

The effect of problem-based learning on student engagement in elementary mathematics learning



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Abstract This study investigated the effect of problem-based learning (PBL) on student engagement (SE) in elementary mathematics, with a focus on behavioral, emotional, and cognitive aspects. Employing a quasiexperimental pretest–posttest control group design, the research involved 128 fourth-grade students (aged 9–11) from two elementary schools in Salatiga, Indonesia. One experimental group ($n = 63$) was taught via the PBL model, whereas the control group ($n = 65$) received a conventional teaching approach (CTA) model. Student engagement was assessed via a validated 13-item scale across three dimensions. Paired-sample t tests demonstrated significant improvements in the PBL group: behavioral engagement increased from a mean of 10.25–11.68, emotional engagement from 13.89–16.43, cognitive engagement from 11.70–13.13, and overall SE from 34.11–41.24 (all $p < 0.05$). ANCOVA results, controlling for pretest scores, revealed significant effects of PBL on overall SE ($F(1,125) = 100.703$, $p < 0.05$, $\eta^2 = 0.446$) and emotional engagement ($F(1,125) = 27.572$, $p < 0.05$, $\eta^2 = 0.181$). However, cognitive engagement had a small effect size and was not statistically significant ($\eta^2 = 0.012$). These findings highlight that PBL effectively fosters behavioral and emotional engagement by encouraging active participation, enthusiasm, and collaboration, aligning with the benefits of student-centered pedagogy. Compared with CTA, which often emphasizes rote knowledge, PBL promotes deeper conceptual understanding and peer interaction, thereby enhancing motivation and classroom engagement. Theoretically, this study contributes to the growing evidence supporting PBL as a viable instructional strategy for improving engagement in mathematics education. Practically, it offers guidance for teachers and policymakers in designing more interactive and relevant learning environments.

Keywords: behavioral engagement, cognitive engagement, emotional engagement, primary education, quasiexperimental design

1. Introduction

Student-centered learning has garnered increasing attention, particularly for its effectiveness in fostering problem-solving skills and enhancing student engagement. A prominent model within this approach is problem-based learning (PBL), which emphasizes the use of real-world problems to encourage active student participation (Al-Busaidi et al., 2021; Hmelo-Silver, 2004; Rizal et al., 2021; Russo & Minas, 2021; Savery, 2015). PBL is a student-centered approach that fosters critical thinking, teamwork, and deeper learning. PBL generates a dynamic learning environment that supports both individual and group development by including students in solving real-world, challenging tasks (Bovill, 2020; Fogg & Fendley, 2024; Nemakhavhani, 2024; Razak et al., 2022; Tadesse et al., 2021). Knowing how PBL affects learning results becomes crucial, as it is increasingly used in many different educational environments. PBL challenges students in building knowledge through group projects and autonomous research motivated by real-life situations that are pertinent to their daily lives. This method enhances education and promotes real and significant student participation (Chaiyasit et al., 2023). PBL also improves academic results and student involvement by encouraging active participation and cooperative learning. Teachers can use planned interventions that support inclusivity and build critical teamwork skills to handle shared issues, including language barriers and unequal degrees of dedication among students (Lila, 2025; Solone et al., 2020). Through active participation in group discussions and problem solving, students can deepen their knowledge and enhance their scientific communication skills (Acharya et al., 2024; Divrik et al., 2021; Oktavia et al., 2024).

Mathematical and other forms of academic performance are influenced by student engagement. Thus, increasing student engagement improves active participation, attentiveness, academic performance, problem-solving skills, and critical thinking skills (Calicdan & Gementiza-Cubio, 2025; Charles, 2024; Razak et al., 2022; Silva et al., 2022; Verdeflor et al., 2024). Engagement is becoming increasingly accepted as a sensible solution for low academic performance-related problems. Research indicates that academic performance correlates favorably with student engagement in the behavioral, cognitive, and



emotional spheres (Kamei & Harriott, 2021). This correlation implies that motivating participation can effectively increase academic results (Asanre et al., 2024; Çali et al., 2024; Liu & Liang, 2023). This holds true across many educational environments and student populations.

