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Changes in mathematical problem-solving abilities of prospective elementary school teachers after the implementation of case-based learning

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ABSTRACT

This study analyzes the changes in mathematical problem-solving abilities of prospective elementary school teachers after the implementation of Case-Based Learning (CBL) and the relationship between student engagement and post-test achievements. This quantitative research uses a one-group pretest-posttest quasi-experimental design with 161 elementary school teacher education students. Data were collected through mathematical problem-solving tests and activity observation sheets, then analyzed using descriptive statistics, paired difference tests, N-Gain, effect size, and correlation. The average score increased from 78.76 in the pre-test to 86.11 in the post-test; the difference was significant ($p < 0.001$) with a large effect size ($d = 1.315$). The average N-Gain of 0.341 falls into the moderate category. Student activity is positively correlated with post-test scores ($r = 0.504$; $p < 0.001$). Because there is no comparison group, this finding shows the observed changes after the implementation of CBL and does not prove a causal relationship.

Keywords: case-based learning, prospective elementary school teachers, student engagement, mathematics education, mathematical problem solving

INTRODUCTION

The ability to solve mathematical problems is one of the fundamental competencies in 21st-century mathematics education because it plays an important role in shaping critical thinking skills, analytical reasoning, decision-making, and individuals' adaptive abilities in facing various complex situations. In the contemporary education paradigm, mathematics learning is no longer viewed merely as a process of mastering algorithmic procedures and symbolic manipulation but to develop higher-order thinking capacities that enable learners to construct knowledge, evaluate alternative solutions, and connect mathematical concepts with real-life contexts (Kartika et al., 2026; Kassa & Ding, 2025; Temel, 2026). Therefore, the ability to solve mathematical problems becomes an important indicator of the quality of mathematics education as well as one of the core competencies in the development of higher-order thinking skills, numeracy, mathematical creativity, and students' readiness to face authentic problems in real life (Mardia & Indra Putri, 2025; Pramasdyahsari et al., 2025; Yayuk et al., 2026).

The urgency of developing mathematical problem-solving skills is becoming stronger because this competence is related to mathematical literacy, problem formulation, strategy selection, logical argumentation, and solution reflection. In contemporary mathematics education, the success of learning is not only seen from correct answers but also from the ability to understand context, choose representations, build mathematical reasoning, and interpret results in real-life situations (Nusantara & Putri, 2025; Temel, 2026). These abilities are also related to reflective thinking, decision-making, cognitive engagement, and meaningful learning through the exploration of strategies, modeling, and connections with real-life contexts or digital technology (Bekene et al., 2025; Cevikbas & Kaiser, 2026; Kuncoro et al., 2025; Yayuk et al., 2026). Therefore, mathematical problem-solving can be positioned as an important indicator of the quality of mathematics education.

Although mathematical problem-solving skills have become an important focus in contemporary mathematics education, these skills still pose a serious challenge, including in Indonesia. Students still often experience difficulties in solving non-routine problems that require deep reasoning, strategy flexibility, context interpretation, and connections to real-life situations (Budayasa & Rahaju, 2025; Putri et al., 2026). These difficulties are also evident in the low mathematical argumentation in PISA tasks, particularly in explaining reasons, connecting representations, and constructing logical justifications (Nusantara & Putri, 2025), as well as in conceptual, procedural, and interpretative barriers in algebra word problems (Ario et al., 2025). This condition indicates that mathematics learning still tends to emphasize procedures and final answers, while mathematical reasoning, reflection, metacognition, and higher-order thinking have not been fully facilitated (Hadi et al., 2025; Subba et al., 2025; Susilawati et al., 2025).

