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The Effect of Integrated Problem-Based Learning with Multiple Representations on Elementary School Students' Computational Thinking Skills in Mathematics

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Abstract

Computational thinking constitutes a fundamental competency that learners need to cultivate as part of their educational development process to systematically analyze problems and construct effective solutions. **Objective:** This study modified the Problem-Based Learning (PBL) method integrated with Multiple Representations (MR) in enhancing elementary students' computational thinking encompasses a set of essential skills. **Novelty:** This study offers empirical support for the contribution of an innovative instructional approach in fostering students' computational thinking skills, thereby supporting the attainment of SDG 4 through improved learning quality at the elementary level. **Method:** A quantitative methodology was implemented through a quasi-experimental research design. The participants were selected using purposive sampling (N = 62). Data were analyzed through prerequisite tests and hypothesis testing to examine the effectiveness of the PBL-MR method in improving students' computational thinking skills. **Results:** The findings derived from the t-test analysis demonstrated that there was a statistically significant difference between students in the experimental group and those in the control group, ($p < 0.001$), indicating that the implementation of the PBL-MR method significantly enhanced students' computational thinking skills. **Conclusion:** The findings indicate that the PBL-MR method is more effective in enhancing students' computational thinking skills compared to the conventional approach employed in the control group, thereby contributing to the attainment of SDG 4 Quality Education through the enhancement of meaningful learning in elementary education.

Keywords: Computational Thinking, Problem-Based Learning, Multiple Representations, SDGs 4.

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INTRODUCTION

Within the context of primary education, mathematics serves as a fundamental domain for cultivating students' computational thinking abilities, which are increasingly recognized as essential competencies in contemporary education competencies for 21st-century learning and global educational development (Kaya et al., 2025). Computational thinking is regarded as an essential skill in the contemporary era that enables individuals to engage in problem solving, including system design processes and an understanding of human behavior through the integration of fundamental concepts from computer science (Kong et al., 2020). Computational thinking supports students in understanding and solving mathematical problems by engaging them in systematic processes, including decomposition to break down complex problems, pattern recognition to identify underlying regularities, abstraction to focus on relevant information, and algorithmic thinking to construct structured and logical solution steps (Wing, 2006).

In solving mathematical multiplication problems, systematic strategies are required to obtain accurate solutions (Iskandar et al., 2025). The multiplication skills possessed by students are not merely limited to the skills of completing basic arithmetic operations, but also include the ability to apply multiplication concepts to solve more complex and contextual mathematical problems (Hafifah et al., 2024). Mathematical problem solving not only emphasizes the ability to solve numerical problems, but also aims to equip students to be able to internalize mathematical concepts into multiple representational forms into other mathematical forms without changing the meaning, allowing them to utilize these skills across diverse real-world situations (Situngkir & Dewi, 2022).

In the study of mathematics education, there are two forms of knowledge, namely knowledge that is only remembered mechanically and knowledge that is constructed through meaningful understanding by connecting with many forms of representations (Bullock, 2024). Students often need to connect abstract concepts with concrete representations to achieve a deeper level of understanding. Therefore, meaningful understanding in mathematics learning should be developed through the use of various representations so that the goal of fostering students' conceptual understanding can be achieved.

In the reality of elementary school mathematics education, a gap is often found between the ideal conditions and the actual conditions. Ideally, fourth-grade students should be able to master multiplication not only as a procedural skill but also as a tool for solving more complex problems, thereby fostering computational thinking skills (Okatafianti & Purnomo, 2025; Voon et al., 2022). Computational thinking skills enable individuals to recognize problems and make appropriate decisions to find effective solutions (Inganah et al., 2023). However, the reality of classroom learning often prioritizes memorization and algorithmic procedures, neglecting conceptual understanding and computational thinking (Muthma'innah, 2023; Palop et al., 2025). Based on PISA results, students must be able to interpret and recognize problems without direct instruction and simplify problems by converting them into simpler representations (OECD, 2023). Students often have difficulty when they have to convert problem solving questions into representations that can help them find solutions (Kaitera & Harmoinen, 2022). Therefore, students need to use mathematics learning methods that can overcome these problems.

