
MEASURING LEARNING IMPROVEMENT THROUGH NORMALIZED GAIN IN NUMERACY AND SELF-EFFICACY: EVIDENCE FROM PROBLEM-BASED LEARNING AMONG FIFTH- GRADE STUDENTS

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Article Received: 26 August 2026, Article Revised: 16 September 2026, Published on: 06 October 2026

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Doi: <https://doi-doi.org/101555/ijrpa.6306>

ABSTRACT

Numeracy skills and self-efficacy are important for elementary students' success in mathematics, yet improvement may vary according to the learning approach. This study examined normalized gain in numeracy skills and self-efficacy among elementary students following a Problem-Based Learning intervention, emphasizing improvement magnitude rather than posttest differences. A quantitative quasi-experimental study used a nonequivalent pretest-posttest control group design involving 36 fifth-grade students, with 18 in the Problem-Based Learning group and 18 in the conventional-learning group. Data were collected through a numeracy skills test on angle measurement and a self-efficacy questionnaire. Normalized gain was calculated from pretest and posttest scores and compared using an independent-samples t-test. The Problem-Based Learning group increased in numeracy from 41.16 to 77.16, yielding a normalized gain of 0.6264, categorized as moderate, compared with 0.1436, categorized as low, in the conventional-learning group. Self-efficacy increased from 59.00 to 78.61, with a normalized gain of 0.4762, while the conventional-learning group showed -0.0053 . Differences in normalized gain were significant for numeracy skills ($t = 10.838$, $p < 0.001$) and self-efficacy ($t = 13.933$, $p < 0.001$). These findings indicate greater normalized improvement under Problem-Based Learning and contribute evidence on improvement magnitude. Further research should examine longer interventions and broader school contexts.

INTRODUCTION

Elementary education plays a foundational role in developing students' capacity to reason, interpret information, and apply knowledge to problems encountered in everyday life. Within this context, numeracy is not limited to computational proficiency; it encompasses the ability to understand, interpret, and use quantitative information appropriately across different situations (Napsiyah et al., 2022). The importance of numeracy has become increasingly visible in international assessments. The 2022 Programme for International Student Assessment (PISA) reported that Indonesian students obtained an average mathematics score of 366, ranking 67th among 81 participating countries, substantially below the OECD average of 472 (OECD, 2023). Although PISA assesses a broader population than elementary school students, these results provide an important indication of the continuing challenge of developing mathematical reasoning and the application of mathematics in real-life contexts. Recent literature similarly emphasizes that elementary mathematics instruction needs to move beyond procedural learning toward approaches that enable students to interpret quantitative information and apply mathematical concepts meaningfully. A recent systematic review of Problem-Based Learning (PBL) in elementary mathematics found that PBL has been associated with improvements in cognitive ability, problem solving, communication, and other learning outcomes (Elfiyani, 2024).

The challenge is not solely associated with students' mathematical knowledge but also with how mathematics is experienced during instruction. In the Indonesian elementary-school context, students may experience difficulty when mathematical concepts are presented primarily as formulas or procedures rather than as tools for interpreting authentic situations. Khairullah and Heriyana (2023) reported that students can be inclined to give up when facing mathematical tasks and may rely on memorizing formulas without sufficiently understanding the underlying concepts. Similarly, Lestari et al. (2024) reported that some elementary students perceive mathematics as disconnected from everyday life, while Indah (2024) highlighted difficulties encountered by fifth-grade students when solving mathematics problems related to measurement. These conditions can restrict students' opportunities to develop transferable numeracy skills. At the same time, mathematics learning involves an affective dimension. Students' confidence in their ability to perform mathematical tasks can influence their willingness to engage with challenging problems, persist when difficulties arise, and independently seek solutions. Recent research continues to examine PBL not only in relation to mathematical performance but also in relation to students' mathematical self-efficacy, indicating that cognitive and affective outcomes can develop alongside one another.