The issue of low mathematical problem-solving skills becomes increasingly important in the context of primary school teacher education because teachers play a strategic role in building the foundation of numeracy, representation, and mathematical thinking patterns among students from the beginning of formal education. Therefore, prospective teachers need not only to master mathematical concepts procedurally but also to possess problem-solving, reasoning, representation, and reflection skills to design meaningful and responsive learning to students' needs (Maulyda & Wuryandani, 2025; Pramasdyahsari et al., 2025). The ability to solve mathematical problems is also an important part of pedagogical readiness because it relates to the ability to identify misconceptions, choose appropriate representations, design learning strategies, and develop contextual mathematical activities. Strengthening problem-solving skills in prospective teachers is related to problem-solving disposition, mathematical motivation, cognitive engagement, and readiness to teach mathematics in an exploratory and reflective manner (Dangkulos et al., 2025; Masingila et al., 2025; Rodrigues et al., 2026; Yayuk et al., 2026).

However, the mathematical problem-solving abilities of prospective elementary school teachers still face various challenges. This ability is important because future teachers will be responsible for teaching basic mathematical concepts and fostering problem-solving skills in their students, but the problem-solving performance of prospective teachers is still not optimal (Dangkulos et al., 2025). Prospective teachers also still show weaknesses in mathematical representation and can be influenced by math anxiety (Maulyda & Wuryandani, 2025), as well as tend to rely on previous experiences, provide superficial solutions, and use symbolic or numerical representations in a limited way (Salido et al., 2025). This condition indicates that prospective teachers have not yet fully developed conceptual reasoning, heuristic strategies, diverse representations, and metacognitive reflection. Therefore, strengthening self-regulation, metacognitive awareness, and problem-based learning experiences is necessary for prospective teachers to be able to understand problem structures, design strategies, evaluate solutions, and develop relevant pedagogical knowledge for elementary school mathematics (Filiz & Gür, 2025; Landa et al., 2025b; Masingila et al., 2025; Rexigel et al., 2024; Sridana et al., 2025).

In Polya's perspective, mathematical problem-solving ability encompasses four main stages: understanding the problem, planning a strategy, executing the solution, and reviewing the solution (Kitchen et al., 2024). The four stages require procedural skills and involve metacognition, reflective reasoning, strategy selection, and solution evaluation. Contemporary research shows that metacognitive skills, scaffolding, self-regulation, and heuristic strategies play a crucial role in helping students and prospective teachers solve mathematical problems more systematically and meaningfully (Azizah & Lefrida, 2025; Landa et al., 2025b; Subba et al., 2025; Temel, 2026; Utami et al., 2025). Therefore, the development of mathematical problem-solving skills requires a learning approach that encourages students to actively think, discuss, explore strategies, and reflect on the problem-solving process.

Unfortunately, mathematics education in teacher training programs is still often dominated by conventional lecturer-centered approaches, causing students to tend to be passive and focus more on routine exercises. This pattern provides little room for students to explore strategies, build mathematical arguments, collaborate, and reflect on their thinking processes. However, the development of problem-solving skills in prospective teachers requires active, contextual, collaborative, and reflective learning so that students can construct knowledge and solve mathematical problems authentically and transferably (Fitriani et al., 2025; Kassa & Ding, 2025; Landa et al., 2025b; Masingila et al., 2025; Yayuk et al., 2026).

To overcome the limitations of conventional learning, an approach that can create active, collaborative, contextual, and reflective learning experiences is needed. One of the relevant approaches is case-based learning (CBL), which is a learning method that places authentic cases at the center of the learning activity. Through CBL, students are encouraged to analyze complex situations, identify the core problems, discuss alternative strategies, and make decisions based on logical arguments. Recent research shows that CBL can enhance student engagement, analytical skills, decision-making, and conceptual understanding because learners do not just receive information but actively build knowledge through discussion and reflection on cases (Hao et al., 2026; Li et al., 2025; Sayed et al., 2025; Shen et al., 2025). In the context of teacher education, the characteristics of CBL also align with the needs of mathematics learning, which require students to integrate concepts, contexts, problem-solving strategies, and pedagogical considerations (Masingila et al., 2025; Rodrigues et al., 2026; Yayuk et al., 2026).

