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THE EFFECTIVENESS OF PROBLEM-BASED LEARNING UTILIZING DIENES BLOCKS ON IMPROVING STUDENTS' DIVERGENT THINKING IN ELEMENTARY SCHOOL

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ABSTRACT

The inability of primary school students to solve mathematical problems using multiple strategies, often rigidly adhering only to methods taught by the teacher, highlights a critical issue: a low level of Divergent Thinking. This study aims to investigate the effectiveness of the Problem-Based Learning (PBL) model utilizing Dienes Blocks in enhancing the Divergent Thinking skills of fourth-grade students in whole number operations. The research employed a quantitative One-Group Pretest-Posttest Design involving a sample of 30 students from a public elementary school in Cimahi City. The intervention was conducted over two meetings, focusing on guiding students through the PBL process to discover and articulate various methods for solving calculation problems. Data were collected using a six-item essay test designed to measure the students' fluency and flexibility in problem-solving strategies, a core indicator of Divergent Thinking. The findings indicate a significant improvement in students' Divergent Thinking ability after the implementation of the PBL model with Dienes Blocks. The increase in scores, analyzed using the N-Gain method, was categorized as moderate. This suggests that the combination of authentic problem contexts provided by PBL and the concrete manipulation offered by Dienes Blocks effectively enables students to break free from rote memorization and explore alternative problem-solving pathways. The study concludes that this integrated approach is an effective strategy for fostering cognitive flexibility and creativity in elementary mathematics education.

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INTRODUCTION

Mathematics is universally recognized as a fundamental academic discipline that extends far beyond calculation, serving as a critical foundation for logical reasoning, analytical skills, and real-world problem-solving (Setiawan et al., 2022). In the context of elementary education, the goal of mathematics instruction is not merely to enable students to memorize algorithms but to foster deep conceptual understanding and procedural flexibility (NCTM, 2020). Students who achieve genuine mathematical proficiency are those who can navigate seamlessly between concepts and procedures, utilizing a repertoire of strategies to address novel problems (Rittle-Johnson et al., 2015). However, achieving this holistic proficiency remains a significant challenge in many primary school settings.

Despite the aspirational goals of mathematics education, a pervasive issue observed globally and particularly in Indonesian schools is the phenomenon of procedural rigidity (Habeaha et al., 2025; Rohman et al., 2017). Procedural rigidity occurs when students exclusively rely on a single, taught algorithm, even when an easier or more efficient alternative exists, or when the problem structure is slightly altered. In the present context, the condition of fourth-grade students in a primary school in Cimahi City clearly exemplifies this issue. Observational data indicates that these students are only capable of solving mathematical problems that have been previously encountered and directly demonstrated by the teacher. Furthermore, they fail to employ any alternative methods beyond the single approach presented by their instructor. The lack of transferability is so pronounced that students cannot solve structurally similar problems even if only the numerical values are changed, demonstrating a severe deficit in adaptive reasoning and conceptual generalization.

This inability to generate multiple, valid solution pathways points directly to a deficiency in a key higher-order cognitive skill: Divergent Thinking (Kwon et al., 2006). Divergent thinking, a core component of mathematical creativity (Cropley, 2006; Brophy, 1998), is the ability to generate a wide range of unique and creative ideas or solutions to a problem, contrasting sharply with convergent thinking, which seeks a single best answer (Guilford, 1973). In mathematical problem-solving, divergent thinking is typically measured by three components: fluency (the number of relevant ideas generated), flexibility (the number of different categories or types of methods used), and originality (the uniqueness of the solution) (Acar & Runco, 2014; Simon & Bock, 2016). When students are rigid and rely on a single method, their fluency and flexibility scores inevitably remain low, trapping them within a cycle of rote memorization rather than deep conceptual engagement. Addressing this rigidity requires instructional interventions designed specifically to cultivate the exploratory and generative nature of divergent thought (Jeon et al., 2011).

To effectively counter procedural rigidity and enhance divergent thinking, a pedagogical shift toward student-centered, non-routine tasks is necessary (Kurniasih et al., 2024). Problem-Based Learning (PBL) emerges as an ideal instructional model to facilitate this transition. PBL is a teaching method characterized by the use of complex, authentic, and ill-structured problems as the starting point for learning (Savery, 2015). Unlike traditional teaching that presents concepts before problems, PBL challenges students to identify what they need to learn, seek relevant information, and explore multiple strategies to solve a given real-world challenge (Salsabila, 2024).

