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The Effect of *the Problem-Based Learning Model* Assisted by Polypad Media on the Understanding of Mathematical Concepts of Elementary School Students

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ABSTRAK

Kemampuan pemahaman konsep matematis menjadi dasar penting bagi siswa sekolah dasar karena dapat melatih kemampuan berpikir yang logis, sistematis, serta bermakna dalam memecahkan masalah geometri. Atas dasar dari urgensi kompetensi tersebut, penelitian ini dilakukan dengan tujuan untuk menguji dampak dari penerapan model pembelajaran *Problem Based Learning* (PBL) yang berbantuan media Polypad terhadap kemampuan pemahaman konsep matematis siswa pada materi ciri-ciri bangun datar. Jenis penelitian yang dipilih adalah pendekatan kuantitatif menggunakan metode eksperimen semu (*quasi-experiment*) serta menerapkan rancangan *nonequivalent control group design*. Untuk mengumpulkan data, peneliti menggunakan alat ukur berupa tes tertulis berbentuk soal uraian. Soal-soal ini dibuat secara khusus dengan mengacu pada indikator pemahaman konsep matematis. Dari analisis data yang dilakukan, hasil uji *independent sample t-test* menunjukkan angka signifikansi sebesar 0,000. Karena nilai ini berada di bawah 0,05, hal tersebut membuktikan adanya perbedaan sekaligus pengaruh yang nyata dari perlakuan pembelajaran yang diberikan, dengan kontribusi pengaruh sebesar 57%. Kesimpulannya, kombinasi antara model *Problem Based Learning* (PBL) dan media Polypad terbukti efektif dalam memberikan pengaruh positif terhadap kemampuan pemahaman konsep matematis pada siswa di tingkat sekolah dasar.

Keywords:
Problem Based Learning; Polypad; Mathematical Elementary School

ABSTRACT

Mathematical concept understanding ability becomes an important foundation for elementary school students because it can train logical, systematic, and meaningful thinking skills in solving geometry problems. Based on the urgency of these competencies, this study was conducted with the aim of examining the impact of implementing the Problem Based Learning (PBL) model assisted by Polypad media on students' mathematical concept understanding ability in the material of flat shape characteristics. The type of research chosen was a quantitative approach using a quasi-experimental method and applying a nonequivalent control group design. To collect data, the researcher used a measuring instrument in the form of a written test in the form of essay questions. These questions were specifically made with reference to indicators of mathematical concept understanding. From the data analysis conducted, the results of the independent sample t-test showed a significance value of 0.000. Since this value is below 0.05, it proves a real difference as well as a significant influence of the learning treatment given, with an influence contribution of 57%. In conclusion, the combination of the Problem Based Learning (PBL) model and Polypad media is proven effective in providing a positive influence on mathematical concept understanding ability in elementary school students.

1. Introduction

Teaching mathematics at the elementary school level plays a crucial role in forming a logical, critical, and structured mindset, as well as honing children's problem-solving skills (Pratiwi et al., 2021). The main target of learning mathematics at this level is to instill substantial mastery of concepts, not just the ability to memorize formulas mechanically (Susanto, 2013). The ability to master basic concepts is an essential foundation so that students can categorize objects based on their characteristics, project ideas into various forms of representation, and utilize these basic principles to overcome real problems in their lives (Nabila, 2021). The urgency of mastering this concept is evident in the subject of flat building geometry in grade IV, where students are required to have strong spatial reasoning as well as visual sensitivity in recognizing the properties of geometric buildings (Putri & Nugroho, 2023).

However, the reality in the field shows that the ability of grade IV students to master geometry materials is still relatively low and prone to misconceptions. The abstract nature of geometry study objects is often considered difficult by children; moreover, the learning process in the classroom is still dominated by conventional one-way lecture methods and a culture of meaningless memorization (Sari & Putra, 2021). This problem is increasingly complex due to the low use of innovative digital technology-based learning media in elementary schools (Fauzi & Arisetyawan, 2020). Referring to Piaget's theory of cognitive development, elementary school-age children are in a concrete operational phase, so digital visualization and object manipulation are needed to bridge abstract concepts so that the process of understanding construction runs optimally (Susanto, 2013). Therefore, there is a need to update learning strategies that are student-centered and supported by interactive digital manipulative media.