Broader empirical evidence also supports the use of active and contextual learning. Freeman et al.'s (2014) meta-analysis shows that active learning is associated with better student performance in the fields of science, technology, engineering, and mathematics compared to traditional lectures. Various problem-based, design, technology, learning trajectory, and cultural context innovations also demonstrate the importance of tasks that encourage reasoning, representation, and student engagement (Amelia & Yulianti, 2025; Blancia, 2025; Chonchaiya & Srithammee, 2025; Jannah et al., 2026; Nguyện et al., 2025; Serepinaha et al., 2026; Widiantari et al., 2022). The evidence provides context for CBL, but it is not used as direct evidence regarding the causal effects of the intervention in this study.

Theoretically, CBL can be explained through constructivism, social constructivism, and experiential learning. From the perspective of constructivism, students connect new cases with prior knowledge to build understanding, rather than merely accepting procedures. From the perspective of social constructivism, discussion, negotiation of meaning, argumentation, and peer feedback serve as social scaffolding that helps students refine their representations and strategies. From the experiential perspective, case analysis is followed by reflection, concept abstraction, and reapplication to other situations. The principles of problem-based learning outlined by Hmelo-Silver (2004), particularly the activation of prior knowledge, self-directed learning, collaboration, and reflection, provide a relevant conceptual foundation for the application of CBL in mathematics education. This foundation explains why authentic cases can trigger the processes of understanding problems, planning strategies, implementing solutions, and reviewing solutions.

The case-based approach has developed primarily in medical education and medical biochemistry, which demands information analysis, reasoning, and decision-making (Li et al., 2025; Sayed et al., 2025). The broader literature on professional education also emphasizes the importance of the socio-cultural context and the acceptance of digital learning environments in shaping student experiences (Chooniedass et al., 2025; Zheng et al., 2025). In the mathematics education of prospective elementary school teachers, research more often discusses problem-solving, numeracy, representation, and didactic knowledge without placing CBL as the main intervention (Dangkulos et al., 2025; Maulyda & Wuryandani, 2025; Pramasdyahsari et al., 2025; Rodrigues et al., 2026; Yayuk et al., 2026). This gap indicates the need for an exploratory study on the changes in abilities after CBL in the context of primary school teacher education.

Student engagement is positioned as a characteristic of the learning process that may be related to achievement, rather than as a proven causal mechanism. In active learning, engagement can be seen through participation in discussions, diligence in case analysis, idea generation, collaboration, and reflection (Bekene et al., 2025; Ceballos et al., 2026; Landa et al., 2025a). Research by Boateng et al. (2026) shows that engagement can mediate the relationship between teaching innovation and mathematical problem-solving, while Davor et al. (2026) place engagement as a pathway connecting cognitive and affective characteristics with perceived problem-solving ability. Because the design and measurement of both studies differ from this research, the references are used to support the importance of testing the association, not to state that student activities cause an increase in scores.

Based on this gap, this study aims to: (1) compare the mathematical problem-solving ability scores of prospective elementary school teachers before and after the implementation of CBL in the same group; (2) describe the magnitude and distribution of changes through gain and N-gain scores; and (3) explore the relationship between student activities and post-test achievements. The novelty of the research lies in the integration of CBL, mathematical problem-solving, and activity observation within the context of primary school teacher education in Indonesia. According to the design without a comparison group, this study is not intended to prove causal effectiveness or the mediating role of student engagement.

METHODOLOGY

Design and Participants

The research uses a quantitative approach with a one-group pretest-posttest design. The pre-experimental classification is used because the study only involves one group that is measured before and after the implementation of CBL without a comparison group. This design is used to measure score changes in the same participants in an authentic class. The absence of a comparison group makes the design vulnerable to maturation, testing effects, other events during the intervention, and regression to the mean. Therefore, the results are limited to the changes observed after the implementation of CBL and are not used to conclude that CBL is the sole cause of those changes.

