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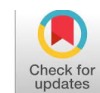
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## Effectiveness of Problem-Based Learning Supported by PELIP Media on Elementary School Students Understanding of Probability

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### ABSTRACT

Probability is one of the subjects that students must master by the end of Phase C in elementary school. To help students understand probability concepts more clearly, the Problem-Based Learning (PBL) approach and the PELIP medium were used. This study aims to examine how the use of the Problem-Based Learning (PBL) approach supported by the PELIP medium, the use of the PELIP medium itself, and the PBL approach influence elementary school students' understanding of probability concepts. This study employs a quantitative method with an experimental design. This study was conducted at two elementary schools SDN Cimasuk and SDN Lembang located in Pamulihan Subdistrict, Sumedang Regency, involving three groups that received different treatments. Data were collected through tests standards for validity, reliability, difficulty level, and the ability to distinguish between answers. Data analysis was conducted by examining baseline conditions, comparing differences between groups, measuring improvement within each group, and calculating N-Gain values. The results of the study show that all types of interventions successfully improved students' understanding of probability concepts. The PBL class that used the PELIP medium saw its average score increase from 37.53 to 76.50, with an N-Gain of 0.63. The class using the PELIP medium saw its average score rise from 45.50 to 74.94, with an N-Gain of 0.56. Meanwhile, the PBL class's scores increased from 40.35 to 80.06 with an N-Gain of 0.68, making it the group with the highest score increase. PBL approach using PELIP media, the use of PELIP media alone, and the PBL approach without PELIP media were all equally effective in improving elementary school students' conceptual understanding of probability.



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## Introduction

Mathematics is a highly important field of study because it helps improve logical, critical, focused, and innovative thinking skills. In addition, mathematics helps people solve various problems that arise in daily life and serves as the foundation for advances in science and technology (Isnaina et al. 2022). Therefore, mathematics is taught starting in elementary school to provide students with a foundation for understanding more complex mathematical concepts at higher levels of education. In learning mathematics, understanding concepts is crucial because it serves as the foundation for students to build knowledge, connect various concepts they have learned, and apply them in different situations (Martiasari & Kelana, 2022). Students who have a solid grasp of concepts are not only able to memorize formulas but can also restate a concept, understand its meaning, and use it to solve problems accurately. Conversely, if conceptual understanding is lacking, students will struggle with subsequent material because mathematical concepts are interconnected (Suherman et al., 2023).

One of the math topics in elementary school that requires a solid conceptual understanding is probability. The purpose of teaching probability is to help students understand the likelihood of an event occurring and to improve their ability to make predictions based on the information provided. However, in practice, the concept of probability is often difficult for students to grasp. Based on field observations, most students have not yet fully grasped the concept of probability and tend to simply memorize how to solve problems without understanding the meaning or significance behind them. This difficulty arises because the concept of probability is abstract, making it hard for elementary school students to visualize it. In this context, Problem-Based Learning (PBL) emerges as a promising alternative approach. PBL is a learning model rooted in the presentation of authentic problems, encouraging students to actively seek solutions through critical thinking, discussion, and collaboration (Rahayu et al., 2024). A number of studies have confirmed the benefits of PBL in improving students' mathematical achievement. Nurkomaria et al. (2022) for example, successfully demonstrated an increase in junior high school students' learning outcomes in probability through the implementation of PBL. Wati et al. (2025) developed a PBL-based learning tool that was shown to improve students' mathematical reasoning skills in probability. Unfortunately, both studies focused on the junior high school level, so there is still significant potential for research at the elementary school level.

In addition to pedagogical approaches, the availability of appropriate learning materials is equally important. According to Piaget's theory of cognitive development, sixth-grade students are generally still in the concrete operational stage phase in which understanding abstract concepts is far more effective when supported by visual representations or concrete manipulatives. The PELIP (Probability Circle Map) learning medium was designed to address this need. Through intuitive visualizations of sample spaces, PELIP provides students with the opportunity to explore probability concepts independently and in an engaging manner. Aeni et al. (2025) emphasize that well-designed learning media are not merely teaching aid but catalysts capable of transforming how students interact with the material. Nevertheless, studies specifically examining the synergy between PBL and PELIP in the context of probability learning in elementary school remain very rare. Based on the identification of this research gap, this study aims to examine the extent to which three treatment variations PBL supported by PELIP, independent PELIP, and independent PBL are effective in enhancing sixth-grade elementary school students' mastery of probability concepts.