A review of the previous literature (state of the art) shows various approaches that have been tested to improve the quality of understanding of mathematical concepts. Martiasari and Kelana (2022) found that the Problem-Based Learning (PBL) model assisted by physical manipulative media was able to significantly improve elementary school students' understanding of mathematical concepts. Meanwhile, Nursyahira et al. (2024) confirmed that the use of interactive digital media has a positive influence on students' motivation and mathematics learning outcomes. In addition, Astriani and Andini (2025) prove that geoboard-based virtual manipulative media has a positive effect on the spatial thinking ability of grade IV students in the context of flat building geometry. Sari and Putra (2021) also explained that PBL that relies on contextual problems has succeeded in encouraging students' active participation in improving understanding of mathematical concepts.

Although the PBL model and the Polypad platform have been studied separately or in combination with other methods, so far no studies have been found that specifically integrate Polypad's virtual manipulative-assisted PBL learning design into a single structured syntax to see its impact on elementary school students' understanding of geometry concepts. The majority of Polypad's previous uses were positioned only as a standalone e-module supplement or paired with the Discovery Learning model, not as a collaborative investigative medium for solving structured problems, as characteristic of the PBL model.

Naufal and Kowiyah (2025) reported that the use of Polypad in mathematics e-modules effectively supports increasing the understanding of the concept of fractions for elementary school students. However, studies on the integration of PBL and Polypad's virtual manipulative media on the ability to understand mathematical concepts in flat building materials are still very limited, especially in the context of implementing the Independent Curriculum for grade IV elementary school students in the Bandung area.

The scientific novelty of this research is based on systematic searches on Google Scholar, SINTA, ERIC, and Scopus. The search used the keywords Problem-Based Learning, Polypad, virtual manipulative, and understanding of flat building mathematical concepts. The search results show that there has been no study that integrates the PBL model with Polypad media in one structured syntax, especially in flat building materials, at the grade IV elementary school level, in the context of the implementation of the Independent Curriculum in the Bandung area. Through this combination, contextual problems within the PBL framework are solved through virtual exploration activities in Polypad—such as shifting, cutting, rotating, and gluing geometric shapes—so that students can construct their understanding of concepts independently, empirically, and collaboratively. Theoretically, this research contributes to the development of constructivism-based mathematics learning in elementary schools, while expanding the conceptual foundation of the use of digital manipulative technology in the design of elementary mathematics.

The main issue of this research targets the extent to which the effectiveness of the combination of models and media can reduce the dominance of abstract-mechanical learning patterns at the elementary school level. The hypothesis proposed is: there is a significant difference in the ability to understand mathematical concepts between students who learn using the Problem Based Learning (PBL) model assisted by Polypad media compared to students who learn using the Discovery Learning model.

Based on this background, this study aims to analyze and test the magnitude of the effect of applying the Problem Based Learning (PBL) model assisted by Polypad media on the ability to understand mathematical concepts of grade IV elementary school students on the properties of flat building materials. This article is an original scientific work that offers methodological novelty in the form of problem-based learning synergy with the interactive virtual manipulative Polypad, which, as far as the author's research has shown, has never been explored before on the focus of understanding geometry concepts for elementary school students.

2. Research Methods

This research applies a quantitative approach by utilizing a quasi-experiment design. The selection of this quantitative approach is based on the main objective of the research, which is to test the hypothesis and measure the real impact of a learning intervention on bound variables through the calculation of statistical data. In line with the view of Sugiyono (2013), the quantitative method focuses on measuring educational phenomena or symptoms objectively using structured instruments and numeric-based data analysis techniques.