The core stages of the PBL model inherently support the development of divergent thinking. When facing an authentic problem, students in the 'guiding individual and group investigation' phase are compelled to brainstorm various approaches and potential solutions. This exploration actively stimulates the generation of multiple ideas (fluency) and the testing of different conceptual frameworks (flexibility) (Nurwidodo et al., 2024; Suryadi et al., 2025). Furthermore, the 'developing and presenting artifacts' stage requires students to articulate and justify their chosen methods, often exposing them to their peers' alternative solutions, thus broadening their solution repertoire and fostering cognitive flexibility (Huang et al., 2020; Singer et al., 2017). Prior research has consistently demonstrated the effectiveness of PBL in improving higher-order thinking skills, including critical thinking, creative thinking, and problem-solving abilities in mathematics (Kurniasih et al., 2024; Savery, 2015).

While PBL provides the necessary conceptual framework and motivational context, the specific mathematical domain of Whole Number Operations (addition, subtraction, multiplication, and division) at the elementary level requires concrete support to bridge abstract concepts with procedural strategies. This is where the utilization of Dienes Blocks (also known as Base Ten Blocks) becomes crucial. Dienes Blocks are a set of proportional manipulatives used to represent units, tens, hundreds, and thousands.

Dienes Blocks serve as powerful concrete manipulatives that facilitate the use of multiple representations—a critical component of flexible and divergent thinking (NCTM, 2020). By integrating Dienes Blocks into the PBL environment, students can physically model a problem like 17×19 not just through the standard vertical algorithm, but through various divergent strategies, such as: (1) Area Model Decomposition: Visualizing the calculation as an area 17×20 minus the area 17×1 (utilizing the distributive property); (2) Repeated Addition/Grouping: Physically grouping the blocks; and (3) Place Value Decomposition: Breaking down the numbers into tens and ones. This physical and visual exploration forces students away from reliance on memorized symbols and instead encourages them to discover and justify the efficiency of different methods (Septian et al., 2019). The synergy between PBL's demands for multiple solutions and Dienes Blocks' capacity to illustrate multiple representations is hypothesized to be highly effective in cultivating the desired fluency and flexibility inherent in divergent thought.

Despite the clear theoretical linkage between PBL, Dienes Blocks, and high-order thinking, research specifically targeting the collective impact of the PBL model utilizing Dienes Blocks on Divergent Thinking ability in the context of elementary whole number operations remains limited. Previous studies have often focused either on PBL's effect on general problem-solving (Salsabila, 2024) or Dienes Blocks' effect on procedural fluency for specific operations (Septian et al., 2019). This study addresses this gap by directly testing the efficacy of this integrated approach.

Based on the critical problem of procedural rigidity observed in the sample of fourth-grade students in Cimahi City and the theoretical grounding of the intervention, this research aims to investigate the effectiveness of the Problem-Based Learning model utilizing Dienes Blocks on improving students’ Divergent Thinking ability in Elementary Mathematics, specifically in the domain of whole number operations. The findings are expected to provide empirical evidence supporting the adoption of this combined strategy as an effective pedagogical solution to foster cognitive flexibility and creative problem-solving skills among primary students.

METHOD

This study employed a quantitative research approach utilizing a Pre-Experimental Design specifically the One-Group Pretest-Posttest Design ($O_1\ X\ O_2$). This design is appropriate for measuring the effect of an intervention (treatment) on a single group by comparing the dependent variable’s measurement before and after the treatment (Campbell & Stanley, 1963; Salsabila, 2024). This methodology was chosen due to logistical constraints that prevented the formation of a comparable control group, but it remains effective for determining the difference in performance before and after the application of the instructional model. The design can be schematically represented as:

$$O_1\ X\ O_2$$

Where O_1 represents the pretest measurement of Divergent Thinking, X represents the intervention (Problem-Based Learning utilizing Dienes Blocks), and O_2 represents the posttest measurement of Divergent Thinking.

The research was conducted at an elementary school in the City of Cimahi, Indonesia. The target population was all fourth-grade students, and the sample was selected using a convenience sampling technique, comprising one intact class of 30 students. The sample composition included 17 female students and 13 male students. This class was chosen based on initial teacher consultation and observation, which identified the prevalent issue of procedural rigidity and the reliance on a single, teacher-provided solution method, affirming the necessity of an intervention focused on divergent thinking. All students provided informed consent for participation in the study.

The sole instrument used for data collection was a Divergent Thinking Test administered in an essay format. The test consisted of six essay questions designed as Multiple Solution Tasks (MSTs) focusing on whole number operations (addition, subtraction, and multiplication of two-digit numbers). MSTs are highly suitable for measuring divergent thinking as they require students to generate multiple, distinct, and mathematically valid methods to solve a single problem (Kwon et al., 2006). The scoring rubric was developed to quantify two key indicators of Divergent Thinking (Runco & Acar, 2012):

- Fluency: The total number of correct and relevant solutions/steps generated by the student.
- Flexibility: The number of different categories or types of strategies used (e.g., using the distributive property, making tens strategy, or using repeated addition, as opposed to only the standard algorithm).