## Method

### Research Design

The chosen research approach is quantitative, given that the required data consists of measurable numerical values that can be statistically analyzed to produce empirically tested conclusions. This approach aligns with the definition proposed by [Damanik et al. \(2025\)](#), namely that quantitative research is a systematic inquiry process that collects numerical data and analyzes it using mathematical or statistical procedures. More specifically, the type of research used is an experiment, in which one or more treatment conditions are administered to subjects and their effects are observed through measurable outcomes ([Siroj et al. 2024](#)).

The design applied is the Nonequivalent Control Group Design, which is a type of quasi-experimental design used when random assignment to groups is not feasible. In this design, each group undergoes pre- and post-treatment measurements, but without a randomization process. The selection of this design was motivated by ethical and practical considerations in a real-world classroom setting. An overview of the research design is presented in [Table 1](#).

**Table 1. Research Design**

Group	Pretest	Intervention	Posttest
Experiment 1	O <sub>1</sub>	X <sub>1</sub>	O <sub>2</sub>
Experiment 2	O <sub>3</sub>	X <sub>2</sub>	O <sub>4</sub>
Experiment 3	O <sub>5</sub>	X <sub>3</sub>	O <sub>6</sub>

Description:

Experiment 1: Implementation of the PBL approach using PELIP media in Class VI B at SDN Cimasuk

Experiment 2: Implementation of PELIP media in Class VI at SDN Lembang

Experiment 3: Application of the PBL approach in Class VI A at SDN Cimasuk

O<sub>1</sub>, O<sub>3</sub>, O<sub>5</sub> : pretest

O<sub>2</sub>, O<sub>4</sub>, O<sub>6</sub> : posttest

### Population and Sample

All sixth-grade students enrolled in public elementary schools throughout Pamulihan Subdistrict, Sumedang Regency, were defined as the population for this study. Following the concept formulated by [Ramadani et al., 2025](#)), a population is a set of subjects or objects within a specific area that possess certain attributes relevant to the focus of the study. From this population, a sample was selected using purposive sampling a goal based sampling strategy employed when the researcher seeks participants with specific characteristics in [Ksayanjaya & Rahayu \(2020\)](#). Two schools were selected as research sites, namely SDN Cimasuk and SDN Lembang, with a total of 99 student participants divided into three experimental groups ( $n = 32$ ,  $n = 36$ , and  $n = 31$ ).

### Instruments

The instrument used was an essay test developed based on seven indicators of conceptual understanding. This instrument was administered at two points before and after the intervention. The seven indicators and the distribution of test items are presented in [Table 2](#).

**Table 2.** Map of Indicators and Distribution of Test Items

No	Concept Comprehension Indicators	Question Format
1	Rearticulating a concept in your own words	There are 8 cards in a box of colored cards. The cards consist of 5 red cards and 3 blue cards. If Linda picks one card at random, determine: a. What is the probability of getting a red card? b. What is the probability of getting a blue card?
2	Classifying objects according to their characteristics	Rani entered a prize drawing. Of the 10 raffle tickets available, only 1 contained a prize. a. In your opinion, is winning a prize easy or difficult? b. Explain your answer by relating it to the probability of an event!
3	Presenting concepts using symbols or mathematical notation	There are 5 pencils and 5 pens in a bag. If someone takes one item at random from the bag, a. Are the probabilities of picking a pencil and a pen the same? b. Explain the relationship between the number of items and the probability of selecting one!
4	Identifying examples and non-examples of a concept	Inside a box are red, blue, and green colored pencils. There are the same number of pencils of each color. A student randomly picks one colored pencil from the box. a. Determine the probability of picking a red-colored pencil! b. Can the probability of picking a red-colored pencil be determined? c. Explain the reasoning behind your answer in simple terms!
5	Determining necessary and sufficient conditions	Inside a box are several dolls in white, pink, and yellow. Risa picks one doll at random from the box. a. Can the probability that Risa gets a pink doll be determined? b. Explain the reasoning behind your answer in simple terms!
6	Performing a procedure or algorithm for calculating probabilities	There are 6 red marbles and 2 blue marbles in a box. If one marble is drawn at random: a. Write the total number of marbles in the box! b. Determine the probability of drawing a blue marble! c. Explain whether the probability of this event is lower or higher than that of drawing a red marble!
7	Applying concepts to solve contextual problems	Ani wants to win a game by choosing the box with the highest probability of getting a gold ball. Box A contains 1 gold ball and 9 silver balls, while Box B contains 3 gold balls and 7 silver balls. a. Which box should Ani choose? b. Explain your thought process step by step!