Problem-Based Learning (PBL) is extensively implemented as an effective approach to improve students' learning outcomes while also fostering essential 21st-century competencies (Rehman et al., 2024). However, most studies implement PBL in a conventional manner without integrating diverse instructional representations. In contrast, multiple representations such as textual, visual, symbolic, numerical, and concrete methods has been shown to strengthen conceptual understanding and deepen problem solving processes (Haque, 2024). Yet, empirical studies that combine PBL with multiple representations within a single, coherent learning framework remain scarce (Van Meteris et al., 2020). Existing literature mainly emphasizes visual representations, while the systematic use of symbolic and numerical representations during each phase of problem solving is still underexplored. Furthermore, many PBL studies focus predominantly on general cognitive outcomes rather than specifically examining computational thinking as a targeted learning goal (Ji & Wong, 2025). Another gap is the limited empirical evidence at the primary and secondary school levels; most research integrating PBL and representation-based instruction is concentrated in higher education contexts (Aditomo & Klieme, 2020). Therefore, there is a need for empirical research that examines how the integration of PBL and multiple representations can significantly enhance students' computational thinking skills and support the attainment of SDG 4 Quality Education, particularly in science learning at school level.

To address this gap, a learning method that can address it is needed. Problem-Based Learning (PBL) method provides students with the opportunity to build a conceptual framework that forms the basis for the emergence of computational thinking skills (Hmelo-Silver, 2004). The PBL method has the advantage of providing significant opportunities for students to construct valuable and relevant knowledge based on their experiences (X. Wu et al., 2025). The Multiple Representations (MR) approach can strengthen students' conceptual understanding, enabling them to transform mathematical methods into more concise mathematical representations (Ainsworth, 2006). Multiple representations encourage students to be active and reflective learners, enabling them to analyze, evaluate, and draw logical conclusions that enhance their computational thinking skills (Simanjuntak et al., 2021). Students' abstraction ability refers to the cognitive capacity to identify relevant information while disregarding unnecessary details in order to construct simplified and generalizable representations Within the context of computational thinking, abstraction functions to reduce the complexity of problems and to support the processes of modeling as well as knowledge transfer to new situations (Fang et al., 2023). The integration of the PBL method with the MR approach allows students to visualize mathematical concepts using various forms of representations, such as images, symbols, or verbal narratives (Adiputra & Hidayah, 2025). Thus, the PBL method integrated with the Multiple Representations (MR) approach can be a solution to improve students' computational thinking skills.

Sustainable development goals (SDGs) 4 seeks to guarantee inclusive and equitable quality education while promoting lifelong learning opportunities for all (UNESCO). The integration of PBL-MR supports Sustainable Development Goals (SDGs) point 4 in order to achieve various points, including; point 4.1: ensuring inclusive and quality basic education; point 4.6: improving literacy and numeracy; and point 4.c: improving teacher capacity through innovative pedagogy (Unesco). Thus, this research not only provides academic contributions, but also a concrete manifestation of strategic efforts directed toward achieving SDG 4 Quality Education.

METHODS

This study employed a quantitative research approach as the primary methodological framework to systematically investigate the research problem. Quantitative methods function to objectively test variables through data analysis using research instruments, resulting in numerical data that is then analyzed using statistical technique (Creswell & Creswell, 2017). This study aimed to examine the effects of instructional methods that involved different treatments administered to the experimental and control groups. To achieve this objective, a quasi-experimental research design with a nonequivalent pretest–posttest control group was employed. This design was selected to enable a systematic comparison between the two groups in order to identify differences in learning outcomes attributable to the applied interventions.

The sampling technique used purposive sampling in one of the elementary schools in Bekasi City. The purposive sampling technique was chosen based on certain criteria in sampling (Sumargo, 2020). The study involved a total of 62 students who were assigned to two groups: an experimental group and a control group. The experimental group, consisting of 31 students, received instruction through the Problem-Based Learning approach integrated with Multiple Representations, while the control group, also comprising 31 students, did not receive the specified instructional treatment. To assess students' computational thinking skills, an instrument in the form of 10 essay questions was administered.

The test items were constructed by adopting four core aspects of computational thinking as conceptualized by Wing (2006) as a fundamental problem solving skill that involves a set of cognitive processes derived from computer science principles and applicable across disciplines. Four core indicators of computational thinking are commonly identified: decomposition, pattern recognition, abstraction, and algorithmic thinking (T.-T. Wu et al., 2024). Decomposition is defined as the ability to divide complex problems into smaller and more manageable components, allowing each part to be examined and addressed in a systematic manner. This process helps reduce cognitive load and enables individuals to solve sub-problems before integrating them into a comprehensive solution. Pattern recognition involves the identification of similarities, regularities, or recurring structures within data or problem situations.