In the context of PBL (Oktavia et al., 2024), teacher support is important for student engagement. This scenario indicates that good teaching strategies such as PBL are most successful when teachers can properly control group interactions and support significant student participation (Shao et al., 2025). Moreover, teacher support directly affects student engagement and influences students' academic self-efficacy and professional commitment (Zhou & Wu, 2023). Students who feel supported by their teachers show better motivation and active participation, thus improving their educational experience and engagement (Savitri et al., 2023). Yang et al. (2024) highlighted the need for more teacher support in mathematics learning since emotional and competency support favors student engagement. They also underline how academic self-efficacy moderates the correlation between several kinds of teacher support and engagement. This emphasizes the importance of teacher participation in realizing a motivating and supportive classroom fit for student success. Although PBL is increasingly implemented, more studies are needed to investigate how this model might improve student engagement in elementary schools, particularly in diverse sociocultural settings, to ensure that strategies are tailored to address the specific needs of each student (Al Hussaini et al., 2024; Nugraha et al., 2024; Sirwesvary & Jamaludin, 2025; Zhao, 2024).

According to a systematic literature review, student engagement is greatly enhanced by intrinsic motivation, perceived value, self-regulation, and social support. A lack of relevance in learning resources and inadequate meaningful interactions are common causes of disengagement among students, undermining their inherent drive and apparent value in education (Lu & Rameli, 2024). Tali (2023) underlines how supportive teacher–student interactions and good peer relationships significantly enhance student engagement. Students who feel close to their peers and under the direction of their teachers are more inclined to engage actively in school events and perform academically. Moreover, personal traits such as motivation, self-efficacy, and environmental elements such as teacher support and peer interactions significantly affect student participation, resolving the problem of disengagement in educational environments (Hu & Abu Talib, 2023; Tali, 2023). On the other hand, poor environmental support and poor teacher behavior can prevent participation. Prior research suggests that enhancing meaningful interactions and ensuring the relevance of instructional materials are essential strategies for improving student engagement and mitigating persistent disengagement in educational settings (Hennessy & Murphy, 2023; Li & Xue, 2023).

PBL has been extensively studied in secondary and higher education contexts. Moreover, prior studies have consistently demonstrated that it can enhance critical thinking, collaboration, and active participation. However, there is a lack of empirical research specifically targeting elementary school settings, where foundational skills and engagement strategies are crucial for long-term academic success (Al Hussaini et al., 2024; Zhao, 2024). Furthermore, although student engagement has been acknowledged as a reliable indicator of academic success, there is a limited understanding of how PBL specifically influences each engagement dimension in young learners, especially in mathematics, a subject often perceived as abstract and challenging in early grades. Another notable gap lies in the interaction between teacher support and the effectiveness of PBL. While teacher facilitation is recognized as critical in managing group dynamics and sustaining engagement, few studies have systematically examined how varying levels of teacher support modulate the effectiveness of PBL in elementary mathematics classrooms (Yang et al., 2024; Zhou & Wu, 2023). Addressing these gaps is essential, as early positive experiences in mathematics can shape students' long-term attitudes and performance in STEM fields. Understanding how PBL increases student engagement and under what circumstances it is most successful can guide evidence-based teaching plans and teacher professional development, ultimately producing better academic results in elementary education. The following hypotheses were proposed on the basis of the identified gaps and the body of the present research:

The Introduction should briefly place the study in a broad context and highlight why it is important and necessary. It should provide a general background of the study, define a problem, emphasize the purpose/justification for its execution, and present a clear and concise study objective. Hypotheses should also be addressed here.

The current state of the research field should be carefully reviewed, and key publications, especially recent ones, should be cited. The Introduction should be comprehensible and connect the points mentioned above with a dynamic flow of reading, making it accessible to scientists outside the specific research field. Citations should be presented in parentheses, using only the first author's last name followed by the year, without commas or periods.

H1: Implementing the PBL model significantly improves student behavioral engagement in elementary mathematics learning.

H2: Implementing the PBL model significantly improves student emotional engagement in elementary mathematics learning.