Before being widely used, the instrument underwent a content validation process by three experienced teachers, and all test items were deemed appropriate. A field test was conducted with students who had already covered the probability material. Item quality analysis using IBM SPSS Statistics 16 included tests of validity (Pearson correlation), reliability (Cronbach's alpha), difficulty level, and discriminant validity.

**Table 3. Summary of Validation Test**

Test Item	p-Value	Significance Level	Status
1	0,021	5%	Valid
2	0,012	5%	Valid
3	0,016	5%	Valid
4	0,010	5%	Valid
5	0,018	5%	Valid
6	0,000	5%	Valid
7	0,000	5%	Valid
8	0,000	5%	Valid
9	0,000	5%	Valid
10	0,000	5%	Valid

The Cronbach's alpha coefficient obtained was 0.806, which, according to the classification by [Anggraini et al. \(2022\)](#), falls into the high category. This means that the instrument has an adequate level of internal consistency to be used as a measure of conceptual understanding of probability.

**Table 4. Characteristics of Item Difficulty Levels**

Item	Index	Category Range
1	0,317	0,31–0,70
2	0,360	0,00–0,30
3	0,390	0,31–0,70
4	0,450	0,31–0,70
5	0,307	0,00–0,30
6	0,527	0,31–0,70
7	0,523	0,31–0,70
8	0,400	0,31–0,70
9	0,367	0,31–0,70
10	0,407	0,31–0,70

The discrimination power test was based on the formula  $DP = (\bar{X}A - \bar{X}B) / SMI$  developed [Revita et al. \(2023\)](#). Most test items fell into the “adequate” to “good” categories, and one item with low discrimination power was retained after undergoing content revisions based on feedback from the validation team.

## Procedure and Analysis

Data collection began with administering a pretest to determine the initial level of each group. Next, each group learned according to the assigned treatment for a predetermined period. At the end of the learning period, a posttest was administered using the same instrument as the pretest. Each experimental class underwent three learning sessions, with each session lasting two class periods, each 45 minutes long. The first experimental group used the PBL approach with the aid of the PELIP (Circle of Opportunities Map) medium. The learning process was conducted in accordance with the five-stage PBL steps, namely: (1) introducing the problem to students using the PELIP medium as a tool to present the problem, (2) guiding students in learning and understanding the given problem, (3) providing guidance to students individually or in groups in finding solutions, (4) assisting students in presenting their work, and (5) analyzing and evaluating the problem-solving process and results. In the first session, the problem presented was Circle 1 regarding the concept of probability; in the second session, the problem presented was Circle 2 regarding probability scales; and in the third session, the problem presented was Circle 3 regarding comparing two probabilities.



Figure 1. PELIP (Opportunity Circle Map)

