



The Effect of the Problem-Based Learning Model Assisted by Baamboozle Game on Students' Mathematical Problem-Solving Skills in Cube and Rectangular Prism Volume for Grade VI

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Abstract:

This study aimed to examine the effect of the Problem-Based Learning (PBL) model assisted by the Baamboozle Game on the mathematical problem-solving abilities of sixth-grade students on the topic of cube and rectangular prism volume. The study was motivated by students' difficulties in understanding mathematical problems, planning appropriate solutions, carrying out calculations, and checking the accuracy of their answers. A quantitative approach was employed using a Pre-Experimental One Group Pretest-Posttest Design. The subjects were 37 sixth-grade students of SD IT Al-Ikhlâs, Tlogowungu, Pati. Data were collected through a ten-item essay test, observation, and documentation. The data were analyzed using normality testing, Paired Sample t-Test, and N-Gain analysis. The results showed that the mean score increased from 52.43 in the pretest to 81.35 in the posttest, representing an increase of 28.92 points. The Paired Sample t-Test yielded a significance value of $0.000 < 0.05$, indicating a statistically significant difference between the pretest and posttest scores. Furthermore, the N-Gain score of 0.61 indicated a moderate level of improvement. The specific contribution of the PBL-Baamboozle integration lies in combining contextual problem-solving activities through the PBL stages with interactive and game-based learning through Baamboozle. This combination provided opportunities for students to understand problems, formulate solution strategies, carry out calculations, and evaluate their answers in an active, collaborative, and engaging learning environment. Therefore, the findings support the conclusion that the PBL model assisted by the Baamboozle Game was associated with a significant improvement in students' mathematical problem-solving abilities on cube and rectangular prism volume, with the level of improvement categorized as moderate.

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Introduction (مقدمة)

Mathematics is a subject that requires students to understand concepts, think logically, and apply appropriate strategies to solve problems accurately. Mathematical problem-solving ability is one of the essential competencies that elementary school students need to develop because it involves more than performing calculations. Students are required to understand the information presented in a problem, identify what is known and asked, formulate an appropriate solution strategy, carry out the planned procedure, and evaluate the correctness of the obtained answer. Therefore, mathematical problem-solving ability plays an important role in developing students' logical, critical, and systematic thinking skills. In elementary education, this ability is particularly important because students are frequently faced with contextual and non-routine mathematical problems that require them to apply mathematical concepts rather than merely memorize formulas.

One of the mathematical topics that requires adequate problem-solving ability is the volume of cubes and rectangular prisms. Students often experience difficulties when solving problems related to this topic because they need to connect abstract mathematical concepts with concrete situations. Difficulties may occur when students identify relevant information, determine the appropriate formula, select the necessary steps, and interpret the final answer. Based on the initial observations conducted at SD IT Al-Ikhlâs, Tlogowungu, Pati, sixth-grade students experienced difficulties in solving mathematical problems related to the volume of cubes and rectangular prisms. The learning process was still predominantly teacher-centered, while the use of innovative and interactive learning media was limited. Consequently, some students tended to be passive and had difficulty developing systematic problem-solving strategies.

The Problem-Based Learning (PBL) model provides a relevant instructional approach for addressing these problems because it places students in situations where they are required to investigate and solve contextual problems. Through PBL, students are encouraged to understand the problem, organize relevant information, conduct investigations, develop possible solutions, and evaluate the problem-solving process. These stages are closely related to the four indicators of mathematical problem solving proposed by Polya: understanding the problem, devising a plan, carrying out the plan, and looking back. In this context, PBL provides a learning structure that allows students to practice mathematical problem solving systematically rather than simply applying memorized formulas.

However, the implementation of PBL can be strengthened through the use of interactive learning media. In this study, Baamboozle Game is used as a supporting medium because it provides game-based activities that can make the problem-solving process more interactive and engaging. Baamboozle allows students to participate in questions, challenges, scoring activities, and group-based tasks. Within the PBL framework, Baamboozle does not replace the problem-solving stages of PBL; rather, it serves as an interactive medium that supports students during the implementation and evaluation of problem-solving activities. The game format can encourage active participation, collaboration, concentration, and immediate engagement with mathematical problems. Thus, the contribution of Baamboozle lies in providing an interactive and enjoyable learning environment that complements the problem-oriented structure of PBL.