H3: Implementing the PBL model significantly improves student cognitive engagement in elementary mathematics learning.

H4: Elementary students who learn mathematics through the PBL model exhibit significantly higher overall engagement levels than those taught via the conventional approach.

2. Materials and Methods

This study included two classes in Salatiga, Indonesia, consisting of 128 fourth-grade elementary school students aged 9--11. An experimental or a control group was assigned to each class. Whereas the control group ($n = 65$) received instruction via a conventional teaching approach (CTA), the experimental group ($n = 63$) received instruction via the problem-based learning (PBL) model. Student engagement was thoroughly measured by administering a validated questionnaire with 13 items covering three dimensions, including behavioral engagement (5 items), emotional engagement (3 items), and cognitive engagement (5 items). The instrument uses a four-point Likert-type scale, with response options ranging from "never" (1) to "always" (4). SPSS analysis of the data was used to evaluate the instrument's validity and reliability. With correlation values exceeding 0.1927, the validity test revealed that all 13 items were valid. The reliability test yielded a Cronbach's alpha of 0.859, well above the acceptable threshold of 0.70, indicating high internal consistency. These results demonstrate that the instrument used in this study was valid and reliable. Thus, it was appropriate for measuring student engagement in learning activities.

2.1. Research design

This study employed a quasiexperimental pretest–posttest control group design, with classes randomly assigned to the experimental or control group. The study incorporated quantitative and qualitative data, with qualitative data serving a supplementary role in the overall research design [34]. Specifically, two intact heterogeneous classes were used: one served as the experimental group, which received instructions through the PBL model, while the other functioned as the control group, which was taught via the CTA model. The pretest–posttest control group design, a type of experimental design, was used to compare the effectiveness of the two instructional methods. This design is suitable when pre- and postintervention evaluations are conducted via random assignment to groups. Students in the experimental and control groups were selected on the basis of analytical criteria.

The present study addresses the following research questions: 1) Does implementing the PBL model significantly improve students' behavioral engagement in elementary mathematics learning? 2) Does implementing the PBL model significantly improve students' emotional engagement in elementary mathematics learning? 3) Does implementing the PBL model significantly improve students' cognitive engagement in elementary mathematics learning? 4) Do elementary students who learn mathematics through the PBL model demonstrate significantly higher overall engagement levels than those taught via the conventional approach?

2.2. Experimental procedure

At the outset, the Student Engagement (SE) scale for geometry was administered to both the experimental and control groups as a pretest to assess their initial level of engagement. In the experimental group, instruction on the topic of numerical arithmetic operations was delivered via the PBL model over a total of six instructional hours. Using the CTA model, the control group received instructions on the same material during the same period. All instructional activities were conducted according to the preestablished teaching and learning materials.

3. Results

The results are presented according to the hypotheses derived from the research objectives. Table 1 below displays the paired-sample t test results comparing the mean pretest and posttest scores for student engagement (SE) within the experimental group. The findings indicated statistically significant differences in favor of the posttest scores across all subdimensions and the overall SE scale. The mean pretest score for the experimental group's behavioral engagement (BE) subdimension was $\bar{X} = 10.25$. In contrast, the mean posttest score was $\bar{X} = 11.68$, with the difference being statistically significant in favor of the posttest score, $t(62) = 4.181$, $p < 0.05$. The mean pretest score for the emotional engagement (EE) subdimension was $\bar{X} = 13.89$. The mean posttest score was $\bar{X} = 16.43$, indicating a significant improvement, $t(62) = 7.587$, $p < 0.05$. The cognitive engagement (CE) subdimension had a mean pretest score of $\bar{X} = 11.70$ and a mean posttest score of $\bar{X} = 13.13$, with the difference again being statistically significant, $t(62) = 4.832$, $p < 0.05$. Finally, the overall SE score for the experimental group improved from a mean of $\bar{X} = 34.11$ on the pretest to $\bar{X} = 41.24$ on the posttest, with a highly significant difference in favor of the posttest, $t(62) = 8.567$, $p < 0.05$. These findings suggest that the problem-based learning (PBL) model effectively improved student engagement in the learning materials of arithmetic operations involving numbers.