The second experimental group used the PELIP (Probability Circle Map) medium without employing the PBL approach. Instruction was conducted using the features available in the PELIP medium so that students could understand probability concepts on their own in a guided manner. The first session covered Circle 1: Probability Concepts; the second session covered Circle 2: Probability Scales; and the third session covered Circle 3: Comparing Two Probabilities. The third experimental group used the PBL approach alone; the learning process followed the same structure as the first experimental group, but the problems presented did not utilize the PELIP media. During the problem-orientation phase, problems relevant to everyday life contexts were presented using PowerPoint (PPT) presentations as a substitute for the PELIP media. All three experimental groups received the same material, namely the concepts of probability, probability scales, and how to compare two probabilities. In addition, each group was given the same pre-test and post-test instruments to measure students' ability to understand mathematical concepts. The main difference between the three groups was the learning method used: the PBL model with PELIP media, PELIP media without PBL, and the PBL model without PELIP media. Data analysis followed a stepwise process. First, prerequisite tests including the Shapiro-Wilk normality test and Levene's test of homogeneity were applied to assess the assumptions of normal distribution and homogeneity of variances. Based on the results of these assumption tests, a paired-sample t-test was conducted to determine differences between groups, followed by an N-Gain test to assess improvement in each group. To assess the effectiveness of the three experimental classes, the Kruskal-Wallis's test was selected to analyze the pretest data (due to heteroscedasticity), while a one-way ANOVA was used to analyze the posttest data (since it met the prerequisite assumptions).

## Research Findings

### Research Implementation

Instruction in each experimental class was conducted according to the treatments prepared by the researcher. In the first experimental class, instruction utilized the Problem-Based Learning (PBL) method with the aid of the PELIP medium, namely the Circle of Probability Map. The learning process began with an explanation of problems related to probability. Students were then instructed to identify problems, conduct investigations, engage in group discussions, and present their solutions. During the investigation phase, the PELIP tool was used to help students understand probability through clearer and more concrete visualizations. The integration of the PBL approach with PELIP media provides students with the opportunity to understand concepts through problem-solving activities supported by learning aids that reflect real-world situations.

In the second experimental class, the learning process was conducted using the PELIP media without applying the PBL approach. The teacher used the PELIP media to explain the probability material and provide examples related to the lesson content. The media was used as a visual aid to help students better understand the probability material. After the teacher presented the material, students completed exercises and worksheets using the PELIP media, making it easier for them to grasp the concepts taught. Meanwhile, in the third experimental class, instruction was conducted using the Problem-Based Learning (PBL) approach without the support of the PELIP media. Learning activities still followed the PBL steps, namely starting with a problem, organizing students, investigating, developing and presenting results, and evaluating the problem-solving process. Through these steps, students participated in discussions and conducted investigations to find answers to the problems presented. Student-centered learning involves a process in which students construct their knowledge by thinking and solving problems related to the probability material.



**Figure 2.** Overview of the Experimental Class

### Analysis of Pretest Data

The average pretest scores for the three experimental classes are presented in Table 5 as follows.

**Table 5.** Average Pretest Scores for the Three Experimental Groups

Group	Results
Experiment 1 – PBL + PELIP	37,53
Experiment 2 – PELIP	45,50
Experiment 3 – PBL	40,35

The normality test for the pretest data was conducted using the Shapiro-Wilk test with a significance level of  $\alpha = 0.05$ . A distribution is considered normal if the resulting significance value exceeds 0.05. Table 6 summarizes the results of this test.

**Table 6.** Pretest Normality Test (Shapiro-Wilk)

Group	W	df	p-value
Experiment 1 – PBL + PELIP	0,975	32	0,649
Experiment 2 – PELIP	0,957	36	0,180
Experiment 3 – PBL	0,943	31	0,103

All three p-values (0.649; 0.180; 0.103) exceeded the 0.05 threshold, indicating that the assumption of normality was met for all groups. However, Levene's test of homogeneity revealed that the variances across groups were not equal, with a p-value of 0.000 well below 0.05. This finding led to the selection of the Kruskal-Wallis test as a more robust nonparametric alternative.

**Table 7.** Kruskal-Wallis Test Results for Pretest Data

Parameter	Value
Chi-Square	8,776
df	2
Asymp. Sig.	0,012

With a Chi-Square value of 8.776 and a significance level of  $0.012 < 0.05$ , the null hypothesis is rejected. This means that the initial levels of probability concept comprehension differ significantly among the three experimental groups. Consequently, comparisons of treatment effectiveness must account for these unequal initial conditions; therefore, N-Gain is used as a more equitable measure of improvement.

### Posttest Data Analysis

The data on the average posttest scores for the three experimental classes are presented in Table 8.