The data analyzed encompasses the entire reachable population, namely 161 students of the Elementary School Teacher Education Program at one of the universities in Indonesia (N = 161). All fifth-semester students taking the School Mathematics Learning course in 2025, distributed across four classes, were involved thru the total population sampling technique. Thus, no selection of a portion of the population was made based on certain considerations; all students who met the population characteristics participated in the research.

The number of 161 participants is not the result of a prospective sample size calculation, but rather the entire accessible population that was available and met the research criteria. As a post-hoc statistical sensitivity check, 161 observations in a two-tailed paired t-test with a significance level of 0.05 and a statistical power of 0.80 can detect a minimum standardized change of approximately $d_z = 0.22$, while in a two-tailed correlation analysis, this number can detect a minimum correlation coefficient of approximately $r = 0.22$. These results indicate that the number of population members analyzed has adequate sensitivity to support paired difference and correlation analyzes; however, this sensitivity assessment is not the basis for determining the number of participants since the study initially involved the entire accessible population. The generalization of the research results still needs to be done with caution because the research population is limited to students from one study program and one university.

Implementation of Case-Based Learning

The implementation of Case-Based Learning (CBL) is carried out over 12 sessions, with an allocation of 100 minutes for each session, and follows five main stages: case orientation, problem identification, exploration of solution strategies, presentation and discussion of solutions, and learning reflection. The learning is conducted by the lecturer in charge of the school mathematics learning course. In each session, students work in small groups of 5–7 people to identify relevant information, construct mathematical representations, compare various alternative strategies, solve problems, explain mathematical reasoning, and formulate appropriate pedagogical responses. During the learning process, the lecturer acts as a facilitator by providing triggering questions, concept clarification, argument reinforcement, and feedback on both the process and the students' solutions.

The cases used are contextual cases related to elementary school mathematics learning, including students' misconceptions in fraction operations, difficulties in understanding word problems, errors in geometric reasoning, and teachers' strategies in guiding students to solve non-routine problems. Each case directs students to identify the sources of students' difficulties, determine appropriate concepts and representations, evaluate alternative strategies, formulate mathematical solutions, and design explanations that are easy for elementary school students to understand. The consistency of CBL implementation in the four classes is maintained through the use of the Semester Learning Plan, learning stages, case materials, facilitation guides, task instructions, and the same time allocation so that all participants receive a learning experience with relatively uniform implementation procedures.

Research Instruments

The research instruments consist of a mathematical problem-solving ability test and an observation sheet for student activities. The mathematical problem-solving ability test consists of 10 essay questions to be completed in 50 minutes, with a score range of 0–100. Each answer is scored using an analytic rubric that refers to the four stages of problem-solving, namely understanding the problem, planning a solution strategy, executing the solution, and reviewing the results. The scores obtained on each indicator are summed and converted into a scale of 0–100. The student activity observation sheet consists of four main indicators: participation in discussions and idea presentation, involvement in case analysis, collaboration in groups, and engagement in presentations and learning reflections. Each indicator is assessed using a 1–4 scale by two observers during the 100-minute learning process. Before the observation, both observers received explanations and alignment on the operational definitions of each indicator, scoring criteria, and the use of the observation guidelines to ensure consistent assessment.

Before being used, both instruments were validated by two experts, namely a mathematics education expert and a mathematics expert. Content validation is carried out through the assessment of the alignment of items with the measured indicators, the accuracy of mathematical concepts, the clarity of question construction, language use, the appropriateness of the scoring rubric, and the measurability of observation indicators. Suggestions from both validators are used to improve the wording of questions, the accuracy of the context, the scoring rubric, and the clarity of the observation guidelines before the instruments are applied in the research. The test results show that the mathematical problem-solving ability test has a reliability coefficient of 0.80, indicating a good level of internal consistency. Meanwhile, the reliability coefficient of the observation sheet is 0.85, and the agreement level between the two observers is 0.825. Summary of the constructs, formats, scoring, validity, reliability, and procedures of both instruments are presented in **Table 1**.