Table 2 presents the mean pretest and posttest scores for the control group's subdimensions of student engagement (SE). For the behavioral engagement (BE) subdimension, the mean pretest score was $\bar{X} = 9.78$, and the posttest score was $\bar{X} = 9.94$. The difference was not statistically significant, $t(64) = 0.632$, $p < 0.05$. For emotional engagement (EE), the mean pretest score was $\bar{X} = 13.08$, and the posttest score was $\bar{X} = 14.02$, indicating a statistically significant increase, $t(64) = 2.691$, $p < 0.05$. In terms of cognitive engagement (CE), the mean pretest score was $\bar{X} = 12.09$, and the posttest score was $\bar{X} = 12.83$, also indicating a statistically significant difference, $t(64) = 2.254$, $p < 0.05$. The overall student engagement (SE) score increased from $\bar{X} = 34.95$ (pretest) to $\bar{X} = 36.78$ (posttest), with the difference being statistically significant, $t(64) = 3.143$, $p < 0.05$. These findings

suggest that the PBL model effectively enhances student engagement in the context of arithmetic operations in elementary school environments.

Table 1 Paired-samples t test results for student engagement pretest and posttest scores in the experimental group.

Sub-Dimension	Variants	N	\bar{X}	SD	df	t	p
Behavioral Engagement (BE)	Pretest	63	10.25	2.213	62	4.181	< 0.05
	Posttest	63	11.68	2.139			
Emotional Engagement (EE)	Pretest	63	13.89	2.080	62	7.587	< 0.05
	Posttest	63	16.43	2.100			
Cognitive Engagement (CE)	Pretest	63	11.70	2.107	62	4.832	< 0.05
	Posttest	63	13.13	2.012			
Overall Score of Student Engagement (SE)	Pretest	63	34.11	3.844	62	8.567	< 0.05
	Posttest	63	41.24	4.196			

Source: Research data processed with SPSS, 2025.

Table 2 Paired-samples t test results for student engagement pretest and posttest scores in the control group.

Sub-Dimension	Variants	N	\bar{X}	SD	df	t	p
Behavioral Engagement (BE)	Pretest	65	9.78	2.589	64	0.632	> 0.05
	Posttest	65	9.94	2.585			
Emotional Engagement (EE)	Pretest	65	13.08	2.648	64	2.691	< 0.05
	Posttest	65	14.02	2.660			
Cognitive Engagement (CE)	Pretest	65	12.09	2.343	64	2.254	< 0.05
	Posttest	65	12.83	2.759			
Overall Score of Student Engagement (SE)	Pretest	65	34.95	5.524	64	3.143	< 0.05
	Posttest	65	36.78	6.426			

Source: Research data processed with SPSS, 2025.

Table 3 summarizes the ANCOVA results comparing students' mean behavioral engagement (BE) scores in the experimental and control groups, as measured by the postintervention questionnaire. The analysis revealed that students' preintervention BE scores significantly affected their postintervention scores, $F(1, 125) = 36.207$, $p < 0.05$, $\eta^2 = 0.225$. Additionally, the results indicated a significant effect of the instructional model on the postquestionnaire scores, $F(1, 125) = 16.560$, $p < 0.05$, $\eta^2 = 0.117$. These findings suggest that both the pretest BE scores and the instructional model significantly affected the posttest BE outcomes. However, the instructional model had a greater effect size than the initial BE scores did, indicating that the intervention administered to each group played a more substantial role in shaping students' behavioral engagement. However, the results also revealed no significant difference in postintervention BE scores between students in the experimental group, who followed the PBL model, and those in the control group, who received the CTA model.

