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Empowering Primary School Students Through Problem-Based Learning: A Path to Literacy and Numeracy Mastery

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Abstrak

Keterampilan literasi dan numerasi sangat penting untuk mencapai potensi penuh dalam menjalani kehidupan yang bermakna dan produktif. Penelitian ini bertujuan mengkaji efektivitas Problem-Based Learning (PBL) dalam meningkatkan literasi dan numerasi siswa sekolah dasar di Kota Medan. Menggunakan desain quasi-eksperimen, sampel terdiri dari 37 siswa kelompok eksperimen (PBL) dan 35 siswa kelompok kontrol (konvensional). Data dikumpulkan melalui tes prior knowledge (PK), literasi, dan numerasi, dianalisis dengan ANOVA dua jalur. Hasil menunjukkan bahwa kelompok eksperimen mengalami peningkatan signifikan, dengan N-Gain literasi (0.449) dan numerasi (0.439) lebih tinggi dibanding kelompok kontrol (0.268 dan 0.236). Selain itu, PK berpengaruh signifikan terhadap numerasi, tetapi tidak terhadap literasi. Penelitian ini merekomendasikan integrasi PBL dalam kurikulum untuk meningkatkan keterampilan siswa serta penelitian lanjutan terkait motivasi dan konteks sosial-budaya. PBL terbukti sebagai pendekatan inovatif yang relevan bagi peningkatan kualitas pendidikan di Indonesia.
Kata Kunci: Literasi; Numerasi; PBL

Abstract

Literacy and numeracy skills are essential for individuals to reach their full potential, lead meaningful and productive lives, and participate fully in society. This study aims to examine the effectiveness of Problem-Based Learning (PBL) in enhancing the literacy and numeracy skills of primary school students in Medan, Indonesia. Employing a quasi-experimental design, the study involved 37 students in the experimental group (PBL) and 35 students in the control group (conventional learning). Data were collected through prior knowledge (PK) tests, as well as literacy and numeracy assessments, and analyzed using two-way ANOVA. The results revealed that the experimental group showed significantly greater improvement, with N-Gain scores for literacy (0.449) and numeracy (0.439) exceeding those of the control group (0.268 and 0.236, respectively). Additionally, prior knowledge had a significant effect on numeracy outcomes, but not on literacy. The study recommends integrating PBL into the curriculum to enhance student skills and encourages further research on motivational and sociocultural factors. PBL is demonstrated to be an innovative and relevant approach for improving the quality of education in Indonesia.
Keywords: Literacy; Numeracy; PBL

I. INTRODUCTION

Literacy and numeracy are currently of paramount importance in the realm of education. In numerous countries, including Australia, Hong Kong, China, Singapore, Malaysia, and others, literacy and numeracy are imparted as essential life skills within the school curriculum. These skills are fundamental to an individual's holistic development, enabling them to lead fulfilling and productive lives and actively participate in their communities. Moreover, literacy and numeracy are recognized as social practices (Barton, Hamilton, & Ivanic, 2000; Gee, 2000). Consequently, educators play a pivotal role in ensuring that all students acquire these skills, thereby contributing significantly to the achievement of social justice and equality within our nation.

In today's global marketplace, literacy and numeracy skills are indispensable for personal and professional success. Individuals with proficiency in these areas are more likely to secure full-time employment and attain higher wages. Moreover, developing literacy and numeracy skills fosters self-confidence and enables students to excel in academic and practical endeavors. These skills serve as a foundation for acquiring more advanced skills, including critical and creative thinking.

Today's students require a robust foundation in literacy and numeracy to foster innovation, adaptability, and responsiveness. This equips them with the knowledge and skills necessary for future success. However, a survey conducted by the Programme for International Student Assessment (PISA) in 2018 revealed that Indonesia's ranking was at the bottom among participating countries. The OECD-organized PISA test was administered to 79 countries in 2018. The PISA measurement results indicated that the average score of Indonesian students in reading was 371, ranking 72 out of 77 countries. Similarly, the average score in mathematics was 379, ranking 72 out of 78 countries, and the average score in science was 396, ranking 70 out of 78 countries. The score achievement fell below the average of the 79 PISA participating countries, which was 487 for reading ability, 489 for mathematics and science ability (OECD, 2019).