Table 1. Summary of constructs and characteristics of the research instrument

Instrument	Construction/indicator	Format and scoring	Validity, reliability, and procedures
Test mathematical problem-solving skills	Understanding the problem; planning the strategy; implementing the solution; reviewing the results.	10 essay questions; 50 minutes to complete; analytic rubric; final score converted to a scale of 0–100	Validated by two experts, namely a mathematics learning expert and a mathematician. The validation includes content suitability, concept accuracy, construction, language, and rubric. The test reliability coefficient is 0.80.
Student activity observation sheet	Participation in discussions and idea presentation; case analysis; group collaboration; presentation and reflection	Structured observation sheet with four indicators; scale 1–4; observed by two observers for 100 minutes.	The observer receives briefing and alignment of perceptions before the observation. The assessment uses the same guidelines and criteria. The observation reliability coefficient is 0.85 and the inter-rater agreement coefficient is 0.825.

Data Collection Procedure

Data collection was conducted in three stages. In the first stage, all participants completed a pre-test consisting of 10 essay questions within 50 minutes to measure their initial mathematical problem-solving abilities. In the second stage, participants engaged in learning using the Case-Based Learning approach over 12 sessions, while their activities were observed using a structured observation sheet by two observers. In the third stage, after the entire learning sequence was completed, participants took a post-test using the same set of questions as the pre-test and the same time allocation, which was 50 minutes, so that score changes could be compared based on the difficulty level and equivalent measurement conditions. Pre-test and post-test scores are used to analyze changes in mathematical problem-solving abilities, while activity scores are used to analyze their relationship with students' final achievements. All participants also received an explanation regarding the purpose, procedures, benefits, data confidentiality, and the right to not participate or withdraw without academic consequences and then expressed their willingness through written consent. The identities of the participants are encoded, and all data are used solely for research purposes.

Data Analysis

Descriptive analysis includes the number of participants, mean, standard deviation, median, minimum score, and maximum score. The gain score is calculated as the post-test score minus the pre-test score. N-Gain is used to describe the relative change toward the maximum score improvement space, and its distribution is presented in low, medium, and high categories.

The normality of the difference scores was examined using the Shapiro-Wilk test. The paired t-test was retained as the primary analysis to estimate the mean difference in the large sample ($n = 161$), while the Wilcoxon signed-rank test was used as a sensitivity analysis because the difference scores were not normally distributed. The conclusion is considered more robust if both approaches yield consistent directions. Cohen's d_z is calculated from the mean difference divided by the standard deviation of the difference.

The relationship between student activities and post-test scores was analyzed using Pearson correlation and reexamined with Spearman correlation. Probability values smaller than 0.001 are reported as $p < 0.001$. Correlation is interpreted as an association and is not used as evidence that involvement causes changes in mathematical ability.

RESULTS

Descriptive statistics show that the average post-test scores are higher than the average pre-test scores. These findings illustrate changes within the group after the implementation of CBL, but they have not yet shown that these changes were solely caused by CBL because the study did not use a comparison group. Complete descriptive statistics for student activities, pre-test, post-test, and gain scores are presented in **Table 2**.

Table 2. Descriptive statistics of activity, pre-test, post-test, and gain

Variable	N	Mean	SD	Median	Min	Max
Student Activity	161	81.66	2.66	80.0	75	90
Pre-Test Score	161	78.76	3.79	78.0	50	85
Post-Test Score	161	86.11	5.22	90.0	70	95
Gain Score	161	7.35	5.59	10.0	-5	30

The paired t-test showed a significant mean difference between pre-test and post-test, $t(160) = 16.691$, $p < 0.001$, with Cohen $d_z = 1.315$. Because the Shapiro-Wilk test showed that the difference scores were not normally distributed, $W = 0.918$, $p < 0.001$, the results were examined using the Wilcoxon signed-rank test. The Wilcoxon test also showed a significant difference, $W = 143.5$, $p < 0.001$. Summary of the paired difference test results, effect size, and normality check are presented in **Table 3**.