Previous studies have examined the use of PBL and Baamboozle in mathematics learning. However, the existing studies show several limitations that provide an opportunity for further research. Previous research has investigated PBL assisted by Baamboozle in relation to problem-solving ability, but some studies were conducted on different mathematical topics and grade levels. For example, (Ingke Joanna, 2024) examined the use of PBL and Baamboozle in relation to

mathematical problem-solving ability and learning motivation, but the research focused on data presentation material at the elementary school level. Other studies focused on learning outcomes rather than mathematical problem-solving ability. In addition, research conducted by (Febriany A. Mahagia, Agnes M. Goni, 2023) examined PBL without specifically integrating it with an interactive game medium, while (Hartanti Utami, 2025) examined PBL assisted by Baamboozle but focused on mathematics learning more generally.

Therefore, the research gap in this study lies in the limited research specifically examining the integration of the PBL model and Baamboozle Game to improve mathematical problem-solving ability on the topic of cube and rectangular prism volume among sixth-grade elementary school students, particularly in the context of SD IT Al-Ikhlâs, Tlogowungu, Pati. This study differs from previous studies in terms of the combination of instructional model and interactive medium, the dependent variable, the mathematical topic, and the characteristics of the research subjects. The novelty of this study is therefore positioned in the specific integration of PBL and Baamboozle Game to support the four stages of mathematical problem solving: understanding the problem, devising a plan, carrying out the plan, and looking back.

The integration of PBL and Baamboozle is expected to create a complementary learning process. PBL provides the pedagogical framework for presenting contextual problems and guiding students through systematic investigation and problem solving, while Baamboozle provides an interactive and game-based environment that encourages students to actively engage with questions and challenges during the learning process. This combination is expected to bridge the gap between conceptual understanding and practical problem-solving activities. Through group discussion, problem investigation, interactive challenges, and evaluation of answers, students are given opportunities to practice mathematical problem-solving skills in a contextual, collaborative, and engaging learning environment.

Based on this research gap and the potential contribution of integrating PBL with Baamboozle Game, this study aims to determine the effect of the Problem-Based Learning model assisted by Baamboozle Game on the mathematical problem-solving ability of sixth-grade students on the topic of cube and rectangular prism volume at SD IT Al-Ikhlâs, Tlogowungu, Pati. The study is expected to contribute empirically to the development of innovative mathematics learning by demonstrating how an interactive game-based medium can complement a problem-based instructional model in developing elementary students' mathematical problem-solving abilities.



Method (منهج)

This study employed a quantitative research methodology using a Pre-Experimental One-Group Pretest-Posttest Design. This design was selected to evaluate the differences in students' mathematical problem-solving skills before and after receiving the instructional treatment, namely the Problem-Based Learning (PBL) model assisted by the Baamboozle Game. The research design is presented as follows:

$$O_1 \rightarrow X \rightarrow O_2$$

Where:

O_1 = Pretest score administered before the intervention.

X = Treatment using the Problem-Based Learning model assisted by the Baamboozle Game.

O_2 = Posttest score administered after the intervention.

The primary limitation of this single-group pre-experimental design is the absence of a control group for comparison. Therefore, external confounding variables, such as student maturation and testing effects, cannot be completely isolated as they could be in a true quasi-experimental or experimental design. Nevertheless, this design provides an efficient preliminary empirical approach for examining changes in students' mathematical problem-solving skills following the implementation of the treatment within the specific local research context.

Research Participants and Implementation Procedure

The study was conducted at SD IT Al-Ikhlas, Tlogowungu District, Pati Regency, during the even semester of the 2025/2026 academic year. The participants consisted of 37 sixth-grade students ($N = 37$), who were selected using total population sampling.

The research was conducted over a four-week period and consisted of three main phases: the initial phase, treatment phase, and final phase.

1. Initial Phase (Week 1)

In the initial phase, the students completed a 70-minute pretest (O_1) consisting of mathematical problem-solving tasks. The pretest was administered to establish the students' baseline mathematical problem-solving abilities before the instructional treatment.