The PISA survey does not assess students' proficiency in curriculum content, but rather evaluates their ability to apply acquired knowledge in practical, everyday situations (Masfufah & Afriansyah, 2021; Purnomo & Sari, 2021). This proficiency demands literacy and numeracy skills. Consequently, based on the 2018 PISA survey results, it can be concluded that the literacy and numeracy levels of students aged 15 and above in Indonesia are relatively low.

The Victorian Curriculum and Assessment Authority (2017) defines literacy as the capacity of students to interpret and create texts with precision, accuracy, confidence, fluency, and efficacy for learning both within and outside the school environment, as well as for participating in the workplace and society. Numeracy encompasses the knowledge, skills, behaviors, and dispositions necessary for students to utilize mathematics in diverse contexts. These skills enable students to respond effectively to both

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familiar and unfamiliar situations by employing mathematics to make informed decisions and solve problems efficiently (Victorian Curriculum and Assessment Authority, 2017).

In sectors experiencing rapid technological transformation, the capacity for continuous learning is paramount, and the general skills that support this ability are highly valued by employers (Ghost, 2002; Smits, 2007). The labor market undergoes frequent and unpredictable changes, necessitating skills such as literacy, which facilitate the acquisition of new knowledge, for long-term success (Kézdi, 2006). The significance of literacy for full societal participation has long been recognized. Numeracy skills are also equally important and are now regarded as more challenging than literacy skills. The impact of poor numeracy skills on future employment opportunities is often overlooked. In educational institutions, students' numeracy levels significantly influence their academic performance and subsequent career choices (Lamb, 1997; Fullarton, Walker, Ainley, & Hillman, 2003; Marks, McMillan, & Hillman, 2001). Individuals with limited literacy skills are more prone to dropping out of school and encounter difficulties in securing and retaining employment. Moreover, poor literacy skills often restrict employment opportunities, resulting in lower wages and diminished prospects for advancement (Bynner & Parsons, 1997; Parsons & Bynner, 1997; Lago & DiPerna, 2010). In essence, proficient literacy and numeracy skills are essential for developing complex problem-solving and communication abilities (Levy and Murnane, 2004).

Given the paramount importance of literacy and numeracy skills for students in navigating the challenges of the future, concrete measures are imperative to enhance their quality. One effective strategy to address obstacles in mastering literacy and numeracy is the implementation of problem-based learning.

The Problem-Based Learning (PBL) approach is believed to enhance students' literacy and numeracy proficiency by fostering contextual-based learning that encourages exploration, analysis, and active problem-solving. In literacy instruction, PBL enables students to acquire critical reading skills, interpret information effectively, and communicate their ideas through discussions and presentations. Simultaneously, in numeracy, this approach entails solving intricate mathematical problems, refining logical reasoning abilities, and enhancing conceptual understanding by applying theoretical concepts to practical scenarios.

Furthermore, Problem-Based Learning (PBL) fosters active student participation in the learning process, thereby enhancing motivation and fostering a sense of ownership over the acquired knowledge (Rinaldi & Afriansyah, 2019). Consequently, this approach not only enhances conceptual literacy and numeracy proficiency but also equips students with higher-order thinking skills that are indispensable for future academic and professional endeavors.

Despite the recognition of Problem-Based Learning (PBL) as a valuable

approach to enhancing critical thinking and problem-solving abilities (Hawamdeh & Adamu, 2021; Jonassen & Hung, 2012; Schmidt et al., 2011), several research gaps remain to be addressed, particularly regarding the efficacy of PBL in simultaneously improving literacy and numeracy. Previous studies have predominantly focused on the effectiveness of PBL in enhancing numeracy skills (Arviana et al., 2018; Mulyanto et al., 2018) or literacy separately (Jannah et al., 2024). However, research investigating the simultaneous integration of literacy and numeracy through an integrated approach is still limited. This raises questions about the holistic implementation of PBL in learning contexts that necessitate a multidisciplinary approach.