To summarize, paired-sample t tests comparing pre- and posttest scores for the experimental group revealed statistically significant increases across all three engagement dimensions and overall student engagement (SE). Behavioral engagement (BE) improved from a mean of 10.25 to 11.68, $t(62) = 4.181$, $p < 0.05$; emotional engagement (EE) rose from 13.89 to 16.43, $t(62) = 7.587$, $p < 0.05$; and cognitive engagement (CE) increased from 11.70 to 13.13, $t(62) = 4.832$, $p < 0.05$. Overall, the SE rose from 34.11 to 41.24, with a highly significant change, $t(62) = 8.567$, $p < 0.05$. These findings support H1 (behavioral engagement), H2 (emotional engagement), and H3 (cognitive engagement) on the basis of within-group comparisons. They also support H4, which proposed that PBL significantly improves overall engagement. However, interpretation requires caution due to contextual limitations. The study was conducted in two fourth-grade classrooms in a single Indonesian city, which might limit the generalizability of the findings. Furthermore, the engagement instrument was based on self-reported data, which introduced the potential for response bias.

Table 3 ANCOVA results comparing behavioral engagement scores between the experimental and control groups.

Source	df	Mean Square	F	Sig.	η^2
Corrected Model	2	128.547	29.129	< 0.05	0.318
Intercept	1	236.909	53.684	< 0.05	0.300
Pre_BE	1	159.779	36.207	< 0.05	0.225
Instructions	1	73.078	16.560	< 0.05	0.117
Error	125	4.413			
Total	128				
Corrected Total	127				

Source: Research data processed with SPSS, 2025.

Table 4 summarizes the ANCOVA results comparing the experimental and control groups' mean emotional engagement (EE) scores on the basis of their postintervention behavioral engagement (BE) questionnaire scores. The analysis revealed that students' preintervention EE scores had a statistically significant effect on their postintervention student engagement (SE) scores, $F(1, 125) = 17.038$, $p < 0.05$, $\eta^2 = 0.120$. The ANCOVA results also indicated that the preintervention EE scores and the instructional group assignment significantly affected the dependent variable. Notably, the effect of the instructional group was greater than that of the initial EE scores, suggesting that the type of instruction or intervention provided to each group significantly affected students' emotional engagement. However, the analysis revealed no significant difference in EE between the experimental group, which followed the PBL model, and the control group, which followed the CTA model.

Table 4 ANCOVA results comparing emotional engagement scores between the experimental and control groups.

Source	df	Mean Square	F	Sig.	η^2
Corrected Model	2	136.720	26.733	< 0.05	0.300
Intercept	1	423.452	82.799	< 0.05	0.398
Pre_EE	1	87.135	17.038	< 0.05	0.120
Instructions	1	141.010	27.572	< 0.05	0.181
Error	125	5.114			
Total	128				
Corrected Total	127				

Source: Research data processed with SPSS, 2025.

Table 5 summarizes the ANCOVA results comparing the mean Cognitive Engagement (CE) scores of the experimental and control groups using postintervention scores from the Behavioral Engagement (BE) Questionnaire. The analysis revealed that students' pretest CE questionnaire scores significantly affected their posttest CE scores, $F(1, 125) = 27.408$, $p < 0.05$, $\eta^2 = 0.180$. The ANCOVA results indicate that the pretest CE scores and the instructional group significantly affected the dependent variable. However, the effect of the pretest CE score was greater than that of the instructional score. This result suggests that the intervention administered to each group had a measurable, albeit limited, effect on students' cognitive engagement. Furthermore, the results indicate no statistically significant difference in posttest cognitive engagement (CE) scores between the experimental group, which followed the PBL model, and the control group, which followed the CTA model, $F(1, 125) = 1.494$, $p = 0.224$, $\eta^2 = 0.012$.

Table 5 ANCOVA results comparing cognitive engagement scores between the experimental and control groups.

Source	df	Mean Square	F	Sig.	η^2
Corrected Model	2	67.774	13.994	< 0.05	0.183
Intercept	1	241.084	49.799	< 0.05	0.285
Pre_CE	1	132.741	27.408	< 0.05	0.180
Instructions	1	7.237	1.494	< 0.05	0.012
Error	125	4.843			
Total	128				
Corrected Total	127				

Source: Research data processed with SPSS, 2025.