2. Treatment Phase (Weeks 2-3)

The treatment phase consisted of four instructional sessions, each lasting 70 minutes. The learning activities integrated the syntax of the Problem-Based Learning model with the interactive features of the Baamboozle Game.

a) Session 1: Cube Volume Problem Orientation

Students were introduced to contextual problems involving cube-shaped containers. Baamboozle was integrated into the initial question-and-answer activities to encourage students to identify the information provided in the problem and determine what was being asked.

b) Session 2: Cube Volume Investigation and Strategy

Students worked collaboratively in groups to investigate cube volume problems and apply the formula $V=3$. Baamboozle was used to present gamified quiz challenges designed to strengthen students' understanding and calculation accuracy.

c) Session 3: Rectangular Prism Problem Orientation

Students explored contextual problems involving rectangular prisms. They were guided to identify the relevant dimensions, including length, width, and height (pp, ll, and tt), and determine the information required to solve the problems.

d) Session 4: Investigation and Evaluation of Rectangular Prism Problems

Students solved combined word problems involving cubes and rectangular prisms. During the reflection and evaluation stage, Baamboozle was used to present interactive questions that required students to identify and match appropriate solution steps. Immediate scoring feedback was provided to support students' evaluation of their solutions.

3. Final Phase (Week 4)

In the final phase, the students completed a 70-minute posttest (O_2). The posttest was administered using an equivalent problem-solving assessment to measure students' mathematical problem-solving abilities after the implementation of the treatment.

Assessment Indicators and Research Instrument

Data were collected using a written test consisting of 10 essay items. The test items were developed based on Polya's four indicators of mathematical problem solving, namely understanding the problem, devising a plan, carrying out the plan, and looking back (Kania & Ratnawulan, 2022).

a. Understanding the Problem

This indicator measured students' ability to identify and explicitly state the information given in the problem and determine the information being asked.

b. Devising a Plan

This indicator measured students' ability to select an appropriate mathematical formula, such as $V = s^3$ for cubes or $V = p \times l \times t$. $V = p \times l \times t$ for rectangular prisms, and formulate systematic solution steps.

c. Carrying Out the Plan

This indicator measured students' ability to carry out the planned mathematical procedures accurately and systematically, including performing arithmetic calculations and using appropriate volume units, such as cm, m, or liters.

d. Looking Back

This indicator measured students' ability to review their solution steps, verify the accuracy of their calculations, and provide a clear and logical final answer.

Instrument Validity and Reliability

To ensure the empirical rigor of the research instrument, several procedures were conducted to establish its validity and reliability.

Content and Construct Validity

The test items were evaluated by two expert judges, consisting of a mathematics education lecturer and a senior Grade VI teacher. The validation process examined the

alignment of the items with the curriculum, the correspondence between the items and Polya's problem-solving indicators, and the clarity of the language used in the instrument.

Empirical Validity

Empirical testing of the instrument was conducted in a non-sample class with characteristics equivalent to those of the research participants. Item validity was analyzed using the Pearson Product-Moment correlation. An item was considered valid when the obtained r -value (r_{count_count}) was greater than the critical r -value at a significance level of 5%.

Reliability

The reliability of the instrument was examined using Cronbach's Alpha (α). The instrument was considered reliable and internally consistent when the Cronbach's Alpha coefficient was at least 0.70.

Scoring Rubric

Each essay item was assessed using an analytical scoring rubric based on Polya's four mathematical problem-solving indicators. Each item had a maximum score of 10 points, resulting in a maximum total score of 100 points for the 10 items.

Mathematical Problem-Solving Indicator	Score	Performance Criteria
1. Understanding the Problem	0	Fails to state the known information and what is being asked.
	1	States the known information and/or requested information incompletely or with conceptual errors.
	2	Correctly and completely identifies all relevant known information and what is being asked.
2. Devising a Plan	0	Provides no plan or selects a completely incorrect formula.
	1	Identifies the appropriate formula but presents unsystematic or incomplete solution steps.
	2	Correctly selects the appropriate volume formula ($V = s^3$ or $V = p \times l \times t$) and systematically structures the solution steps.
3. Carrying Out the Plan	0	Provides no response or calculations are entirely incorrect.
	1-2	Demonstrates some correct initial steps but makes major arithmetic errors.
	3	Performs the calculation steps correctly but omits the volume unit or makes a minor final calculation error.
	4	Executes the calculations accurately and systematically and includes the correct volume unit.
4. Looking Back	0	Does not check the calculations or provide a final conclusion.
	1	Provides a final conclusion that contradicts the calculation steps or the context of the problem.
	2	Verifies the solution steps and explicitly provides an accurate and logical final conclusion.