Furthermore, most previous studies have been conducted in the context of higher or secondary education, while research on the effectiveness of PBL in enhancing literacy and numeracy at the elementary education level has received inadequate attention (Suswandari et al., 2019). In fact, the elementary education level serves as a crucial foundation for the development of students' literacy and numeracy skills, which subsequently impact their academic performance at higher levels. The absence of research at the elementary level creates a substantial knowledge gap, particularly in understanding how PBL can be adapted for younger students with varying cognitive and emotional maturity compared to students at middle or high levels. Based on the identified research gaps, the present study endeavors to explore the effective application of the Problem-Based Learning approach in simultaneously improving literacy and numeracy, particularly at the elementary education level. This study aims to address the gap in the literature by providing empirical evidence on the effectiveness of Problem-Based Learning (PBL) in the context of integrated learning. This approach does not solely focus on one aspect of skills but rather integrates literacy and numeracy as two interrelated components. Consequently, this research is anticipated to make a substantial contribution to the development of innovative learning methods that are pertinent to the needs of basic education. Additionally, it is expected to enhance the comprehension of the potential of PBL in fostering students' comprehensive academic development.

II. METHOD

This study employed a quasi-experimental methodology with a structured research design comprising three distinct stages: preparation, implementation, and data analysis. The population of this study consisted exclusively of sixth-grade elementary school students residing in Medan City. From this population, two homogeneous parallel classes were randomly selected as research samples. The primary objective of this study was to investigate the effectiveness of problem-based learning (PBL) in comparison to conventional learning methods. The first class was designated as the experimental group, implementing PBL with a total of 37 students. Conversely, the second class served as the control group, employing

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conventional learning methods with a total of 35 students. The selection of these sample classes was conducted with the utmost care to ensure the equality of students' initial characteristics, including academic abilities and socioeconomic backgrounds. This meticulous selection process was undertaken to enhance the validity and reliability of the research findings.

The research design comprises three distinct stages: (1) the development of learning devices and research instruments, (2) the trial of these devices and instruments, to ensure the validity of the content, all instruments were developed based on indicators that refer to literacy and numeracy skills. Validation was conducted through expert judgment by three experienced lecturers and elementary education practitioners. Revisions were made based on expert input, including language clarity, content relevance, and the appropriateness of question difficulty levels. Subsequently, a trial of the instrument was conducted on a small sample outside the research group. The results of the trial were analyzed using item validity (item-total correlation) and internal reliability with Cronbach's Alpha, which demonstrated a value greater than 0.7 for all instruments, thereby indicating their reliability. and (3) the implementation of the research, this research was conducted during the even semester of the 2023/2024 academic year. Each experimental and control group received five treatment sessions, excluding the pretest and posttest. The treatment was administered in a structured manner, adhering to the learning design of each model. Each stage is meticulously designed to ensure the validity of the data collected, adhering to the characteristics of the variables and the objectives of the research. Data collection was conducted through the administration of three types of tests: prior knowledge (PK) tests, literacy tests, and numeracy tests. The PK test comprises 12 multiple-choice questions, while each literacy and numeracy test consist of five essay-type questions.

Quantitative data analysis was conducted to assess the impact of learning interventions on students' literacy and numeracy skills. Initial and final data from each group were collected through pre-test and post-tests administered for literacy and numeracy assessments. N-Gain scores were calculated to quantify the improvement in students' proficiency. Additionally, a two-way analysis of variance (two-way ANOVA) was employed to evaluate the effects of treatment and the interaction between learning models (PBL versus conventional) and prior knowledge levels (low, medium, high). Prior to conducting ANOVA, the data underwent testing to ensure adherence to the assumptions of normality and homogeneity. This study not only quantifies the direct impact of learning interventions but also considers the role of students' prior knowledge in shaping learning outcomes.

III. RESULT AND DISCUSSION

This section presents the primary findings of the study investigating the efficacy of the Problem-Based Learning (PBL) model in enhancing the literacy and

numeracy proficiencies of elementary school students. The findings are presented in the form of descriptive and inferential statistics, which are subsequently critically analyzed to address the research objectives and are substantiated by prior research findings. Table 1 elucidates the literacy and numeracy accomplishments of students belonging to the experimental group. Table 1 elucidates the literacy and numeracy gains achieved by students within the experimental group.

Table 1.
Descriptive Statistics for Experimental Group

	Valid	Mean	SD	Min	Max
PreTest_Lit	37	53.47	9.25	35.87	73.52
PostTest_Lit	37	73.42	10.42	55.83	95.33
PreTEST_Num	37	48.16	9.11	23.8	68.86
PostTest_Num	37	70.11	11.07	45.67	91.79
N_Gain_Lit	37	0.449	0.153	0.25	0.82
N_Gain_Num	37	0.439	0.138	0.22	0.74

Concurrently, the acquisition of literacy and numeracy data for the control group is presented in Table 2.

