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Metaphorical Thinking Intervention in Learning and Its Impact on Mathematical Reasoning Ability

Kristianus Viktor Pantaleon[1*], Maximus Tamur[2], Fulgensius Efrem Men[3]

[1*,2,3]Universitas Katolik Indonesia Santu Paulus Ruteng
Jalan Jend. A. Yani No. 10, Ruteng, NTT, Indonesia
[1*]*christianvictor1979@gmail.com*

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Abstrak
Dalam beberapa tahun terakhir, penelitian tentang intervensi Metaphorical Thinking (MT) dalam pendidikan matematika semakin mendapat perhatian. Namun, penelitian terbatas telah meneliti bagaimana intervensi MT, ketika diintegrasikan dengan model pembelajaran yang menantang, dapat meningkatkan Kemampuan Penalaran Matematis (MRA) siswa. Untuk mengatasi kesenjangan ini, penelitian kuasi-eksperimental dengan menggunakan desain kelompok kontrol posttest-only dilakukan terhadap 50 siswa di SMP Widya Bhakti Ruteng, NTT, Indonesia. Penelitian ini bertujuan untuk menganalisis pengaruh intervensi MT dalam lingkungan Pembelajaran Berbasis Masalah (PBL) terhadap MRA. Data dikumpulkan melalui tes PMA yang terdiri dari lima soal, dan hasilnya dianalisis menggunakan uji t setelah melakukan analisis prasyarat. Temuannya menunjukkan bahwa siswa yang menerima intervensi MT dikombinasikan dengan PBL menunjukkan MRA yang jauh lebih tinggi dibandingkan dengan mereka yang tidak menerima intervensi MT. Hasil ini menggarisbawahi potensi manfaat dari mengintegrasikan intervensi MT dengan pendekatan pedagogi menantang lainnya.
Kata Kunci: Berpikir Metaforis; Kemampuan Penalaran Matematis; Pembelajaran Berbasis Masalah

Abstract
In recent years, research on Metaphorical Thinking (MT) interventions in mathematics education has gained increasing attention. However, limited studies have examined how MT interventions, when integrated with challenging instructional models, can enhance students' Mathematical Reasoning Ability (MRA). To address this gap, a quasi-experimental study utilizing a posttest-only control group design was conducted with 50 students at SMP Widya Bhakti Ruteng, NTT, Indonesia. The study aimed to analyze the effects of MT interventions in a Problem-Based Learning (PBL) environment on MRA. Data were collected through a PMA test consisting of five questions, and the results were analyzed using a t-test after performing a prerequisite analysis. The findings revealed that students who received MT interventions combined with PBL demonstrated significantly higher MRA compared to those who did not receive MT interventions. These results underscore the potential benefits of integrating MT interventions with other challenging pedagogical approaches.
Keywords: Metaphorical Thinking; Mathematical Reasoning Ability; Problem-Based Learning

I. INTRODUCTION

The 21st century is characterized by rapid technological advancements and increasingly complex challenges, which demand enhanced reasoning skills from individuals (Sangestani & Khatiban, 2013; Arnandi et al., 2023; Putra, Juandi, & Jufri, 2023). As a result, reasoning abilities have become a focal point in the development of various educational curricula (Purwanto et al., 2023; Putri Hendana et al., 2024). Reasoning is a critical skill for problem-solving, enabling students to identify problems, analyze them systematically, and make informed decisions through logical and structured thinking processes (Purwanto et al., 2023; Mujib & Sulistyana, 2023). However, evidence suggests that students' reasoning skills remain suboptimal and tend to be inadequate (Gustiadi et al., 2021; Sukmawati et al., 2023; Vebrian et al., 2021; Cahyani & Sritresna, 2023). This finding is further supported by interviews with mathematics teachers at SMP Widya Bhakti Ruteng, who reported significant concerns regarding students' reasoning abilities. Students often struggle with mathematical manipulations, drawing conclusions, compiling and justifying evidence, and identifying patterns or properties in mathematical phenomena to make generalizations (Iswanto & Faradillah, 2023; Puspita, Muzdalipah, & Nurhayati, 2023).