**Table 8.** Average Posttest Scores for the Three Experimental Groups

Group	Results
Experiment 1 – PBL + PELIP	76,50
Experiment 2 – PELIP	74,94
Experiment 3 – PBL	80,06

After the intervention, the posttest data were tested for normality using the Shapiro-Wilk test. The significance values obtained were 0.334, 0.070, and 0.158, respectively, for the three groups—all above 0.05. Thus, the assumption of normality was met for the posttest data. Levene's test for homogeneity of variance on the posttest data yielded a significance value of  $0.213 > 0.05$ , indicating that the variances across groups were homogeneous. With both assumptions met, the analysis proceeded to the test for improvement using a Paired Sample T-Test, as presented in Table 9.

**Table 9.** Results of the Paired-Sample T-Test for the Three Experimental Groups

Group	Results
Experiment 1 – PBL + PELIP	0,01
Experiment 2 – PELIP	0,01
Experiment 3 – PBL	0,01

In all three experimental classes,  $0.000 < 0.05$ ; it can be concluded that all three experimental groups improved students' understanding of mathematical concepts related to probability. The analysis continued with the N-Gain scores for the three experimental classes, which are presented in Table 10.

**Table 10.** N-Gain Results for the Three Experimental Groups

Group	Results
Experiment 1 – PBL + PELIP	0,63
Experiment 2 – PELIP	0,56
Experiment 3 – PBL	0,68

It can be concluded that all three experimental classes showed moderate to effective improvement in their understanding of probability concepts. To determine whether there were differences among the three experimental classes, a one-way ANOVA was conducted, the results of which are presented in Table 11.

**Table 11. Results of the One-Way ANOVA on Posttest Data**

Source	SS	df	MS	F	Sig.
Between Groups	450,988	2	225,494	1,007	0,369
Within Groups	21495,760	96	223,914		
Total	21946,747	98			

The F-value of 1.007 with  $p = 0.369 > 0.05$  leads to the decision to accept the null hypothesis. This means that there is no statistically significant difference in posttest scores among the three treatment groups. These findings confirm that PBL supported by PELIP, independent PELIP, and independent PBL result in equivalent levels of final conceptual mastery.

## Discussion

The results of the paired-sample t-test indicate that there are significant differences between pretest and posttest scores in all experimental groups. These findings indicate that all the learning methods used, namely Problem-Based Learning (PBL) supported by PELIP (Circular Probability Map) media, learning with PELIP media, or PBL without PELIP media, were all effective in improving sixth-grade elementary school students' understanding of probability concepts. Therefore, all the learning strategies employed in this study had a positive impact on enhancing students' understanding of mathematical concepts.

These results are supported by the N-Gain analysis, which shows that all three experimental groups experienced moderate improvement. The third experimental group, which used the PBL approach, achieved the highest N-Gain score of 0.68, followed by the first experimental group, which implemented PBL with PELIP support, at 0.63, and the second experimental group, which used PELIP media, at 0.56. Although the PBL group showed the greatest improvement, the differences in N-Gain scores among the groups were still relatively small. These findings indicate that all three methods were equally successful in helping students understand the concept of probability. These results are consistent with the one-way ANOVA test, which showed that there were no significant differences in the posttest scores of the three experimental groups. This means that no single teaching method was statistically more effective than the others in improving students' understanding of the concept of probability.

The greatest improvement achieved by the PBL group indicates that students' active participation in the problem-solving process significantly influences their understanding of the concept. During the learning process, students encounter various problems related to real-world situations. Thus, they are expected to be able to identify available information, discuss various alternative solutions, and draw conclusions based on the results of their investigations. This process helps students construct their own knowledge and connect the concept of probability to a more meaningful learning experience. This aligns with [Rahayu et al. \(2024\)](#) who state that PBL can help improve critical thinking skills and collaboration skills, which are crucial for understanding mathematical concepts. Through the implementation of PBL, students can build their knowledge to identify and solve problems through group discussions ([Mau et al., 2023](#)). Interestingly, without the support of the PELIP media, students in this group appeared more motivated to develop their understanding by engaging directly through problem-solving investigations. Through these learning activities, students can deepen their understanding of the material, and the experience becomes more memorable because they personally experience the learning process ([Fitriyanti et al., 2022](#)).