Table 2.
Descriptive Statistics for Control Group

	Valid	Mean	SD	Min	Max
PreTest_Lit	35	56.25	9.27	42.09	81.2
PostTest_Lit	35	67.11	11.5	45.86	89.63
PreTEST_Num	35	49.12	10.99	28.75	72.15
PostTest_Num	35	60.5	12.77	33.57	85.16
N_Gain_Lit	35	0.268	0.145	0.06	0.68
N_Gain_Num	35	0.236	0.129	-0.1	0.5

Based on the data presented in Tables 1 and 2, the experimental group exhibited a significant improvement in literacy proficiency. The pretest average literacy score was 53.47, which rose to 73.43 after the posttest. Similarly, the numeracy pretest average was 48.16, increasing to 70.11 following the PBL intervention. In contrast, the control group showed a modest improvement in literacy, with an average pretest score of 56.25 that increased to 67.11 after the posttest. The numeracy pretest average was 49.13, which rose to 60.50 after the conventional learning method. The substantial increase in scores among the experimental group suggests that the implementation of PBL is more effective in enhancing students' literacy and numeracy compared to conventional methods.

The standard deviation in the experimental group for literacy pretest (9.25) and posttest (10.42) and numeracy pretest (9.11) and posttest (11.07) demonstrated variation in scores among students. In contrast, the control group exhibited a standard deviation of literacy pretest (9.27) and posttest (11.50) and numeracy pretest (10.99) and posttest (12.77), indicating that this group also experienced an increase, albeit with greater fluctuations.

The experimental group demonstrated an average literacy N-Gain of 0.449 and a numeracy N-Gain of 0.439, suggesting a moderate increase (0.3–0.7). Conversely, the control group exhibited a literacy N-Gain of 0.268 and a numeracy N-Gain of 0.236, falling within the low category (<0.3). Therefore, Problem-Based Learning (PBL) demonstrated a more substantial increase in comparison to conventional learning in enhancing students' literacy and numeracy proficiency.

Based on the descriptive findings, it can be concluded that the implementation of Problem-Based Learning (PBL) exhibits a greater propensity for improving literacy and numeracy skills compared to conventional learning methodologies. This conclusion is supported by the observation of a higher average increase in scores, a

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larger N-Gain, and a broader range of posttest scores in the experimental group.

Subsequently, inferential statistical testing will be conducted using a two-way ANOVA test. Prior to testing, a prerequisite test analysis was performed, comprising normality and homogeneity tests. Based on the test results, all data exhibited normality, and the variance among groups adhered to the assumption of homogeneity. The findings of the analysis pertaining to student literacy improvement test results are presented in Table 3.

Table 3.
Enhancing Student Literacy

ANOVA - N_Gain_Lit

Cases	Sum of Squares	df	Mean Square	F	p
Group	0.168	1	0.168	7.655	0.008
PK	0.028	2	0.014	0.633	0.535
Group ✻ PK	0.032	2	0.016	0.730	0.486
Residuals	1.230	56	0.022		

Note. Type III Sum of Squares

As evidenced by Table 3, the primary effect of the group is statistically significant, with an F-value of 7.655. p = 0.008. Indicating a statistically significant difference between the experimental and control groups in terms of increasing literacy (N_Gain_Lit). In other words, the intervention or treatment administered to the experimental group has a substantial impact on enhancing literacy. Conversely, in the main effect of PK, the value of F = 0.633 is obtained. p = 0.535 indicates that there is no significant difference between PK levels (eg, low, medium, high) in terms of increasing literacy. This means that the PK level does not significantly affect literacy increases. And the interaction between the group and PK obtained a value of F = 0.730 with p = 0.486 indicating that there is no significant interaction between the group and the PK level. This means that the effect of the intervention (Group) does not differ significantly based on the PK level.

To assess the extent of student literacy improvement, a post-hoc test was conducted, as presented in Table 4.