Table 3. Comparison of pre-test and post-test scores

Analysis	Statistics	p	Interpretation
Paired t-test	t(160) = 16.691	< 0.001	Significant difference
Wilcoxon signed-rank test	W = 143.5	< 0.001	Significant difference
Cohen d_z	1.315	-	Large effect size
Shapiro-Wilk normality test	W = 0.918	< 0.001	Difference scores are not normally distributed.

Note. The significance level is set at alpha = 0.05

The consistency of the results from parametric and non-parametric tests strengthens the conclusion that there is a change in scores within the group. However, statistical significance and the large size of the change do not eliminate the limitations of the one-group design and do not prove that CBL is the sole cause of the change.

The average N-Gain of 0.341 falls into the moderate category. A total of 61 students (37.89%) are in the low category, 94 students (58.39%) in the moderate category, and 6 students (3.73%) in the high category. This distribution shows that the changes are not uniform among all participants. The summary statistics of N-Gain are presented in **Table 4**, while the distribution of N-Gain categories is visualized in **Figure 1**.

Table 4. N-gain summary

Statistics	Value
N	161
Average N-Gain	0.341
SD	0.24
Median	0.50
Minimum	-0.333
Maximum	0.773

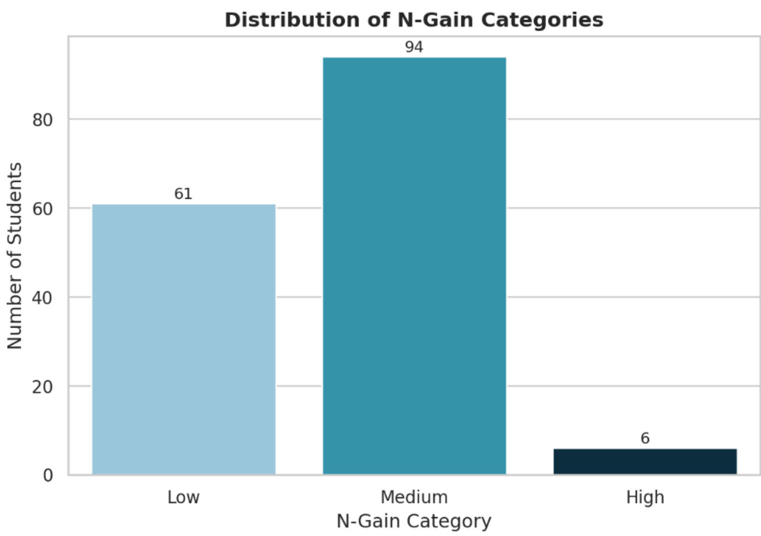

Figure 1. Distribution of gain categories (Source: Authors' own elaboration)

The minimum gain value of -5 and minimum N-gain of -0.333 indicate that there are students who obtained post-test scores lower than their pre-test scores. This study did not collect diagnostic data to determine the causes of individual declines. Possibly, the pattern may be related to post-test fatigue, measurement fluctuations, inconsistent participation, differences in strategy fit with the case, or limited room for improvement due to the relatively high pre-test average. That explanation is a possibility that needs to be tested, not a direct conclusion from the data.

Pearson correlation shows a positive relationship between student activity and post-test scores, r = 0.504, $p < 0.001$. Examination with Spearman correlation yields a similar direction, rho = 0.483, $p < 0.001$. Thus, students with higher activity scores tend to achieve higher post-test scores. These findings indicate an association and do not prove that activity causes an increase in problem-solving ability. A summary of the correlation coefficients is presented in **Table 5**, and the pattern of the relationship between student activities and post-test scores is visualized in **Figure 2**.