Table 6 summarizes the ANCOVA results comparing the mean scores of student performance in the experimental and control groups on the basis of their post-Student Engagement (SE) Questionnaire scores. The analysis indicated that students' pre-SE scores significantly affected their post-SE scores, $F(1, 125) = 74.432$, $p < 0.05$, $\eta^2 = 0.373$. Additionally, there was a significant treatment effect on the postquestionnaire scores, $F(1, 125) = 100.703$, $p < 0.05$, $\eta^2 = 0.446$. The effect size of 44.6% suggests that the instructional group variable contributed substantially to the model, even more so than the prequestionnaire scores did. These findings demonstrate that the treatment group significantly affected the dependent variable. The initial scores (prequestionnaire) and the instructional group significantly affected the dependent variable, with the instructional group having a greater effect. This result suggests that the intervention applied to each group effectively improved student engagement. Overall, the model significantly explained the variance in the dependent variable, with a considerable effect size of 46.4%. However, despite the significant effects observed, the final output suggests no statistically significant difference in outcomes between students in the experimental group (following the PBL model) and those in the control group (following the CTA model), which might require further clarification or examination.

ANCOVA tests were utilized to examine whether the instructional method had a significant effect when pretest scores were controlled for. The analyses confirmed that the instructional method significantly affected the posttest scores for behavioral engagement ($\eta^2 = 0.117$) and emotional engagement ($\eta^2 = 0.181$). For Cognitive Engagement, however, the effect of instruction was not statistically significant ($F(1, 125) = 1.494$, $p = 0.224$, $\eta^2 = 0.012$). This partial support suggests that H3, while accepted in the t test analysis, was only partially accepted when controlling for preexisting differences, indicating a more

nuanced effect of PBL on cognitive processes. Overall, student engagement also demonstrated a strong treatment effect in ANCOVA ($F(1, 125) = 100.703, p < 0.05, \eta^2 = 0.446$), confirming H4. Compared with the conventional method, the large effect size indicates that the PBL model substantially affects engagement. Although PBL showed more significant results, the brief 6-hour intervention and small sample size indicated that more research is needed to confirm these conclusions in more extensive environments and longer durations.

Table 6 ANCOVA results comparing student engagement scores between the experimental and control groups.

Source	df	Mean Square	F	Sig.	η^2
Corrected Model	2	1014.140	54.159	< 0.05	0.464
Intercept	1	1869.255	99.826	< 0.05	0.444
Pre_QUESTIONNAIRE	1	1393.763	74.432	< 0.05	0.373
Instructions	1	1885.675	100.703	< 0.05	0.446
Error	125	18.725			
Total	128				
Corrected Total	127				

Source: Research data processed with SPSS, 2025.

4. Discussion

The application of problem-based learning (PBL) and its significant effect on student engagement (SE) in elementary school mathematics learning were investigated in this study. Comparatively, the results of the SE levels before and after PBL demonstrate that this teaching strategy might successfully improve mathematical student engagement. By presenting real-world and contextually relevant problems, PBL encourages students to engage more actively in the learning process, thereby deepening their understanding and enhancing their interaction with the subject matter (Bovill, 2020; Chaiyasit et al., 2023; Fogg & Fendley, 2024; Nemakhavhani, 2024; Tadesse et al., 2021). Students who believe that their education is relevant to their lives are more likely to be actively engaged and intrinsically motivated (Chastnyk et al., 2024; Lu & Rameli, 2024). These findings also match earlier research confirming PBL's efficacy in increasing student engagement (Amrin & Ritonga, 2024; Kodinar et al., 2024; Naik et al., 2024; SV et al., 2024). This study thus added to the increasing corpus of empirical data confirming PBL's contribution to higher student engagement, thus improving the quality of education.

Conventional methods of teaching problem solving sometimes focus on separate parts of a subject. With the aim of obtaining a deeper conceptual understanding rather than just finding the right answer, PBL supports broader, orderly content exploration (Doz et al., 2024; Fitria et al., 2025; Raghu et al., 2025; Vélez Silva et al., 2024). For instance, the conventional teaching approach (CTA) usually stresses definitions and descriptive qualities, which might restrict the development of a complete conceptual framework (Gennen, 2023; Hu, 2024). PBL, on the other hand, challenges students to see connections between ideas, create knowledge on their own, and own their learning. The learning process also encourages self-evaluation, active participation, and autonomy (Dianasari et al., 2025; Hasiana et al., 2024; Sidiki et al., 2024; Tymoshenko et al., 2024). PBL also promotes teamwork since it forces students to interact, share knowledge, and practice critical personal skills (Oktavia et al., 2024; Shvets et al., 2024). Ten heterogeneous groups composed the experimental group for the present study; students collaborated to solve problem-based scenarios. They improved their academic knowledge and cooperative skills through peer review, group problem solving, and conversation.