Statistical Analysis Procedures

The quantitative data were processed using SPSS through several statistical procedures to ensure systematic and reproducible data analysis.

1. Descriptive Statistics

Descriptive statistics were used to summarize the pretest and posttest scores. The analysis included the minimum score, maximum score, mean, and standard deviation.

2. Normality Test

A normality test was conducted using the Kolmogorov-Smirnov test at a significance level of $\alpha=0.05$. The data were considered normally distributed when the significance value (pp) was greater than 0.05.

3. Hypothesis Testing

Hypothesis testing was conducted using the Paired Sample t-Test at a significance level of $\alpha=0.05$. This analysis was used to determine whether there was a statistically significant difference between students' pretest and posttest scores following the implementation of the PBL model assisted by the Baamboozle Game.

The hypotheses were formulated as follows:

H₀ : Indicating that there is no statistically significant difference between students' mathematical problem-solving scores before and after the implementation of the PBL model assisted by the Baamboozle Game.

H_a : Indicating that there is a statistically significant difference between students' mathematical problem-solving scores before and after the implementation of the PBL model assisted by the Baamboozle Game.

The decision rule was that if the significance value (Sig. 2-tailed) was less than 0.05 ($p < 0.05$), H₀ was rejected and H_a was accepted. Conversely, if $p \geq 0.05$, H₀ was not rejected.

4. Normalized Gain (N-Gain) Analysis

Normalized Gain (N-Gain) analysis was conducted to determine the magnitude of improvement in students' mathematical problem-solving performance following the treatment. The N-Gain index was calculated using the following formula:

$$g = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum Score} - \text{Pretest Score}}$$

The N-Gain scores were interpreted according to the following categories:

High : $g > 0.70$

Medium : $0.30 \leq g \leq 0.70$

Low : $g < 0.30$

The combination of the Paired Sample t-Test and N-Gain analysis provided information regarding both the statistical significance of the difference between pretest and posttest scores and the magnitude of students' improvement in mathematical problem-solving performance after the implementation of the instructional treatment.

Result (نتائج)

Statistical Analysis Results

Before conducting the hypothesis test, a normality test was performed to determine whether the pretest and posttest scores followed a normal distribution. The Kolmogorov Smirnov test was used at a significance level of 0.05. The results showed that the pretest data had a significance value of 0.184, while the posttest data had a significance value of 0.200. Since both significance values were greater than 0.05, the pretest and posttest scores were considered normally distributed. Therefore, the assumption of normality was satisfied, and the Paired Sample t-Test could be appropriately applied to examine the difference between the pretest and posttest scores.

Table 1. Descriptive Statistics of Pretest and Posttest Scores

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Pretest	37	35.00	70.00	52.43	9.12
Posttest	37	65.00	95.00	81.35	7.64

Descriptive analysis showed an improvement in students' mathematical problem solving performance following the implementation of the Problem-Based Learning (PBL) model assisted by the Baamboozle Game. The mean pretest score was 52.43 (SD = 9.12), with scores ranging from 35.00 to 70.00. Following the intervention, the mean posttest score increased to 81.35 (SD = 7.64), with scores ranging from 65.00 to 95.00. Thus, the mean score increased by 28.92 points.

Table 2. Test of Normality (Kolmogorov-Smirnov)

Variable	Statistic	df	Sig.
Pretest	0.118	37	0.184
Posttest	0.104	37	0.200

To determine whether the observed increase was statistically significant, a Paired Sample t-Test was conducted. The analysis produced a mean difference of 28.92 for the pretest-posttest comparison and a two-tailed significance value of 0.000. The negative mean difference reflects the higher posttest scores compared with the pretest scores.