The maximum score for the test was determined based on the potential number of different solutions for each item. The instrument's validity was established through expert judgment (content validity) and the reliability of the essay scoring was established using inter-rater reliability analysis (Acar & Runco, 2014) to minimize subjectivity often associated with essay scoring (Badjadi, 2013).

The collected quantitative data were analyzed using descriptive statistics (mean, standard deviation) and inferential statistics to test the intervention's effectiveness. Prior to testing the hypothesis, the normality of the pretest and posttest data distribution was checked using the Kolmogorov-Smirnov test. To determine whether there was a statistically significant difference between the pretest (O_1) and posttest (O_2) scores, a Paired Sample t-Test was conducted, appropriate for a single group measured twice (Setiawan et al., 2022). The magnitude and effectiveness of the increase in students' Divergent Thinking ability were determined using the Normalized Gain (N-Gain) score (Hake, 1998), calculated using the formula:

$$g = \frac{PostTest - PreTest}{Max - PreTest}$$

The N-Gain score (g) was then interpreted using the criteria adapted from Hake (1998) to categorize the level of improvement, as summarized in Table 1.

Table 1. Normalized Gain (N-Gain) Categorization Criteria

N-Gain Score (g)	Category of Improvement
g≥0.7	High (Effective)
0.3≤g<0.7	Moderate (Moderately Effective)
g<0.3	Low (Less Effective)

The final interpretation of the findings relies on the Paired Sample t-Test to confirm significance and the N-Gain analysis to quantify the practical magnitude of the improvement, which, based on the preliminary findings, is expected to fall into the moderate category.

RESULTS AND DISCUSSION

Results

This study was conducted with 30 fourth-grade students ($N = 30$) in Cimahi City to examine the effect of the Problem-Based Learning (PBL) model utilizing Dienes Blocks on students' Divergent Thinking ability in whole number operations. The results are presented in three parts: (a) Descriptive Statistics and Preliminary Analysis, (b) Hypothesis Testing via Paired Sample t-Test, and (c) Effectiveness Analysis using Normalized Gain (N-Gain) Score.

The initial analysis involved assessing the students' Divergent Thinking scores before (Pretest) and after (Posttest) the intervention. The maximum possible score for the test instrument was 50. The descriptive statistics, including the mean, standard deviation, and minimum/maximum scores, are summarized in Table 2.

Table 2. Descriptive Statistics of Divergent Thinking Scores (N=30)

Test Phase	Maximum Score	μ	SD	Minimum Score	Maximum Score
Pretest	100	44,74	7,02	30	56
Posttest	100	77,20	8,24	62	96

As shown in Table 2, the mean score for Divergent Thinking significantly increased from $\mu = 44{,}74$ in the pretest to $\mu = 77{,}20$ in the posttest. This indicates an average score increase of points following the implementation of the PBL model utilizing Dienes Blocks, suggesting a substantial positive impact of the intervention on students' ability to generate multiple solutions (fluency and flexibility).

A prerequisite assumption test for the parametric Paired Sample t-Test, the Shapiro-Wilk normality test, indicated that both the pretest scores ($p = {,}112$) and the posttest scores ($p = {,}098$) were normally distributed (where $p > {,}05$), allowing the use of the t-test.

The primary hypothesis test was conducted using a Paired Sample -Test to determine whether the difference between the pretest and posttest mean scores was statistically significant.

The results of the paired sample t-test revealed a statistically significant difference between the pretest and posttest scores on the Divergent Thinking Test, $t(29) = 18{,}91, p < {,}001$. This significant finding leads to the rejection of the null hypothesis (H_0), confirming that the implementation of the Problem-Based Learning model utilizing Dienes Blocks resulted in a statistically significant improvement in the fourth-grade students' Divergent Thinking ability.

The details of the statistical test are presented in Table 3.

Table 3. Paired Sample -Test Results for Divergent Thinking Scores

Paired Sample	Mean Difference	SD Difference	t	df	p (2-tailed)	Cohen's d
Posttest – Pretest	32.46	9.38	18.91	29	<.001	3.45

The large Cohen's effect size of (Cohen, 1988) further underscores the practical significance of this finding, indicating an extremely substantial effect of the intervention.