The experimental design integrated in this study is the Non-Equivalent Control Group Design. The format of this design involved two groups of observation subjects, namely the experimental group and the control group. The determination of the position of the two groups is not carried out through the technique of random assignment, but by utilizing parallel classes that have been formed naturally based on policies and divisions from the school. The experimental group was given special treatment in the form of the implementation of the Problem-Based Learning learning model combined with Polypad virtual manipulative media. Meanwhile, the control group received treatment in the form of the Discovery Learning learning model. To identify fluctuations and differences in learning outcomes, both groups were given a pre-test before the intervention began and a post-test after the treatment period ended.

This research involved grade IV students in one of the elementary schools in West Bandung Regency as research subjects, consisting of 23 students in the experimental class and 23 students in the control class. In determining the sample, the purposive sampling technique was applied based on inclusion criteria including: (1) grade IV students who participated in the full learning of flat building material mathematics during the study, (2) schools that have implemented the Independent Curriculum, and (3) students who took the complete pretest and posttest. The exclusion criteria include students who do not take part in one of the measurement stages or have incomplete research data.

Some aspects considered in this study include equal initial academic ability levels, the number of benches or students in similar classes, and suggestions from classroom teachers and schools. This effort is taken so that the characteristics of the two classes do not trigger a conspicuous bias, so that the final results of the study truly show the magnitude of the influence of the combination of models and learning media tested.

Data on students' ability to understand mathematical concepts were taken using research instruments in the form of written tests in the form of essay questions. The preparation of the question items refers to five indicators of competence in understanding mathematical concepts, including restating a concept; classifying objects based on certain properties; presenting concepts in various forms of mathematical representation; using and selecting certain procedures; and applying concepts in problem solving (Susanto, 2013). This instrument is specifically designed to measure students' capacity to construct geometric thinking logically and systematically on the material of flat building characteristics. The following is a grid of instruments for understanding mathematical concepts.

1. Level C4 Analyze: Measure the aspect of understanding the concept of flat building on the indicator of restating mathematical concepts, where students are asked to analyze the physical characteristics of a rectangular cake pan.
2. Level C5 Evaluate: Measure the aspect of understanding the concept of flat building on the indicator of classifying objects and providing examples and non-examples, where students are asked to distinguish polygon-shaped tiles and circular coins and their reasons.
3. Level C4 Analyze: Measure the aspect of understanding the concept of flat building on indicators classifying objects and providing examples and non-examples, where students are asked to analyze the difference in lateral properties between rhombus and parallelogram.
4. Level C6 Creating: Measuring the aspect of understanding the concept of flat building on the indicator of presenting concepts in various forms of mathematical representation, where students are asked to present a hexagonal arrangement of wall decorations from the combination of several triangles.
5. Level C5 Evaluate: Measure the aspect of understanding the concept of flat building on the indicator of using and choosing the right mathematical procedure or operation, where learners are asked to determine the step of cutting a trapezoidal fabric into a rectangle.
6. Level C6 Create: Measure the aspect of understanding the concept of flat building on the indicator of using and choosing the right mathematical procedure or operation, where learners are asked to combine two pieces of wood with a right triangle into a rectangle.
7. Level C5 Evaluate: Measure the aspect of applying the concept of flat building in problem solving on indicators of applying mathematical concepts or algorithms, where students are asked to evaluate the correctness of the cut-off technique on parallelograms.
8. Level C6 Create: Measure the aspect of applying the concept of flat building in problem solving on indicators of applying mathematical concepts or algorithms, where students are asked to design creative house drawings from a combination of at least three flat buildings.

Before being tested on the actual research sample, the test instrument first goes through the content validity test process through expert judgment conducted by supervisors and classroom teachers who are competent in the field of elementary school mathematics. The test results showed that all questions were valid with a Cronbach's alpha reliability coefficient of 0.90 (very high category). The difficulty level is in the easy and medium categories, while the distinguishing power is qualified enough to be good. Treatment was given during three meetings in each class with a time allocation of 2×30 minutes per meeting. The experimental class used a polypad-assisted PBL model, while powerpoint media powered the Discovery Learning control class. The data collection process in the field is carried out through test techniques, namely the provision of pre-tests and post-tests to the experimental and control groups. The pre-test is used to map the baseline or initial ability of the student before receiving treatment, while the post-test functions to measure the final achievement after treatment. The raw data in the form of numerical scores that have been collected are then analyzed using inferential statistical techniques to test hypotheses.