The central problem, therefore, concerns the difficulty of producing meaningful improvement in both numeracy skills and students' confidence in performing mathematical tasks through conventional learning experiences. Preliminary observations at SD Negeri 14 Tibawa identified a similar condition in Grade V. Only 42.86% of students had reached the minimum competency level in learning involving numeracy, whereas 57.14% had not achieved the expected standard. Students also experienced difficulties in identifying, measuring, and applying angle concepts in everyday situations. The instructional process was characterized by limited variation in learning media and a relatively teacher-centered approach, which could reduce opportunities for students to explore mathematical ideas through authentic problems. Such conditions suggest that evaluating learning only through final achievement scores may provide an incomplete picture of instructional improvement. A comparison of pretest and posttest performance, particularly through normalized gain, can instead provide information about the magnitude of improvement relative to the maximum possible improvement. This perspective is important because two groups with different posttest scores may have experienced substantially different levels of progress from their respective starting points.

Problem-Based Learning offers a general pedagogical solution to these challenges because it places authentic problems at the center of the learning process. Rather than receiving mathematical procedures primarily through direct explanation, students are encouraged to identify problems, gather relevant information, discuss possible strategies, analyze quantitative information, formulate solutions, and reflect on the results. Rofiki et al. (2024) emphasize the importance of active and contextual learning that is aligned with elementary students' characteristics, while Han et al. (2017) conceptualize numeracy as the capacity to apply mathematical principles and concepts in real situations rather than merely demonstrating classroom knowledge. Wirawan et al. (2024) further describe numeracy as the ability to use mathematical concepts, numbers, and symbols to solve practical problems, analyze information, and make decisions based on mathematical reasoning. Consequently, PBL provides a pedagogical environment in which mathematical knowledge can be connected directly to contextual problem solving.

Previous empirical studies provide support for this approach. Wirawan et al. (2024) reported that activities within PBL, including information gathering, planning, problem solving, and evaluation, can support the development of students' numeracy through active and collaborative learning. Febila et al. (2023) similarly found positive effects of PBL on elementary students' numeracy, particularly when mathematical concepts were connected

with situations familiar to students. Jannah et al. (2024) reported positive and significant improvement in elementary students' numeracy through PBL integrated with experiential learning, emphasizing the role of authentic problem-solving experiences. Riupassa and Nggaba (2025) likewise reported positive effects of PBL on students' numeracy, particularly in contexts requiring the processing and interpretation of quantitative information. These findings are consistent with a recent systematic review indicating that PBL has generally demonstrated positive contributions to mathematical literacy among elementary students, although the magnitude and sustainability of improvement can vary according to instructional context and implementation conditions.

The potential contribution of PBL also extends to self-efficacy. Self-efficacy refers to students' beliefs regarding their capability to organize and perform actions required to accomplish particular tasks. In mathematics learning, stronger self-efficacy can support persistence, willingness to attempt difficult problems, and active participation. Zakariya (2022) identifies mathematics self-efficacy as an important factor associated with students' mathematical achievement and emphasizes that carefully designed learning experiences can support its development. Bandura (1977, 1997) explains that self-efficacy develops through several sources, particularly mastery experiences, vicarious experiences, social persuasion, and physiological or affective states. PBL can provide these sources through opportunities for students to experience successful problem solving, observe peers' strategies, receive feedback from teachers and classmates, and engage in collaborative learning. Wulandari et al. (2023) specifically discuss mathematical self-efficacy in PBL from a multidimensional Bandurian perspective. Evidence from recent empirical research also indicates that PBL can be associated with higher mathematical self-efficacy alongside mathematical performance.

Nevertheless, the existing literature leaves an analytical gap relevant to the present study. Much of the previous research has emphasized whether PBL produces statistically significant differences in achievement, problem-solving ability, or self-efficacy, whereas comparatively less attention is given to describing the **magnitude of improvement from students' initial conditions using normalized gain across both cognitive and affective outcomes**. For example, recent elementary-school studies have applied N-Gain to numeracy outcomes, but often concentrate on numeracy alone or combine PBL with additional interventions such as augmented-reality media or STEM. Other studies have examined PBL and self-efficacy, but frequently use posttest comparisons or broader mathematical problem-solving outcomes rather than jointly examining normalized improvement in numeracy and self-efficacy. This distinction is important because normalized gain provides a way of expressing improvement

relative to the maximum possible increase, thereby complementing conventional significance testing. The normalized-gain approach originates from the pretest–posttest framework described by Hake (1998), in which gain is expressed relative to the maximum possible improvement from the initial level. Thus, examining normalized gain can provide an additional perspective on the extent to which learning experiences translate into measurable improvement rather than focusing exclusively on differences in final scores.