To measure the effectiveness and magnitude of the score increase in a normalized manner, the Normalized Gain (N-Gain) score was calculated (Hake, 1998). The average N-Gain score (g) was calculated using the formula and the maximum score of 100:

$$g = \frac{PostTest - PreTest}{Max - PreTest}$$

Based on the recalculated data, the average N-Gain score (g) for the class was determined to be approximately $0{,}58$.

Based on the N-Gain categorization criteria (Hake, 1998), the average improvement achieved by the students falls into the Moderate category $(0{,}3 \leq g < 0{,}7)$. Specifically, the results indicate that the PBL model utilizing Dienes Blocks was moderately effective in enhancing the students' Divergent Thinking ability. The distribution of students across the three N-Gain categories is presented in Table 4.

Table 4. Distribution of Students Based on N-Gain Category

N-Gain Category	Criteria	Frequency (n)	Percentage (%)
High	g≥0.7	8	26.67%
Moderate	0.3≤g<0.7	19	63.33%
Low	g<0.3	3	10.00%
Total		**30**	**100%**

The majority of students (90%) achieved an improvement level classified as either Moderate or High, confirming the intervention's success in fostering greater cognitive flexibility in mathematical problem-solving.

Discussions

The primary finding of this study is the statistically significant improvement in students' mathematical divergent thinking ability following the implementation of the Problem-Based Learning (PBL) model supported by Dienes Blocks. This increase is confirmed by a robust paired t-test result $(t(29) = 18{,}91, p < {,}001)$ and an extremely large effect size $(d = 3{,}45)$. Furthermore, the calculated average Normalized Gain (N-Gain) score of $g = 0{,}58$ places the intervention's effectiveness in the Moderate category (Hake, 1998), thus confirming its practical efficacy in boosting student fluency and flexibility in generating multiple solutions. These results are consistent with existing educational literature. For instance, studies by Huang et al. (2020) and Jeon et al. (2011) have established a correlation between instructional models that promote cognitive flexibility and an increase in creative and divergent thinking skills. The moderate level of effectiveness found here also mirrors the observed gains in other PBL studies focused on problem-solving and critical thinking in mathematics education (Salsabila, 2024; Suryadi et al., 2025).

The effectiveness observed in this research can be largely attributed to the synergy between the Problem-Based Learning framework and the use of the Dienes Blocks concrete media. The PBL structure naturally stimulates divergent thought by beginning with authentic, ill-structured, or open-ended problems (Savery, 2015). As highlighted by Kwon et al. (2006), this open-ended design creates necessary cognitive disequilibrium (Nurwidodo et al., 2024), pushing students away from relying solely on routine, convergent procedures. The inherent demand of solving a single problem using multiple strategies directly trains the two core indicators of divergent thinking: fluency (generating many ideas) and flexibility(generating diverse categories of ideas), as defined by Guilford (1973) and Simon & Bock (2016). Additionally, the inquiry phase of PBL is crucial as it requires students to retrieve and integrate procedural knowledge with conceptual understanding (Rittle-Johnson et al., 2015), which helps to overcome the major barrier of procedural rigidity often found in elementary students (Rohman et al., 2017).

The Dienes Blocks further amplify this effect by providing a crucial physical link to abstract concepts. When engaging with operations, the blocks force students to physically decompose and recombine numbers, such as breaking down 17×19. This tangible manipulation offers multiple conceptual avenues to reach a solution—for instance, using an array model, repeated addition, or applying the distributive property—rather than being constrained to a single mental algorithm (Septian et al., 2019). This concrete, multi-sensory process directly cultivates flexibility by making diverse conceptual approaches visible and accessible, aiding students in moving past typical convergent thinking patterns (Cropley, 2006). Therefore, the significant increase in divergent thinking observed is a combined result of the PBL methodology's demand for open exploration and the Dienes Blocks' ability to provide the necessary concrete tools for flexible, conceptual construction of multiple mathematical pathways.

CONCLUSION

The core conclusion is that the integrated PBL and Dienes Blocks model is an effective and feasible instructional strategy for fostering higher-order thinking skills, particularly the generation of multiple, varied solutions in mathematics. Quantitatively, the intervention yielded a Moderate level of effectiveness (N-Gain score of $g = 0{,}58$), indicating a substantial practical gain in students' ability to move beyond conventional, convergent solution methods. This effectiveness is attributed to the combined power of: (1) the PBL structure, which mandates open-ended inquiry and problem-solving, thereby activating the need for fluency and flexibility; and (2) the Dienes Blocks media, which provides concrete representation, enabling students to explore conceptual variations and multiple pathways for whole number operations.

In summary, the use of PBL supported by concrete manipulatives like Dienes Blocks effectively mitigates procedural rigidity and successfully develops students' divergent thinking, a critical skill for mathematical creativity and problem-solving in the 21st century.

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