Table 3. Paired Samples Statistics

Variable	Mean	N	Std. Deviation	Std. Error Mean
Pretest	52.43	37	9.12	1.50
Posttest	81.35	37	7.64	1.26

The complete Paired Sample t-Test results were as follows: $p < .001$, 95% CI. Because the p-value was below the predetermined significance level of 0.05, the null hypothesis (H_0) was rejected. These results indicate that there was a statistically significant difference between students' mathematical problem-solving scores before and after the implementation of the PBL model assisted by the Baamboozle Game.

Table 4. Paired Samples Test

Paired Differences	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval Lower	95% Confidence Interval Upper	T	df	Sig. (2-tailed)
Pretest - Posttest	-28.92	8.48	1.39	-31.75	-26.08	-20.74	36	0.000

The magnitude of improvement was further examined using the Normalized Gain (N-Gain) index. The mean N-Gain score was 0.61, which falls within the medium category ($0.30 \leq g \leq 0.70$). This result indicates a moderate level of improvement in students' mathematical problem solving performance following the instructional intervention.

Table 5. N-Gain Analysis

Mean Pretest	Mean Posttest	N-Gain Score	Category
52.43	81.35	0.61	Medium

Overall, the statistical results indicate that students' mathematical problem-solving scores increased significantly from pretest to posttest. However, because the study employed a one-group pretest-posttest design without a control group, the statistically significant difference should be interpreted as evidence of improvement following the intervention rather than definitive causal evidence attributable exclusively to the PBL model assisted by the Baamboozle Game.



Discussion (مناقشة)

The empirical findings demonstrate a statistically significant enhancement in sixth-grade students' mathematical problem-solving skills regarding the volume of cubes

and rectangular prisms following the implementation of the Problem-Based Learning (PBL) model assisted by the Baamboozle Game. The mean score increased from 52.43 (SD = 9.12) on the pretest to 81.35 (SD = 7.64) on the posttest, representing an average gain of 28.92 points. Inferential testing using a Paired Sample t-Test yielded $t(36) = -20.74$, $p = 0.000$ ($p < 0.05$), leading to the rejection of H_0 . Furthermore, the normalized gain score of 0.61 places this improvement in the medium effectiveness category.

To address reviewer recommendations, the observed improvements across Polya's four problem-solving indicators are critically examined below using classroom observation data, empirical literature, and methodological reflections:

1. Contributions of PBL Syntax and Baamboozle to Polya's Indicators

a. Understanding the Problem

Prior to intervention, baseline data revealed that students mechanically multiplied numbers in word problems without identifying facts. During PBL's problem orientation phase, students examined real-world contexts. Classroom observation logs in Sessions 1 and 3 confirmed that 84 % of student groups explicitly wrote down known parameters and requested variables before computing.

b. Devising a Plan

Collaborative group investigations enabled students to systematically choose appropriate formulas ($V = s^3$ or $V = p \times l \times t$). Students moved beyond memorization to conceptual mapping. This corroborates (Ingke Joanna, 2024), who highlighted the role of structured peer discussion in strategic mathematical planning.

c. Carrying Out the Plan

The gamified environment of Baamboozle enhanced task focus and computational accuracy. Observational records indicated active group collaboration to double-check algebraic steps before submitting team responses during competitive game turns.

d. Looking Back

Baamboozle's immediate answer validation feature supported the evaluation stage. When correct solutions were displayed on screen, student groups actively cross-checked their written steps and caught unit errors.

2. Empirical Evidence on Engagement vs. "Math Anxiety"

Regarding claims of reducing math anxiety, it must be noted critically that no psychological measurement scale was administered. Therefore, observed behavioral enthusiasms such as active participation during game turns—reflects heightened situational engagement and task concentration rather than a measured reduction in clinical math anxiety.

3. Critical Comparison with Previous Studies

These results support (Ingke Joanna, 2024) and (Hartanti Utami, 2025), confirming that gamified PBL environments foster mathematical understanding. Unlike studies focusing primarily on general science learning outcomes or basic arithmetic (Febriany A. Mahagia, Agnes M. Goni, 2023), this study demonstrates that gamified PBL is particularly effective for 3D spatial geometry requiring multi-step reasoning (Nadia

Angelina Rajagukguk, Regina Sipayung, Antonius Remigius Abi, Bogor Lumbanraja, Nova Florentina Ambarwati, 2025).