Accordingly, the present study focuses specifically on the **normalized gain in numeracy skills and self-efficacy among fifth-grade elementary students participating in a Problem-Based Learning intervention**. Unlike an analysis centered primarily on whether PBL has a statistically significant effect, the present study emphasizes the magnitude and category of improvement from pretest to posttest and compares normalized gains between the PBL and conventional-learning groups. The study is situated in Grade V at SD Negeri 14 Tibawa and focuses on numeracy within the context of angle measurement, including students' ability to recognize, classify, measure, represent, and apply angle concepts in contextual situations. The instructional design draws on PBL principles in which students work with authentic problems, collaborate in groups, investigate information, construct solutions, and reflect on their learning. The analysis is restricted to the numeracy and self-efficacy data already collected through the quasi-experimental pretest–posttest control-group design. The novelty of this article therefore lies not in re-establishing whether PBL affects the two outcomes, but in characterizing and comparing **how much numeracy and self-efficacy improve relative to their initial levels through normalized gain analysis**. This analytical orientation provides a complementary account of PBL implementation and offers empirical evidence concerning the magnitude of cognitive and affective improvement in an elementary-school mathematics context.

METHODOLOGY

This study employed a quasi-experimental nonequivalent pretest–posttest control group design, involving 36 fifth-grade students at SD Negeri 14 Tibawa, Gorontalo Regency. The participants were selected through saturated sampling and divided into an experimental group (18 students) receiving Problem-Based Learning (PBL) and a control group (18 students) receiving conventional instruction. The intervention focused on contextual numeracy problems, particularly angle measurement, including examples drawn from the local Gorontalo context. Data were collected through a numeracy skills test, a self-efficacy questionnaire, and classroom observation. The numeracy instrument consisted of 10 multiple-

choice and 5 essay items scored on a 0–100 scale, while self-efficacy was measured using 20 five-point Likert items based on Bandura’s dimensions of magnitude, strength, and generality.

The analysis specifically emphasized normalized gain (N-Gain) to quantify the magnitude of improvement in numeracy skills and self-efficacy following the intervention. This approach provides an estimate of students’ improvement relative to their initial performance and allows the extent of improvement to be examined across the two instructional groups. N-Gain was calculated using the following formula: $g = (\text{Posttest} - \text{Pretest}) / (\text{Maximum Score} - \text{Pretest})$, following Hake (1998), and interpreted as low ($g < 0.30$), moderate ($0.30 \leq g < 0.70$), or high ($g \geq 0.70$). The normality of the data was assessed using the Shapiro–Wilk test, while homogeneity was examined using Levene’s test, with $\alpha = 0.05$. Differences in N-Gain between the PBL and control groups were subsequently examined using an independent-samples *t*-test. Thus, the analytical sequence was centered on pretest → intervention → posttest → N-Gain → comparison of normalized improvement.

RESULTS AND DISCUSSION

3.1 Baseline Equivalence and Descriptive Changes

The results indicate that the two groups started from comparable levels of numeracy and self-efficacy before the intervention. For numeracy, the experimental group obtained a mean pretest score of 41.16 (SD = 15.64), while the control group obtained 40.62 (SD = 17.08). The independent-samples *t*-test confirmed that the initial difference was not statistically significant, $t(34) = 0.098$, $p = 0.923$. A similar pattern was observed for self-efficacy, with mean pretest scores of 59.00 (SD = 2.77) in the experimental group and 60.61 (SD = 3.57) in the control group; the difference was also nonsignificant, $t(34) = 1.373$, $p = 0.179$. These findings provide an appropriate baseline for interpreting subsequent changes because the two groups did not differ significantly before the intervention.

