highly reliable.

3. RESULT

3.1. Presentation of Teacher Observation Data When Implementing the Problem-Based Learning Model

The details of teacher observation scores when implementing the Problem-Based Learning Model are presented in Table 1 below:

Table 1. Results of Observations of Teacher Activities When Implementing the Problem Based Learning Model

No	Observed Aspects	Score	Category
1.	The teacher conveys contextual problems that are appropriate to real life and related to patterns.		Not enough
2.	The teacher provides initial motivation so that students are interested in the problem.		Enough
3.	The teacher provides clear directions to understand the pattern problem.		Enough
4.	The teacher organizes the division of study groups effectively.		Not enough
5.	Teachers encourage students to explore various picture and number patterns.		enough
6.	Teachers provide learning resources/media that support student investigations.		enough

7.	Teachers provide time and guidance in preparing student solutions.	enough
8.	The teacher gives the group the opportunity to present their results.	Not enough
9.	The teacher guides students to evaluate the correctness of the patterns found.	enough
10.	The teacher provides feedback and directs students' reflection on the learning process.	enough
	Average	**2,7 (**enough**)**

Observations indicate that teacher activity during the learning process is considered adequate, with an average score of 2.7. This indicates that the learning approach used is not yet optimal in facilitating active learning and problem-solving by students.

3.2. Presentation of Teacher Observation Data After Implementing the Problem-Based Learning Model

After implementing the Problem-Based Learning model, further observations were conducted on teacher activities in the experimental class. The results showed significant improvements. The following presents the observation data on teacher activities after the treatment:

Tabel 2. Results of Observation of Teacher Activities After Treatment (Experimental Class)

No	Observed Aspects	Score	Category
1.	The teacher conveys contextual problems that are appropriate to real life and related to patterns.		Good
2.	The teacher provides initial motivation so that students are interested in the problem.		Good
3.	The teacher provides clear directions to understand the pattern problem.		Good
4.	The teacher organizes the division of study groups effectively		Good
5.	Teachers encourage students to explore various picture and number patterns.		Good
6.	Teachers provide learning resources/media that support student investigations.		Good
7.	Teachers provide time and guidance in preparing student solutions.		Good
8.	The teacher gives the group the opportunity to present their results.		Enough

9.	The teacher guides students to evaluate the correctness of the patterns found.	Good
10.	The teacher provides feedback and directs students' reflection on the learning process.	Good
Average	**3,9 (Good)**	

3.3. Presentation of Student Observation Data When Implementing the Problem-Based Learning Model

Based on the observation data, the average score was 2.5, which is considered adequate. This indicates that during the treatment, students demonstrated suboptimal participation and engagement in learning activities.

The following presents the results of observations of student activities when implementing the Problem-Based Learning model:

Table 3. Results of Observations of Student Activities When Implementing the Problem-Based Learning Model:

No	Observed Aspects	Score	Category
1.	Students pay attention when the teacher presents problems with picture patterns or numbers.		Enough
2.	Students demonstrate understanding of picture pattern and number pattern problems.		Not Enough
3.	Students express their opinions in formulating picture pattern and number pattern problems.		Not Enough
4.	Students work together in groups to develop steps to solve picture pattern and number pattern problems.		Not Enough
5.	Students actively try various possibilities for number patterns.		Enough
6.	Students seek other sources or methods to solve picture pattern problems.		Not Enough
7.	Students are able to explain the types of pattern sequences they find.		Enough
8.	Students clearly present how to calculate using picture or number patterns.		Enough
9.	Students evaluate errors in finding ways to calculate patterns.		Not Enough

10.	Students and teachers reflect on their learning methods in understanding patterns.	Enough
	Everage	**2,5 (**Enough**)**

3.4. Presentation of Student Observation Data After Treatment

The results showed significant improvement. The average student activity score increased to 3.9, which is considered good. Students appeared more enthusiastic in paying attention to the lesson, demonstrating understanding, expressing opinions, and working collaboratively in groups to find solutions to problems.

The Problem-Based Learning model has been proven to encourage students to be more active, critical, and independent in learning. The following are the results of observations of student activity after treatment:

Table 4. Results of Observations of Student Activity After Treatment (Experimental Class)

No	Observed Aspects	Score	Category
1.	Students pay attention when the teacher presents a picture or number pattern problem.		Good
2.	Students demonstrate understanding of the picture and number pattern problem.		Good
3.	Students express their opinions in formulating the picture and number pattern problem.		Good
4.	Students work together in groups to develop steps to solve the picture and number pattern problems.		Good
5.	Students actively try various possibilities for the number pattern.		Good
6.	Students seek other sources or methods to solve picture pattern problems.		Enough
7.	Students are able to explain the types of pattern sequences they find.		Good
8.	Students clearly present how to calculate using picture or number patterns.		Good
9.	Students evaluate errors in finding ways to calculate patterns.		Good
10.	Students and teachers reflect on their learning methods in understanding patterns.		Good
	Everage	**3,9 (Good)**	

With the successful implementation of the Problem-Based Learning model, the next step was to measure the students' initial abilities to determine the initial conditions before the learning treatment was administered.