Problem-Based Learning (PBL) is a contemporary educational model centered on solving real-world, complex problems (Roccia et al., 2024; Zamir et al., 2022). It is widely recommended as a means to cultivate essential skills such as reasoning, communication, and collaboration. This approach is effective because it situates real-world problems as contexts in which students can actively construct and internalize knowledge (Aisyah & Usdiyana, 2022; Ranmechai & Poonputta, 2023). Numerous studies have demonstrated the positive impact of PBL on student performance across disciplines such as Science, Technology, Engineering, and Mathematics (STEM) (Jabarullah & Iqbal Hussain, 2019; Fitria et al., 2023). Furthermore, PBL has proven useful in developing Pedagogical Content Knowledge (PCK) skills (Martin & Jamieson-Proctor, 2022), and its application fosters greater student engagement in learning (Engelhardt et al., 2023).

Despite these advantages, PBL presents several challenges. It is often difficult to implement, time-intensive, and complex to manage (Indriani, Wahyudin, & Turmudi, 2023). It requires significant preparation, and students may find it confusing, particularly when attempting to design and execute problem-solving processes (Ranmechai & Poonputta, 2023). Additionally, students are sometimes reluctant to share their ideas during discussions, and teachers often struggle to create open-ended problems suited to the PBL framework (Ng Chin

Leong, 2009). Both students and teachers frequently experience difficulties in visualizing problems concretely, which hampers their ability to devise effective solutions.

To address the aforementioned challenges, Problem-Based Learning (PBL) can be enhanced by integrating the Metaphorical Thinking (MT) approach. The use of MT has been shown to foster students' ability to develop more creative cognitive patterns (Noviani, 2022), which can aid in the problem-solving process. Moreover, MT can help clarify mathematical concepts and problems by illustrating them in a way that is more accessible and comprehensible (Permatasari et al., 2021). Thus, combining MT with PBL has the potential to mitigate the limitations inherent in PBL implementation.

Building on this reasoning, the present study seeks to explore the impact of incorporating MT into a PBL-designed learning environment. Research on the application of MT in mathematics education is still relatively scarce, and no studies to date have investigated the combination of MT with PBL. Over the past decade, some researchers have begun to examine the role of MT in teaching mathematics, particularly its relation to students' abilities in solving algebraic problems (Noviani, 2022). Other studies have explored metaphorical thinking abilities in relation to personality types (Noviani, 2022). (Purwanto, 2021). or examined the effects of MT on reasoning and problem-solving skills (Purwasi & Fitriyana, 2021). Although this latter study is similar to the one presented here, it did not explore the combination of MT with PBL. Additionally, research has also focused on the development of MT-based learning tools (Baharudin et al., 2024).

Collectively, these studies have demonstrated that MT interventions can effectively enhance the quality of learning processes and outcomes. Based on this body of work, it is hypothesized that MT interventions may have a positive impact on the implementation of PBL. These impacts could include increased cognitive engagement, shifts in problem-solving strategies, enhanced critical and analytical thinking, and improved comprehension of mathematical concepts, as evidenced by higher reasoning ability scores (Noviani, 2022). A more tangible benefit could be the increased overall effectiveness of PBL as a teaching method.

This study utilizes two instructional methods: PBL (Problem-Based Learning) and PBL-MT (a combination of PBL and Metaphorical Thinking). The key distinction between the two methods lies in the integration of metaphors as a learning tool. In PBL, the focus is on solving problems through inquiry and collaboration. In contrast, PBL-MT combines this problem-solving approach with the use of metaphors, which serve as cognitive bridges between mathematical concepts and real-world contexts, making these concepts more comprehensible for students (Nurjasia et al., 2021).