4. Acknowledgment of Methodological Threats & Alternative Explanations

Because this study utilized a **Pre Experimental One Group Pretest-Posttest Design without a control group**, attributing the 28.92 point increase solely to the PBL-Baamboozle intervention would be a methodological overstatement. Several alternative confounding factors must be acknowledged:

- Testing / Practice Effects**, Administering similar pre- and post-intervention tests inherently creates test familiarization, enabling students to perform better partly due to repeated practice.
- Maturation and Instructional Time**: The 4 week instructional duration (4 \times 70 minutes) provided additional learning time and general practice, which naturally contributes to score gains over time.
- Novelty / Hawthorne Effect**: Introducing a novel digital platform (Baamboozle) into a traditional classroom temporarily spikes student motivation due to media novelty rather than pedagogical structure alone.



Conclusion (خاتمة)

Based on the empirical findings and data analysis regarding the effect of the Problem-Based Learning (PBL) model assisted by the Baamboozle Game on the mathematical problem-solving skills of sixth-grade students regarding the volume of cubes and rectangular prisms at SD IT Al-Ikhlâs, Tlogowungu District, Pati Regency, the following conclusions are drawn:

1. Mathematical Problem-Solving Skills Prior to Treatment (Pretest):

Prior to the implementation of the PBL model assisted by the Baamboozle Game, students' baseline mathematical problem-solving skills were relatively low. This was evidenced by a pretest mean score of 52.43, with a minimum score of 35.00 and a maximum score of 70.00.

2. Mathematical Problem-Solving Skills Following Treatment (Posttest):

Following the implementation of the PBL model assisted by the Baamboozle Game, students' mathematical problem-solving skills demonstrated a substantial enhancement. This was reflected in the posttest mean score reaching 81.35, with a minimum score of 65.00 and a maximum score of 95.00, representing an average increase of 28.92 points from the pretest baseline.

3. Effect of the PBL Model Assisted by Baamboozle Game:

There is a statistically significant effect of the PBL model assisted by the Baamboozle Game on sixth-grade students' mathematical problem-solving skills regarding the volume of cubes and rectangular prisms. Inferential analysis using a Paired Sample t-Test yielded a two-tailed significance value of $p = 0.000$ ($p < 0.05$), leading to the rejection of the null hypothesis (H_0) and the acceptance of the alternative hypothesis (H_a).

4. Improvement Level (N-Gain):

The magnitude of improvement in students' mathematical problem-solving skills fell within the **medium** category, as indicated by an average Normalized Gain (N-Gain) score of 0.61 (or 61 %). This structural improvement systematically encompassed all four

of Polya's problem-solving indicators: understanding the problem, devising a plan, carrying out the plan, and looking back.

Recommendations

Based on the aforementioned conclusions, the researcher proposes several actionable recommendations for relevant stakeholders:

1. For Mathematics Teachers:

Teachers are encouraged to adopt the Problem-Based Learning model integrated with gamified interactive media, such as the Baamboozle Game, as an effective instructional alternative. This combination has proven effective in fostering an active, engaging learning environment that cultivates critical thinking and structured problem-solving skills among elementary students.

2. For School Administrators and Principals:

School administrators are expected to support the integration of digital learning by facilitating necessary ICT infrastructure (such as reliable internet connection and projectors) and organizing professional development workshops focused on innovative digital pedagogy for primary education.

3. For Students:

Students should consistently apply structured problem-solving steps (understanding the problem, planning, executing, and reviewing) and actively engage in gamified learning activities to enhance computational precision and collaborative group work.

4. For Future Researchers:

Future researchers are advised to investigate the efficacy of the PBL model integrated with Baamboozle across other mathematical topics, varied grade levels, or using rigorous quasi-experimental designs with control groups. Furthermore, future studies could explore additional dependent variables, such as learning motivation, self-directed learning, or psychological constructs like math anxiety using validated measurement scales.

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