Students' understanding of concepts was analyzed using an N-Gain score calculated by the following formula:

$$\text{N-Gain} = \frac{\text{Score Maximum} - \text{Pretest Score}}{\text{Pretest Score} - \text{Pretest Score}}$$

The effectiveness of the treatment was analyzed using the Normalized Gain (N-Gain) index. The N-Gain value was then interpreted based on the Hake category, namely high ($g \geq 0.70$), medium ($0.30 \leq g < 0.70$), and low ($g < 0.30$). The data analysis in this study focuses on the influence of learning models on students' ability to understand mathematical concepts. Statistical tests were used to detect whether there was a significant difference in post-test values between the experimental group and the control group. Before conducting the hypothesis test, the researcher conducted a prerequisite test, namely a data distribution normality test and a variance homogeneity test, to ensure that the data were statistically feasible. Through the application of this methodology, the research is expected to present an objective and empirical portrait of the effectiveness of the Problem-Based Learning model assisted by Polypad media on elementary school students' ability to comprehend mathematical concepts.

3. Results and Discussion

This section presents the results of data processing and an in-depth review to examine differences in students' mathematical concept comprehension skills between the experimental class and the control class. Before testing the main hypothesis, the data is first examined using descriptive statistics to get an overview of the results in the field. After that, inferential statistical analysis was carried out using *an independent-samples t-test*. However, before the test is used, the data passes the prerequisite test stage, which includes a normality test and a homogeneity test. The following are the results of the analysis of *pretest* and *posttest data*.

Table 2. Results of Descriptive Analysis of Pretest and Posttest Data

Test Type	Class Groups	Score Minimum	Score Maximum	Average (Mean)	Standard Deviation
Pretest	Eksperiment	35	65	48,50	7,25
	Control	32	68	47,80	7,80
Posttest	Eksperiment	70	100	86,50	5,45
	Control	60	85	73,40	6,12

Through descriptive statistical analysis in Table 2, the condition of students' abilities before and after learning in both classes can be mapped as in Table 1. The *pretest data* showed that the experimental class recorded a low score of 35 and a high score of 65, with an average achievement of 48.50. On the other hand, the control class had a minimum score of 32, and the maximum score reached 68, with an average of 47.80. These figures indicate that the initial competence of students in both groups in understanding mathematical concepts tends to be equivalent.

After the two classes were given different treatment, there was a noticeable difference in their *posttest* scores. The experimental class experienced a very significant increase, where the students' scores moved from the lowest 70 to the highest, reaching 100, with an average score of 86.50. On the other hand, the scores for the control class were only in the range between 60 and 85, with an average gain of 73.40.

Table 3. Normality Test Results of *Posttest Data*

Test Type	Class Groups	Test Method	Statistics	df	Sig.	Explanation
Posttest	Eksperiment	*Shapiro-Wilk*	0,926	23	0,089	Normally Distributed
	Control	*Shapiro-Wilk*	0,944	23	0,215	Normally Distributed

Based on Table 3. The results of the normality testing shown in Table 2 using the *Shapiro-Wilk method* show the characteristics of the final data distribution in each group of students. In the posttest score of the experimental class, a significance index of 0.089 was obtained. Because the number is above the threshold of 0.05, this proves that the data variables in the experimental class have a normal distribution. The control group scored a significance score of 0.215 in the *posttest session*. Considering that the significance value is also greater than the minimum predicate of 0.05, the final data distribution for the control class is declared to be valid with normal distribution.