II. METHOD

This quasi-experimental study was conducted at SMP Widya Bhakti Ruteng from May 23, 2022, to June 3, 2022, utilizing a posttest-only control group design. A total of 50 seventh-grade students from SMP Widya Bhakti participated, divided into two classes: Class A and Class B, each consisting of 25 students. These two classes were randomly selected from three available classes, with class equivalence established by testing the students' mathematical abilities, confirming that the classes were of similar proficiency. Class A received an intervention through the implementation of a combination of PBL and Metaphorical Thinking (MT), while the control class was taught using the PBL method without the MT intervention.

Data collection was conducted through a test designed to assess students' Mathematical Reasoning Ability (MRA). The test was administered at the end of the intervention to evaluate the effectiveness of both instructional methods. The data collection instrument was a written test comprising four questions, which measured six key indicators of mathematical reasoning: (1) proposing conjectures, (2) performing mathematical manipulations, (3) drawing conclusions, compiling evidence, and providing justification for the correctness of solutions, (4) deriving conclusions from statements, (5) verifying the validity of an argument, and (6) identifying patterns or properties of mathematical phenomena to make generalizations (Enmufida et al., 2023; Riswari et al., 2024).

Prior to implementation, the test was piloted with 20 students from Class VIIC, a class not involved in the study, to determine the validity, reliability, and difficulty level of the questions. Initially, six questions were prepared, but after testing, four were deemed valid while two were discarded due to insufficient validity (r count < r table = 0.468). The reliability of the four valid questions was then calculated, yielding a Cronbach's Alpha value of 0.688, which falls within the high reliability range. The difficulty level of the questions ranged from 0.562 to 0.687, placing them in the moderate category. To prevent leakage of test materials, all answer sheets and question papers were collected immediately after the pilot test.

The collected data were analyzed both descriptively and inferentially. Descriptive statistics were employed to compute the mean, standard deviation, percentage, as well as the highest and lowest scores. Inferential statistics, specifically the t-test, were used to test the hypothesis, with the t-test conducted after satisfying all prerequisite analyses.

III. RESULT AND DISCUSSION

A. Result

The results of the descriptive statistical analysis (see Table 1) indicate that the average scores for the experimental and control groups are 69.16 and 60, respectively. At first glance, the difference in average scores between the two groups appears modest, with a gap of 9.16 points. Similarly, the disparity in minimum scores between the two classes is relatively minor. However, when examining the maximum scores, the difference becomes more pronounced, with a notable gap of 13 points between the two groups.

Table 1.
Result of Descriptive Statistic

Class	N	S	$\bar{x}$
Experimental	25	13,07	69,16
Control	25	12,95	60

Description:
N: Sample size or number of subjects
S: Standard Deviation
$\bar{x}$: Average Score

The differences between the two classes become more evident through parametric statistical analysis. The results indicate that the calculated t-value (2.498) is greater than the critical t-value (2.01), demonstrating a significant difference in the scores between the two groups. This suggests that the MT intervention integrated with PBL has a significant positive effect on students' reasoning abilities compared to the group that only received PBL instruction.

B. Discussion

Numerous studies have successfully demonstrated that the implementation of Problem-Based Learning (PBL) can enhance various aspects of student learning, including achievement and engagement (Jabarullah & Iqbal Hussain, 2019; Suparman et al., 2021). Like other educational methodologies, PBL has certain limitations that need to be addressed. One effective strategy for minimizing these shortcomings is to combine PBL with complementary instructional methods that are theoretically positioned to mitigate its weaknesses.

The findings of this study indicate that the integration of Metaphorical Thinking (MT) effectively addresses the limitations of PBL. The combination of PBL and MT, referred to as PBM-MT, has proven to support the development of students' mathematical reasoning abilities. This aligns with previous research indicating that the implementation of MT enhances students' capacity to construct more creative cognitive patterns in the problem-solving process (Choi & Kim, 2017). Moreover, MT can facilitate the resolution of mathematical problems, rendering them more comprehensible (Hendriana & Rohaeti, 2017).