Through this ability, individuals can anticipate possible outcomes, streamline problem-solving processes, and transfer previously acquired strategies to new yet related contexts. Abstraction refers to the capacity to focus on essential information while disregarding irrelevant details, thereby facilitating the construction of simplified representations or generalized models of a problem. This skill supports the development of general principles, symbols, or representations that can be applied across various situations. Algorithmic thinking, meanwhile, denotes the ability to formulate and execute a structured, logical, and sequential set of steps to effectively solve a problem. This includes determining an appropriate sequence of actions and ensuring that the solution process is efficient and accurate. Each test item was developed to represent one of these aspects, ensuring that the instrument comprehensively measured students' computational thinking skills in mathematical problem contexts. The research design employed in this study is presented schematically in Table 1.

Table 1. Research Design Scheme

Group	Pretest	Treatment	Posttest
Experiment	O_1	X_1	O_3
Control	O_2	-	O_4

Note:
O_1: Experimental group pretest results
O_2: Control group pretest results
X_1: Experimental group treatment
- : No treatment given
O_3: Experimental group posttest results
O_4: Control group posttest results

RESULTS AND DISCUSSION

The data collected in this study were derived from both pretest and posttest measurements administered to the two groups. The experimental group received instructional treatment through the implementation of Problem-Based Learning (PBL) integrated with Multiple

Representations (MR), while the control group was instructed using the Problem-Based Learning (PBL) approach without the integration of Multiple Representations. Data analysis was conducted using SPSS version 31 to evaluate the relative effectiveness of both groups in enhancing students' computational thinking skills, as part of broader efforts to support the attainment of SDG 4 Quality Education.

Analysis Prerequisite Test

The prerequisite analyses conducted in this study included tests of normality and homogeneity. The normality test was used as a reference to determine whether the data obtained in this study was normally distributed. The *Shapiro-Wilk* test was the type of normality test used in this study. The result data from the normality test are shown in Table 2.

Table 2. Normality Test

	Group	Statistic	df	Sig.
Result	Pretest Experiment	.926	31	.053

Based on the results of the normality test, data are considered to be normally distributed when the significance value exceeds 0.05. The findings indicate that both the experimental and control groups obtained significance values greater than 0.05, suggesting that the data follow a normal distribution. Consequently, the data meet the assumption of normality and are appropriate for subsequent homogeneity testing to examine the equality of variances. The results of the homogeneity test are presented in Table 3.

Table 3. Homogeneity of Variance Test

		Levene' Statistic	df1	df2	Sig.
Result	Based on Mean	.022	1	60	.881

Based on the data from the homogeneity test using Lavene's test, the significance level based on the mean was 0.881. This indicates that the Sig. value was > 0.05, obtained based on the homogeneity test data. This means that the variance obtained from both groups has a homogeneous distribution. Homogeneous data indicates that differences in learning outcomes between the two groups are influenced not only by differences in data variability but also by differences in the treatments given to each group.

Following the confirmation that the prerequisite assumptions of normality and homogeneity were adequately satisfied, the dataset obtained from students' learning outcomes was considered statistically appropriate and robust for subsequent inferential analysis. This validation ensured that the data met the necessary conditions for conducting parametric testing. Accordingly, hypothesis testing was performed using an independent samples t-test to rigorously examine the effectiveness of the instructional intervention by comparing the performance of the experimental and control groups. The comprehensive results of this statistical analysis are presented in Table 4.

Hypothesis Test

Table 4. Independent Samples T-test

		t	df	Significance Two-Sided p	Mean Difference
Result	Equal variances assumed	14.949	60	<.001	20.516

The findings from the independent samples t-test revealed a statistically significant difference between the experimental and control groups. Specifically, the experimental group achieved a markedly higher mean score compared to the control group, $t\ (60) = 14.949$, $p < 0.001$, with a mean difference of 20.516. The substantial t-value and the extremely low p-value indicate that the observed difference is statistically robust and not attributable to random variation. Thus, the instructional treatment administered to the experimental group can be inferred to have a significant positive impact on students' learning outcomes.