Table 4. Results of the Posttest *Data Homogeneity Test*

Data	Sig.	Interpretation
Results *of the post test* of the experimental and control class	0,825	Homogeneous

Based on Table 4, the P-value (sig.) obtained in the results of the post-test homogeneity test from the experimental class and the control class is 0.825. It can be said that the significance of 0.825 is greater than 0.05, then H0 is accepted so that the data can be said to be homogeneous. After conducting homogeneity tests on pre-test and post-test data, it can be concluded that the two classes are homogeneous.

Table 5. Results of Descriptive Analysis of N-Gain of Experimental Class and Control Class

Classes	N-Gain	Interpretation
Eksperiment	0,8303	Tinggi
Control	0,6696	Medium

Based on Table 5. Based on the N-Gain calculation, the experimental class obtained an average value of 0.8303, which was in the high category. In contrast, the control class obtained an average value of 0.6696, which was in the medium category. These results showed that the improvement in students' understanding of mathematical concepts in the experimental class was greater than in the control class. Furthermore, to find out the significance of the difference in the increase, a t-test was carried out.

Table 6. Test Results of Independent Sample t-Test N-Gain Experimental and Control Class

Data	Sig. (2 tailed)	(α)	Interpretation

Results of N-Gain Values of Experimental Class and Control Class	0,000	0,05	H_0 Rejected

Based on Table 6. The independent-samples t-test on the N-Gain value in both classes obtained a sig value (2-tailed) ≤ 0.05, which is 0.000; then H0 is rejected, H1 is accepted, so that there is a difference in the N-Gain value of the ability to understand mathematical concepts of students in the experimental class and the control class. This difference shows that the level of improvement in students' mathematical concept comprehension ability in the experimental class is higher than in the control class, so that the treatment in the form of using the Polypad-assisted Problem-Based Learning model is proven to be effective in improving students' mathematical concept comprehension ability compared to the Discovery Learning learning model used in the control class.

Table 7. Results of Simple Regression Analysis and Determination Coefficient Value (R2)

Variable Experiment	Correlation Coefficients (R)	R Square (R2)	Significance of Regression (Sig.)
Polypad-Assisted PBL	0,755	0,570	0,000

Through the regression findings in Table 7, a determination coefficient value (*R Square*) of 0.570 was obtained. These statistical findings confirm that the free variable, in the form of the application *of the Problem-Based Learning model* assisted by Polypad virtual manipulative media, contributed a massive influence, namely 57%, to the variable bound by the ability to understand mathematical concepts of grade IV students. Other external variables beyond the limits of this study influenced the proportion of remaining variability in the achievement. Regression analysis was carried out specifically in the experimental class because it aimed to determine the contribution of the application of *the Polypad-assisted Problem-Based Learning* (PBL) model to students' understanding of mathematical concepts. This analysis was not performed across groups because the control class did not receive the same treatment, but instead used *a PowerPoint-assisted* Discovery Learning *model*. Therefore, the comparison of effectiveness between groups was analyzed through the mean difference test (t-test). At the same time, the regression analysis focused on the relationship and contribution of treatment to learning outcomes in the experimental group.

The scientific findings in this study prove empirically that the operational synergy between the problem-based learning model (PBL) and the use of Polypad digital media triggers stimulation that is much more effective in reconstructing the understanding of mathematical concepts of elementary school students than *Discovery Learning*. The dominance of the excellence of this experimental class stems from its instructional design that places students as active subjects of knowledge construction through contextual puzzle solving, rather than simply being passive consumers of information (Sari & Putra, 2021).

The success of increasing concept understanding in the material characteristics of flat buildings can be traced theoretically through the fulfillment of the five indicators of concept understanding that are accommodated in the implementation of PBL syntax assisted by Polypad in the field:

a. Restating Mathematical Concepts

Students' ability to restate mathematical concepts develops through the problem orientation stage in the PBL model. Students activate the initial knowledge of flat wake-up and communicate it back in group discussions. This finding is in line with Andani et al. (2021), who stated that PBL encourages students to construct and communicate mathematical concepts actively.

b. Classify objects based on whether concept requirements are met or not.