This study contributes considerably to educational theory and practice concerning student engagement. PBL significantly improved student engagement across three dimensions, including 1) behavioral engagement (active participation and adherence to classroom norms), 2) emotional engagement (enthusiasm, interest, and emotional connection to learning), and 3) cognitive engagement (critical thinking, analysis, and deep reflection), theoretically expanding the relevant body of knowledge. The results also provide fresh perspectives on how well PBL creates interactive, student-centered learning environments fit the rigors of modern education. This is consistent with previous studies on the correlation between PBL and student motivation (Hu & Abu Talib, 2023; Savitri et al., 2023; Tali, 2023; Al-Busaidi et al., 2021; Razak et al., 2022; Stanculescu et al., 2022) as well as its efficacy in developing problem-solving ability. Therefore, this study supports the relevance of student-centered pedagogical approaches and offers a strong empirical foundation for creative teaching plans. Practically, the findings draw attention to significant ramifications for teachers, especially those in elementary schools. Through more interesting and relevant learning opportunities, PBL presents a convincing substitute for more traditional teaching strategies, including CTA. It promotes closer ties to the content and active student engagement.

However, several limitations must be acknowledged to help explain the outcomes. First, the sample came from only two classrooms in one city in Indonesia, so the generalizability of the results is restricted to other institutions, areas, or classrooms elsewhere. Students' responses to PBL can vary depending on their sociocultural, institutional, and instructional backgrounds. Future studies should replicate this design across diverse geographical areas and school types to confirm broader applicability. Second, although the student engagement scale used in this study demonstrated good reliability, it relied solely on self-report measures. This condition might introduce response bias or limit the depth of understanding regarding the behavioral

dimension. Complementary qualitative methods, such as classroom observations, teacher interviews, or student focus groups, could enrich the data and capture more nuanced engagement patterns. Third, while the paired-sample t test supported significant gains within the experimental group, the ANCOVA results indicated mixed effects. For example, the instructional method did not significantly outperform the control group in terms of cognitive engagement once pretest scores were controlled, suggesting that the gains might not be attributable to PBL alone. This finding might reflect ceiling effects, limited exposure duration (six hours), or variability in how PBL was implemented across groups. Future work should examine the fidelity of implementation as a mediating factor.

5. Conclusion

This study revealed that problem-based learning (PBL) could significantly improve student engagement, covering behavioral, emotional, and cognitive aspects, by integrating real-world problems into classroom activities. In this context, PBL could encourage active participation, emotional connection, and the development of critical thinking and problem-solving skills. These results highlight the effectiveness of student-centered approaches in fostering meaningful, long-term engagement among elementary students. The findings offer practical guidance for educators in the use of PBL to create dynamic learning environments. For policymakers, this study supports incorporating PBL into curricula to improve educational quality. Notably, PBL promotes active learning, real-life problem solving, and collaboration, all of which positively impact engagement. However, improvements in cognitive engagement were less consistent and should be interpreted cautiously, given the mixed ANCOVA results. The limitations of this study, such as its small sample size, self-reported data, and short intervention period, suggest the need for further research. Hence, future studies should examine long-term effects, involve more diverse school contexts, and explore how instructional and contextual factors affect engagement. Additionally, researchers should assess PBL's cross-subject effectiveness and its application to specific mathematical concepts to evaluate scalability and broader applicability.

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Ethical Considerations

This study involved human participants (elementary school students). All procedures were conducted per institutional and national ethical standards for educational research. Permission was obtained from the school authorities, and the students' parents/guardians provided informed consent. The confidentiality and anonymity of the participants were strictly maintained.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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