This difference suggest that the Problem-Based Learning method integrated with Multiple Representations applied to the experimental group showed a significantly stronger effect in enhancing students' computational thinking skills compared to the control group, which applied the Problem-Based Learning method without treatment. This indicates that computational thinking skills can be improved by using appropriate learning methods. Computational thinking skills can be enhanced if the learning process is designed to stimulate higher-order thinking activities, providing opportunities for students to actively engage in structured problem-solving activities, participate in meaningful and collaborative discussions, and critically reflect on their learning processes and outcomes.

Empirical studies consistently demonstrate that the use of the Problem-Based Learning (PBL) method significantly enhances students' computational thinking skills. For instance, in Problem-Based Learning for Enhancing Students' Research on computational thinking skills has consistently demonstrated that the implementation of Problem-Based Learning (PBL) in mathematics education contexts contributes significantly to the enhancement of students' computational thinking abilities. This occurs because solving mathematical problems requires appropriate strategies that enable students to arrive at correct solutions in accordance with the definition of computational thinking (Cui et al., 2023).

Early elementary students' success in computational thinking tasks is strongly determined by their ability to translate and coordinate multiple representations. Each representational translation entails a cognitive load that must be actively managed, and in more complex tasks, students rely on intermediate representations such as concrete manipulation, self-talk, and gestures to alleviate cognitive load while maintaining and strengthening students' conceptual understanding (Moore et al., 2020). In light of the findings obtained in this study, the implementation of the PBL method through the integration of authentic problem solving, progressive representations, and metacognitive reflection is demonstrated to strengthen students' conceptual understanding and to support the transfer of computational thinking skills across diverse learning contexts. Accordingly, computational thinking constitutes a fundamental cognitive competence that needs to be cultivated through systematic, contextual, and process-oriented learning (Hegade & Shettar, 2023).

This indicates that empirically, student learning outcomes by applying the Problem-Based Learning method integrated with Multiple Representations in the experimental group exhibited a higher level of enhancement in students' computational thinking skills than the control group. group which applied the Problem-Based Learning method without being given treatment. With multiple representations, students have the opportunity to see and solve problems from various representations, for example: symbolic; verbal; and visual representations, which then allows them to compare, evaluate, and reflect on their understanding. Indirectly, they are already engaging in computational thinking processes (Zeng et al., 2023).

The improvement in students' computational thinking skills may be due to the different approaches used in the experimental group. Although both groups implemented the Problem-Based Learning method, a group of experimental was treated differently, applying the Multiple Representations. The Multiple Representations approach provides students with the opportunity to solve problems not only with routine formulas provided by the teacher, but also with the freedom to simplify or create other representations to facilitate their mathematical problem solving. This opportunity allows students to actively participate in developing their own understanding. Learning with a multiple representations approach not only improves problem solving skills but also enhances basic mastery of concepts (Amiroh et al., 2021).

The findings of this study indicate that students actively engage in the learning process and make meaningful contributions toward enhancing the overall quality of education through their participation, interaction, and involvement in instructional activities by enhancing their computational thinking skills. Learning by implementing the PBL-MR method in learning is one of the findings that can be used by teachers in realizing the goals of SDGs 4. Teachers, as facilitators, play a full role in helping students improve their computational thinking skills through learning using the PBL-MR method. By improving students' computational thinking skills, they can optimize all the learning they receive (Rahayu et al., 2024). Thus, the Problem-Based Learning method integrated with Multiple Representations can improve students' computational thinking skills through solving mathematical problems in elementary schools. This improvement is a tangible contribution to meeting the target of SDGs 4 to create quality education globally.

CONCLUSION

Based on the findings of this study, it can be concluded that the Problem-Based Learning approach method integrated with Multiple Representations was effective in improving students' computational thinking skills in addressing real-world problems involving multiplication in fourth-grade elementary school students. This effectiveness was empirically demonstrated by the data obtained on student learning outcomes. Student learning outcomes were analysed using descriptive analysis, prerequisite test, and independent t-test. The results of the independent samples t-test revealed a statistically significant difference, with a value of 0.881 indicating that the Problem-Based Learning method integrated with Multiple Representations effectively enhanced students’ computational thinking skills.

These findings indicate that improving students' computational thinking skills is one way to contribute to achieving SDG 4, namely creating quality education. This contribution is not solely derived from the student aspect but also aligns with SDG targets, namely point 4.1, which ensures inclusive and quality basic education; point 4.6, which improves literacy and numeracy skills; and point 4.c, which improves educator capacity through innovative pedagogy. Thus, all aspects of education have an important role to jointly achieving sustainable development goals (SDGs 4) by equalizing basic education globally.

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