Table 5. The relationship between student activities and post-test scores

Variable X	Variable Y	Pearson r	p	Spearman rho	p	N
Student activities	Post-Test Score	0.504	< 0.001	0.483	< 0.001	161

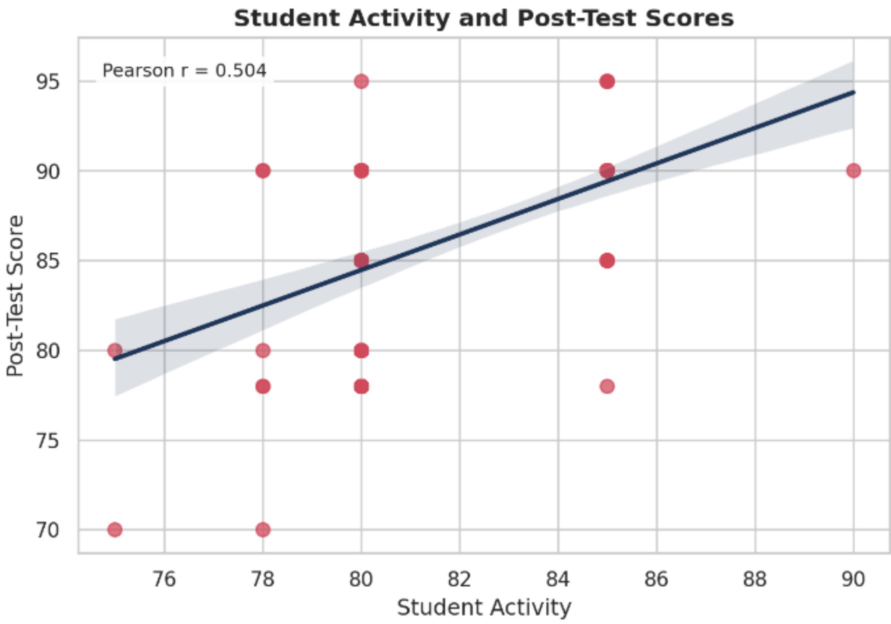

Figure 2. The relationship between student activity and post-test scores (Source: Authors' own elaboration)

DISCUSSION

The main finding is the increase in the average score from 78.76 to 86.11 after the CBL series, with consistent results in the paired t-test and Wilcoxon test. The standardized measure of change is classified as large, but the average N-Gain falls into the moderate category. This combination can occur when the initial scores are already high: an absolute difference of a few points results in a large effect size if the variation in the score difference is relatively small, while N-Gain accounts for the remaining room for improvement toward the maximum score. The results are therefore more accurately understood as meaningful changes within the group, rather than single causal evidence regarding the effectiveness of CBL.

The pattern of change can be interpreted through the characteristics of CBL, which require students to analyse cases, activate prior knowledge, explain reasoning, compare strategies, and reflect on solutions. This process aligns with the principles of constructivism and problem-based learning Hmelo-Silver (2004) and general evidence of active learning in STEM Freeman et al. (2014), as well as research emphasising problem-solving tasks, heuristic strategies, collaboration, scaffolding, and reflection (Ceballos et al., 2026; Kassa & Ding, 2025; Subba et al., 2025; Temel, 2026; Utami et al., 2025). However, this research does not directly measure changes in the quality of argumentation, strategy, or reflection. The mechanism is treated as a possible theoretical explanation, not an empirically tested result.

The N-Gain distribution shows response heterogeneity: the majority are in the moderate category, more than a third in the low category, and a small portion in the high category. Negative gain emphasizes that the average group change does not reflect the experience of each individual. Initial ability, learning strategies, metacognition, representation, math anxiety, and self-confidence can theoretically relate to that variation (Azizah & Lefrida, 2025; Filiz & Gür, 2025; Kumar et al., 2025; Maulyda & Wuryandani, 2025; Rexigel et al., 2024; Salido et al., 2025; Sridana et al., 2025; Wang et al., 2025). Because those variables were not measured, they are all merely possibilities to be tested in further research, not definitive explanations for the participants' results.