Table 4.
Analysis of Differences in Literacy Improvement between Groups

Post Hoc Comparisons - Group

		Mean Difference	SE	t	p_{tukey}
Experiment	Control	0.175	0.063	2.767	0.008

Note. Results are averaged over the levels of: PK

Table 4 reveals a substantial disparity between the experimental and control groups (p = 0.008). The experimental group experienced a significantly higher increase in literacy compared to the control group. To quantify the increase in student literacy in terms of prior knowledge (PK), the Post Hoc analysis results are presented in Table 5.

Table 5.
Analysis of Student Literacy Improvement from Prior Knowledge

Post Hoc Comparisons - PK

		Mean Difference	SE	t	p_{tukey}
Low	Medium	0.041	0.041	1.011	0.573
	High	-0.017	0.091	-0.191	0.980
Medium	High	-0.058	0.089	-0.656	0.790

Note. P-value adjusted for comparing a family of 3
Note. Results are averaged over the levels of: Group

As presented in Table 5, no significant difference was observed between the PK levels (low, medium, high) in terms of their impact on increasing literacy (p>0.05 for all comparisons). Consequently, the PK level does not exert a substantial influence on enhancing literacy. Furthermore, the analysis of the student numeracy

improvement test results is presented in Table 6.

Table 6.
Enhancing Student Numeracy

ANOVA - N_Gain_Num

Cases	Sum of Squares	df	Mean Square	F	p
Group	0.161	1	0.161	10.55	0.002
PK	0.109	2	0.055	3.574	0.035
Group ✻ PK	0.039	2	0.020	1.283	0.285
Residuals	0.857	56	0.015		

Note. Type III Sum of Squares

As evidenced by Table 6, the primary effect of the group is statistically significant, with an F-value of 10.548. p = 0.002. Indicating a statistically significant difference between the experimental and control groups in terms of increasing numeracy (N_Gain_Num). This implies that the intervention or treatment administered to the experimental group has a substantial impact on enhancing numeracy. Conversely, in the main effect of PK, the value of F is obtained as 3.574. p = 0.035 indicating that there is a significant difference between the PK levels (low, medium, high) in terms of increasing numeracy. This means that the PK level significantly affects the increase in numeracy. And the interaction between the group and PK obtained a value of F = 1.283 with p = 0.285 indicating that there is no significant interaction between the group (Group) and the PK level. This means that the effect of the intervention (Group) does not differ significantly based on the PK level.

To assess the extent of students' numeracy improvement, a Post Hoc test was conducted, as presented in Table 7.

Table 7.
Analysis of Differences in Numeracy Improvement between Groups

Post Hoc Comparisons - Group

		Mean Difference	SE	t	p_{tukey}
Experiment	Control	0.171	0.053	3.248	0.002

Note. Results are averaged over the levels of: PK

Table 7 demonstrates a substantial disparity between the experimental and control groups (p = 0.002). The experimental group exhibits a significantly higher increase in numeracy compared to the control group. Furthermore, to ascertain the extent of student numeracy growth in relation to prior knowledge (PK), the Post Hoc analysis results are presented in Table 8.

Table 8.
Analysis of Student Numeracy Improvement from Prior Knowledge

Post Hoc Comparisons - PK

		Mean Difference	SE	t	p_{tukey}
Low	Medium	-0.082	0.034	-2.408	0.050
	High	0.034	0.076	0.446	0.896
Medium	High	0.116	0.074	1.554	0.274

Note. P-value adjusted for comparing a family of 3
Note. Results are averaged over the levels of: Group

As evidenced by Table 8, a substantial disparity was observed (p = 0.050). A significant difference (p < 0.05) was observed between the groups with low PK and the group with medium PK, with the former exhibiting a lower increase in numeracy. Furthermore, no significant difference (p > 0.05) was detected between the groups with low and high PK, as well as between the groups with medium and high PK.

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Based on the research data presented, it can be concluded that Problem-Based Learning (PBL) is demonstrably more effective in enhancing students' literacy and numeracy proficiency compared to conventional learning methodologies. The experimental group employing PBL exhibited a more pronounced increase, with an average N-Gain of 0.449 for literacy and 0.439 for numeracy, whereas the control group only achieved 0.268 for literacy and 0.236 for numeracy. This finding aligns with the constructivist theory proposed by Vygotsky (1978), which posits that problem-solving and social interaction-based learning facilitate the acquisition and retention of knowledge. Furthermore, recent research conducted by Lim (2023) and Hmelo-Silver et al. (2007) corroborates this notion, demonstrating the efficacy of PBL in enhancing critical thinking and problem-solving abilities, which are integral components of literacy and numeracy. Additionally, a study conducted by Loyens et al. (2015) revealed that PBL not only improved conceptual comprehension but also fostered increased student motivation and engagement in the learning process, which may have contributed to the greater improvement observed in the experimental group.