The results presented in this study convincingly illustrate that the MT intervention within the PBL framework significantly enhances students' mathematical reasoning abilities compared to PBL alone. This suggests that the integration of MT enriches the learning model, while also accelerating and deepening students' comprehension of abstract mathematical concepts.

MT employs the use of metaphors, which aid students in grasping abstract mathematical concepts. By connecting these concepts to more concrete contexts from everyday experience, metaphors provide students with a clearer understanding of abstract ideas (Purwanto, 2021), thereby facilitating their comprehension of the material.

Students in the experimental group, who were instructed using the PBL-MT approach, exhibited superior reasoning abilities, including enhanced critical and analytical thinking skills. This improvement can be attributed to MT's encouragement of students to approach problems from multiple perspectives, facilitating the making of analogies, transferring new meanings, and connecting them to abstract concepts, ultimately leading to easier problem resolution (Purwasi, 2021).

Extant literature has highlighted the close relationship between metaphors and analogies as cognitive tools that enhance understanding, particularly when confronting complex or abstract concepts. Both analogies and metaphors can bolster critical and analytical thinking skills, as they prompt students to connect and compare diverse concepts (Mars, 2021). Furthermore, MT interventions have influenced the strategies employed by students in problem-solving. Those engaged in PBL-MT are more inclined to utilize creative and effective approaches in their resolutions. This finding is consistent with prior research, which indicated that students trained to use analogies and metaphors are more likely to develop innovative and effective solutions compared to their peers who did not employ these techniques (J. Purwanto et al., 2021).

The integration of Problem-Based Learning (PBL) with Metaphorical Thinking (MT) intervention also enhances students' cognitive engagement. Students become more active thinkers and are more deeply involved in the learning process, as they must continuously search for appropriate analogies and reflect on their understanding. Previous studies have shown that when students successfully identify suitable metaphors, they become more enthusiastic and engaged in problem-solving activities (Muthmainnah et al., 2021). Cognitive engagement increases significantly when students are encouraged to use metaphors in learning, as this process fosters deeper and more reflective thinking.

IV. Conclusion

This study demonstrates that the Problem-Based Learning method combined with Metaphorical Thinking (PBL-MT) intervention is more effective than conventional PBL in enhancing students' mathematical reasoning abilities.

These findings suggest that integrating metaphors into problem-solving not only helps students understand mathematical concepts more deeply but also promotes critical thinking and cognitive engagement. The PBL-MT approach effectively strengthens students' abilities to internalize and apply mathematical concepts, surpassing the outcomes of traditional PBL without metaphorical intervention.

Based on the findings of this study, it is recommended that educators and education practitioners incorporate the PBL-MT method as a pedagogical strategy in mathematics instruction, particularly for topics requiring profound conceptual understanding. Future research could further explore the application of PBL-MT across diverse educational contexts and levels to evaluate the long-term sustainability of its positive impacts. Additionally, curriculum developers should consider integrating this approach into the design of innovative teaching materials.

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AUTHORS' BIOGRAPHY

Dr. Kristianus Viktor Pantaleon, M.Pd.,Si.

Dr. Kristianus Viktor Pantaleon, M.Pd.,Si is a member of the Indonesian Mathematics Educators Society (IMES) and serves as a faculty member in the Mathematics Education Department at the Catholic University of Indonesia, Santu Paulus Ruteng.

Dr. Maximus Tamur, M.Pd.

Dr. Maximus Tamur, M.Pd is a member of the Indonesian Mathematics Educators Society (IMES) and serves as a faculty member in Mathematics Education and Mathematics Software at the Catholic University of Indonesia, Santu Paulus Ruteng. He has also chaired the Committee for the 2022 ICEHHA International Conference and served as the Chair of Publications for ICEHHA in 2023.

Fulgensius Efrem Men, M.Pd.

Fulgensius Efrem Men, M.Pd is a teaching staff member in mathematics education in the field of mathematics education at the Catholic University of Indonesia, Santu Paulus Ruteng.