The positive relationship between activity and post-test scores indicates that more engaged participants tend to achieve higher final scores. This direction is in line with research that places engagement as an important component in the relationship between learning conditions and mathematical problem-solving (Boateng et al., 2026; Davor et al., 2026) and with studies on engagement, collaboration, and active learning (Bekene et al., 2025; Fitriani et al., 2025; Sjølie et al., 2026; Yayuk et al., 2026). However, the analysis of this research is bivariate and has not yet controlled for initial ability. Students who are stronger from the beginning can also be more active and achieve higher post-test scores. Therefore, the correlation of activity-gain or post-test analysis with pre-test control is necessary before claims regarding the unique contribution of engagement can be made.

Pedagogically, elementary school mathematics learning cases provide opportunities for prospective teachers to connect mathematical problem-solving with didactic considerations. Students not only seek answers but also need to anticipate students' misconceptions, choose representations, and design appropriate aids. These implications are consistent with the importance of didactic knowledge, creativity, visualization, and contextual learning in teacher education (Mardia & Indra Putri, 2025; Masingila et al., 2025; Pramasdyahsari et al., 2025; Rodrigues et al., 2026). However, this research does not measure the transfer to teaching practice; the implications should be tested through pedagogical tasks or field practice.

The low proportion of N-Gain and the presence of negative gain indicate the need for more structured support, such as case analysis guides, reflective questions, representation examples, and strategy rubrics. Strategies for finding relationships, using variables, drawing diagrams, and simplifying problems can be used as explicit scaffolding (Temel, 2026). Reflection should also be directed toward the quality of reasoning and strategy selection, not just the correctness of the answer (Budayasa & Rahaju, 2025). This recommendation is a practical implication of the pattern of results, not evidence that specific components have been tested separately.

Limitations and Directions for Future Research

The most important limitation is the absence of a control group, making it impossible to convincingly separate the changes from maturation, history, regression to the mean, or other factors outside the intervention. Additionally, the use of the same problem-solving test items in both pre-test and post-test has the potential to create testing or practice effects. Participants may become more familiar with the question format, task demands, or problem-solving strategies after taking the pre-test; therefore, some of the score changes may be related to the test-taking experience, rather than solely to the CBL sequence. Although the two measurements are separated by 12 sessions, the potential effects cannot be dismissed. Participants come from a single study program at one institution, so generalization needs to be done with caution. Observation-based activity measurements may inadequately capture cognitive and emotional engagement, and the bivariate relationship analysis did not control for capturing cognitive and emotional engagement, while the relationship analysis is bivariate and has not controlled for pretest scores. Further research needs to use a comparison group, involve multiple institutions, use equivalent test forms to minimize practice effects, document implementation fidelity quantitatively, and analyze engagement with a model that controls for initial ability.

CONCLUSION

The average mathematical problem-solving ability of 161 prospective elementary school teachers was higher in the post-test than in the pre-test after the implementation of case-based learning. The difference was significant in the paired t-test and Wilcoxon test, with a large standardized change, while the average N-gain was in the moderate category. Student activity is also positively correlated with post-test scores.

These findings support CBL as an approach worthy of further investigation in teacher education but do not prove a causal relationship. The absence of a substantial comparison group limits the attribution of changes solely to CBL, and the post-test activity correlation does not indicate that engagement causes improvement. Stronger conclusions require a design with a comparison group, testing in a multi-institutional context, the use of equivalent test forms to reduce practice effects, and analysis that controls for initial ability.

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AI statement: The authors stated that generative AI tools are only used to assist in minor sentence restructuring and language editing of certain sentences. AI tools are not used to generate research data, modify data, or conduct primary statistical analyzes. All AI outputs are reviewed, verified, and edited by the authors, who are fully responsible for the accuracy and integrity of the final content.

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