3.5. Presentation of Pre-Test and Post-Test Data for the Experimental Class

The pretest and posttest were used to measure the effect of the Problem-Based Learning (PBL) model on improving student achievement in the picture and number patterns topics.

The table above shows that the average pretest score for students was 55.42, while the average posttest score increased to 82.08. This increase indicates that after implementing the Problem-Based Learning (PBL) model, there was a significant improvement in student learning outcomes.

The average increase of 26.66 points (from 55.42 to 82.08) is a strong indicator that the Problem-Based Learning method has a positive impact on student achievement in mathematics in fourth-grade Islamic elementary schools.

3.6. Presentation of Pre-Test and Post-Test Results for the Control Class

Pre-test and post-test results for 24 students in the control class, the class not treated with the Problem-Based Learning (PBL) model. The following table presents the pre-test and post-test results for 24 students in the control class:

The table above shows an increase in the average score from 45.00 to 65.83 after the conventional learning process. This means that even without treatment, learning still had an impact on improving student achievement, although not significantly compared to the experimental class, which achieved an average posttest score of 82.08.

Compared to the experimental class, which experienced an increase in the average score from 55.42 to 82.08, the increase in the control class from 45.00 to 65.83 is relatively low. This confirms that the Problem-Based Learning (PBL) model has a significant impact on improving student achievement.

4. DISCUSSION

4.1. N-Gain Test

The pretest and posttest data for students in the experimental class were then calculated using the normalized gain formula. The goal was to determine the extent of improvement in mathematics learning outcomes of fourth-grade students at Madrasah Ibtidaiyah Hidayatul Ulum Tempel Sidoarjo after implementing the Problem-Based Learning model. The data processing results showed the normalized gain, or average normalized gain, of students after the implementation of the Problem-Based Learning model.

Table 7. Normalized N-Gain Classification of Students at Madrasah Ibtidaiyah Hidayatul Ulum Tempel Sidoarjo

GainNormality Coefficient	Classification	Frequency	Percentage %
g<0.3	Low	0	0%
0.3≤g<0.7	Medium	17	70.8%
g>0.7	High	7	29.2%
Average gain= 0,62		**24**	

Based on the table above, the improvement in fourth-grade students' mathematics learning outcomes after implementing the Problem-Based Learning model is in the moderate category, with an average normalized gain of 0.62, which means it falls into the moderate category.

To calculate Normalized Gain (N-Gain), use the formula from Hake (1999):

Keterangan:

$$g = \frac{\text{Skor Posttest} - \text{Skor Pretest}}{\text{Skor Maksimum} - \text{Skor Pretest}}$$

- **g** = N-Gain
- **Posttest** = score after treatment
- **Pretest** = score before treatment
- **Score Maksimum** = score ideal (generally 100)
- $g = \frac{29{,}08}{47}$

$$g = 0{,}62$$

$$g = 0{,}62$$

Based on the calculation results, the N-Gain value was obtained as 0.62. Referring to the N-Gain criteria, this value is included in the moderate category because it is in the range $0{,}3 \leq g < 0{,}7$.

4.2. ANCOVA Hypothesis Test

The ANCOVA test was conducted to determine whether the use of the Problem-Based Learning (PBL) model had an effect on students' mathematics achievement. Prior to conducting the ANCOVA (Analysis of Covariance), several assumptions must be met, including: normality and homogeneity of variance. Once all assumptions are met, the ANCOVA test may be conducted. The ANCOVA test criteria are: if the Sig. value is > 0.05, H0 is accepted; and if the Sig. value is < 0.05, H0 is rejected. The results of the one-way ANOVA test indicate a significant difference between the learning models used by one class and another using the problem-based learning model on improving student mathematics achievement [F = 17.821, sig. = <.001, partial eta squared = 0.279]. Based on the analysis above using SPSS version 30, the sig. value (0.001 <0.05) indicates that the average student learning outcome after implementing the problem-based learning model in mathematics learning is >74.9. This means that H0 is rejected and H1 is accepted, namely, the average post-test learning achievement of students in the experimental class is 82.08, indicating an effect on improving student mathematics achievement at Madrasah Ibtidaiyah Hidayatul Ulum Tempel Sidoarjo.

5. CONCLUSION

Based on the research results above, it can be concluded that the implementation of the Problem-Based Learning (PBL) model significantly improved the mathematics achievement of fourth-grade students at Madrasah Ibtidaiyah Hidayatul Ulum Tempel Krian Sidoarjo. This model was implemented well, following the learning syntax and increasing teacher and student engagement in the learning process.

The analysis showed that the mathematics achievement of students in the experimental class was higher than that of students in the control class, as indicated by the average posttest score and the results of the ANCOVA statistical test with a significance value of <0.05. Furthermore, the N-Gain value

was in the moderate category, indicating a significant improvement in learning outcomes.

The implementation of the Problem-Based Learning model not only had a positive impact but also significantly improved student mathematics achievement and became an effective alternative learning strategy for implementation in Madrasah Ibtidaiyah.

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