The extent of prior knowledge (PK) or students' initial knowledge appears to have distinct effects on literacy and numeracy acquisition. Research findings indicate that PK does not significantly enhance literacy levels but does have a notable impact on increasing numeracy proficiency. Students with lower PK exhibited a smaller increase in numeracy compared to those with moderate PK. This phenomenon can be elucidated by schema theory (Anderson, 1978), which posits that prior knowledge plays a pivotal role in the learning process, particularly in domains that necessitate robust conceptual understanding, such as numeracy. Furthermore, a study conducted by Sweller et al. (2011) demonstrated that PK exerts a more pronounced influence on mathematics learning (numeracy) compared to language learning (literacy). This disparity can be attributed to the hierarchical structure of mathematics, which necessitates a solid foundation of knowledge.

The study also revealed notable disparities between the experimental and control groups in terms of enhancing literacy and numeracy skills. Analyses conducted using ANOVA revealed significant F values (F = 7.655 for literacy and F = 10.548 for numeracy), indicating the substantial impact of the PBL intervention. The cognitive load theory (Sweller, 1988) provides a theoretical framework that explains how PBL can reduce cognitive load by dividing intricate tasks into smaller components, thereby enabling students to concentrate more on problem-solving (van Nooijen et al., 2024; Krieglstein et al., 2024; Kirschner et al., 2018). Several previous research findings also support the findings of this study, indicating that Project-Based Learning (PBL) can enhance information retention and knowledge transfer to novel contexts (Rehman et al., 2024; Wijnia et al., 2024; Mutanga, 2024; Granado-Alcón et al., 2020; Kirschner et al., 2006).

The practical implications of these findings are that PBL can be an effective learning method to enhance students' literacy and numeracy, particularly in the context of education in Indonesia. Teachers can consider integrating PBL into the curriculum, especially for subjects that require problem-solving and critical thinking. However, it should be noted that students' prior knowledge levels, particularly in numeracy, can influence learning outcomes. Therefore, learning strategies need to be tailored to students' initial knowledge levels. For further research, it is recommended to explore other factors that may affect the effectiveness of PBL, such as student motivation, teacher support, and socio-cultural context. Additionally, longitudinal research can be conducted to assess the long-term impact of PBL on students' literacy and numeracy.

IV. CONCLUSION

Based on the research findings, Problem-Based Learning (PBL) has demonstrated superior efficacy in enhancing students' literacy and numeracy proficiency compared to conventional learning methodologies. The experimental group employing PBL exhibited a more pronounced improvement, with an average N-Gain of 0.449 for literacy and 0.439 for numeracy. Conversely, the control group achieved only 0.268 for literacy and 0.236 for numeracy. This finding aligns with the constructivist theory proposed by Vygotsky, which posits that learning through problem-solving and social interaction facilitates comprehension and retention of knowledge. Furthermore, PBL fosters active student engagement within the learning process, thereby augmenting motivation and fostering a sense of ownership over acquired knowledge.

The impact of prior knowledge (PK) on literacy and numeracy varies. PK does not exert a significant influence on literacy improvement, but it does demonstrate a notable impact on numeracy enhancement. The group with low PK exhibited a lower numeracy increase compared to the group with moderate PK.

The practical implications of these findings are multifaceted. Teachers can incorporate PBL into their curricula, particularly for subjects that necessitate problem-solving and critical thinking, such as mathematics and language education. Schools can adopt PBL as an innovative learning paradigm, while policymakers can consider this approach when designing more effective curricula, particularly for elementary education. Additionally, further research can explore factors such as student motivation, teacher support, and socio-cultural context. Longitudinal studies can also be conducted to assess the long-term impact of PBL. These findings not only support the development of learning theories but also provide opportunities for enhancing the quality of education through more holistic and innovative learning methodologies.

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