The ability to classify flat shapes develops through object exploration on the Polypad. Students group the build based on the number of sides, angles, and symmetry so that it is easier to distinguish examples and non-examples of a concept. These findings are in line with the research of Martiasari and Kelana (2022), which shows that the use of manipulative media-assisted PBL models helps students understand the characteristics and attributes of mathematical concepts more accurately.

c. Presenting Concepts in Various Forms of Mathematical Representation

The interactive character of the Polypad platform allows students to represent abstract flat shapes from the text of the question into the form of colorful, dynamic, and scalable visual sketches. When solving problems involving wide discovery or polygonal features, students no longer just resign themselves to dry memorization formulas in a textbook, but project them into a digital, concrete visual form (combining color blocks, drawing grid lines, changing the side scale). These findings are in line with research by Martiasari and Kelana (2022), who show that the use of manipulative media in mathematics learning can improve students' ability to represent abstract concepts in more concrete and easy-to-understand visual forms.

d. Using, Utilizing, and Selecting Specific Procedures or Operations

In the phase of developing and presenting the group's work, students are required to decide on an efficient problem-solving strategy. The experience of manipulating objects in Polypad, such as cutting one diagonal rectangle to produce two congruent right triangles, automatically reinforces the child's procedural operational understanding. This finding is in line with Widyastuti and Airlanda (2021), who found that PBL improves students' ability to choose problem-solving strategies systematically.

e. Applying Concepts in Problem Solving

This highest cognitive indicator is fully realized in the final syntax of PBL, namely the analysis and evaluation of the problem-solving process. Through the accumulation of concrete understanding transferred from gadgets to group worksheets, students can use that knowledge transfer to solve new, more complex application problems. The habit of exploring real problems makes students' reasoning more adaptive when they find variations of geometry problems that require high-level thinking analysis (HOTS). These findings are in line with Widyastuti and Airlanda (2021), who show that PBL is effective in improving the mathematical problem-solving skills of elementary school students.

In terms of cognitive psychology, the jump in the contribution of influence of 57% in this research is rooted in the alignment of methods with the phase of child growth and development according to Jean Piaget. Children aged 9–10 years (Phase B/Class IV) absolutely need a bridge of concrete objects to digest the mathematical scientific structure that is purely abstract (Susanto, 2013). Polypad media serves as *interactive virtual manipulatives* that can turn dead geometric objects into dynamic objects that students can disassemble independently (Genç, 2024; Moyer-Packenham & Westenskow, 2013).

In addition, the group learning atmosphere within the PBL framework facilitates *social scaffolding* in line with Vygotsky's sociocultural learning theory. Peer interaction during discussions to solve geometry puzzles in Polypad helps students in the Zone of Proximal Development (ZPD) achieve a complete understanding of concepts through the help of their more proficient peers (Salsabila & Muqowim, 2024). The convergence between the activeness of looking for solutions (PBL) and the availability of cutting-edge concrete visualizations (Polypad) is the main differentiator, which has succeeded in shifting the saturation of the conventional memorization learning system towards the formation of meaningful and lasting mathematical understanding (*long-term retention memory*).

This study has limitations because it only involves grade IV students in one elementary school in West Bandung Regency and focuses on flat building material in three meetings. Therefore, generalization of findings needs to be done carefully. Further research is suggested involving a wider sample, more diverse material, and a longer duration of implementation.

4. Conclusion

The application of *the Problem-Based Learning* (PBL) learning model assisted by Polypad media has been proven to have an empirically significant influence on the ability to understand mathematical concepts of grade IV elementary school students, with a contribution of 57% and resulting in a higher increase than *the Discovery Learning* model. These findings corroborate the importance of virtual manipulatives in bridging students' concrete thinking to abstract geometry material. However, there is a residual influence of 43%, which is suspected to be sourced from other factors such as motivation, learning style, and the student learning environment. These results have a real impact on the development of teaching strategies in schools through the integration of problem-based models and interactive digital media to visualize concepts while minimizing misconceptions in a meaningful way. Therefore, future research can be directed to a wider scope of material or subjects, as well as consider other students' psychological variables to enrich the effectiveness of this learning model.

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