In the group that used PBL with the aid of PELIP media, the improvement in conceptual understanding fell into the moderate category, with an N-Gain score of 0.63. These results indicate that combining a problem-based learning model with visual media can provide a more diverse learning experience. In this learning process, PELIP media helped students understand probability concepts that are difficult to grasp directly, while the PBL method guided students in analyzing problems, discussing them, and finding solutions in a structured manner. Visual media were used to help students better understand the concepts of sample space, the probability of an event occurring, and the relationships between events in a clearer and more concrete way. Meanwhile, the PBL framework encourages students to think critically when facing and solving various problems presented to them. These findings support the argument by [Nurahman et al. \(2025\)](#) that the synergy between active learning approaches and appropriate media not only enhances understanding but also fosters intrinsic motivation to learn. The integration of media into mathematics learning through PBL has a positive impact on improving mathematical abilities ([Rohmatulloh et al., 2022](#)). The group that combined PBL and PELIP appeared active throughout the learning process. This is consistent with the research conducted by [Anggol et al. \(2025\)](#) which found that the implementation of the PBL model and learning media encourages student engagement during the teaching and learning process.

Meanwhile, the group that used only the PELIP medium also demonstrated a fairly good increase in conceptual understanding, with an N-Gain score of 0.56. These results indicate that the PELIP medium can help students learn probability material even without using the PBL model. This medium is effective because it presents probability concepts visually and concretely. By observing the sample space and illustrations of various possible events, students can more easily grasp concepts that previously seemed complex and unclear. For elementary school students who are still in the concrete operational stage of thinking, images or visuals like these are very helpful in understanding and forming concepts. This aligns with research conducted [Aeni et al. \(2025\)](#), which found that effective instructional media can encourage students to actively engage with the material being studied, rather than merely being passive listeners. Additionally, such media contribute to improving the quality of learning ([Sawitri et al., 2024](#)). In general, the research results show that the PBL learning method, the use of PELIP media, or a combination of both are equally effective in improving elementary school students' understanding of probability concepts. Although the PBL group achieved the highest N-Gain scores, the ANOVA test indicated that the differences in improvement among the groups were not statistically significant. These findings suggest that teachers have a variety of learning strategies to choose from based on student characteristics, learning objectives, and the resources available at the school, which can help improve students' understanding of probability concepts.

## Conclusion

Based on the research results, it can be concluded that the Problem-Based Learning (PBL) approach using the PELIP medium, the use of the PELIP medium, and the PBL approach combined were able to improve sixth-grade elementary school students' conceptual understanding of probability. Although each group had different initial abilities, all groups showed significant improvement after receiving instruction. The N-Gain results show that the class that implemented the PBL method experienced the greatest improvement, at 0.68, followed by the PBL class that used the PELIP media with an improvement of 0.63, and the class that used only the PELIP media with an improvement of 0.56. All these improvements fell into the moderate category. The results of the ANOVA test on the posttest data showed that there were no significant differences in the final achievement scores among the three groups ( $p > 0.05$ ). These findings suggest that all three methods are nearly equally effective in improving

students' understanding of probability concepts. However, since this study did not include a control group using conventional instruction, the results can only be compared among the three methods implemented. Thus, the PBL approach using PELIP media, the use of PELIP media alone, or the PBL approach itself can all be viable instructional options for teaching probability in elementary school. Future research should include a standard control group and a longer treatment duration to gain a more comprehensive understanding of the effectiveness of the learning approach.

### Conflict of Interest

The authors declares that there is no conflict of interest.

### Auhor Contributions

P. was responsible for the initial research concept, field data collection and documentation, and the preparation of the first draft of the manuscript. M. and A.N.A. contributed to the development of the theoretical framework, methodological design, statistical analysis, interpretation of findings, manuscript refinement, and final approval. Proportion of contributions: P.: 40%, M.: 30%, A.N.A. 30%.

### Data Availability Statement

The authors declare that data supporting the results of this study will be provided by the corresponding author, [P.], upon reasonable request.




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