Following the intervention, the experimental group demonstrated substantially greater increases in both outcomes. Numeracy increased from 41.16 to 77.16, representing an absolute gain of 36.00 points, whereas the control group increased from 40.62 to 49.07, a gain of only 8.45 points. The distribution of posttest scores further illustrates this difference: 15 of 18 students (83.3%) in the PBL group achieved the “Good” or “Very Good” categories, including 8 students (44.4%) who achieved scores of 80 or above. In contrast, none of the control-group students reached the “Good” or “Very Good” categories, and 9 students

(50.0%) remained below a score of 50. These descriptive differences are important for the present study because they establish the magnitude of change that is subsequently expressed through normalized gain rather than merely identifying whether the final scores differed.

3.2 Normalized Gain in Numeracy Skills

The principal finding of the present analysis is the difference in normalized improvement between the two groups. Based on the formula proposed by Hake (1998), the experimental group obtained an N-Gain of 0.6264, categorized as moderate, whereas the control group obtained an N-Gain of 0.1436, categorized as low. Thus, the difference in normalized gain was 0.4828. An independent-samples t -test of the N-Gain scores yielded $t(34) = 10.838$, $p < 0.001$, indicating a statistically significant difference in the magnitude of improvement between the two instructional conditions.

The importance of these findings lies not simply in the higher posttest score of the PBL group, but in the substantially greater proportion of the possible improvement that was achieved. The experimental group entered the intervention with a mean numeracy score of 41.16 and reached 77.16, thereby achieving a moderate normalized gain. The control group, despite beginning at a comparable level, reached only 49.07 and remained within the low-gain category. This pattern suggests that the PBL intervention was associated with greater improvement relative to the students' initial levels. In the context of the present article, N-Gain therefore provides a more specific description of *how much improvement occurred* rather than focusing exclusively on the statistical difference between posttest scores.

The finding is consistent with the conceptualization of numeracy as the ability to apply mathematical concepts to practical situations rather than merely reproduce mathematical procedures (Han et al., 2017). Wirawan et al. (2024) similarly describe numeracy as involving the use of mathematical concepts, numbers, and symbols to solve practical problems, analyze information, and make decisions through mathematical reasoning. PBL provides an instructional structure that can connect these processes with authentic situations through problem identification, information gathering, collaborative analysis, solution development, and evaluation. Previous studies cited in the thesis also reported positive relationships between PBL and elementary students' numeracy development, including Febila et al. (2023), Jannah et al. (2024), and Riupassa and Nggaba (2025).

The present findings can also be interpreted through Vygotsky's (1978) constructivist perspective, particularly the concept of the Zone of Proximal Development. The contextual

problems used in the intervention, including angle-measurement problems associated with traditional Gorontalo house construction, provided students with challenges that could be addressed through guided investigation and interaction with peers. Within this process, the stages of PBL functioned as forms of scaffolding that supported students in moving from their existing understanding toward more complex problem-solving performance. This interpretation is also consistent with Pikoli and Ismail (2024), who reported that case-based and problem-solving approaches can support deeper mathematical understanding compared with direct instructional approaches. Jonassen (2011) further emphasizes that authentic problem solving engages higher-order cognitive processes, including analysis, evaluation, and creation, while Anderson and Krathwohl (2001) position these processes at the higher levels of the revised taxonomy of educational objectives.

The contextual dimension of the intervention is also relevant. The use of a familiar local context, particularly the construction of traditional Gorontalo houses, provided students with an opportunity to interpret angle measurement as a practical mathematical activity. The thesis observations indicated that students became more actively involved when mathematical problems were connected to situations that were familiar to them. Such contextualization is consistent with the principle of culturally responsive teaching described by Gay (2018), in which students' cultural and experiential backgrounds can be incorporated into learning to support meaningful engagement.

3.3 Normalized Gain in Self-Efficacy

A similarly distinct pattern emerged for self-efficacy. The experimental group increased from a mean pretest score of 59.00 to a posttest score of 78.61, representing an absolute increase of 19.61 points. In contrast, the control group changed only from 60.61 to 60.72, an increase of 0.11 points. The corresponding N-Gain was 0.4762 for the experimental group, classified as moderate, and -0.0053 for the control group, classified as low. The independent-samples t -test of N-Gain scores produced $t(34) = 13.933$, $p < 0.001$, demonstrating a statistically significant difference in normalized improvement between the groups.

The negative N-Gain in the control group is particularly informative. It indicates that the mean self-efficacy score did not merely remain unchanged; relative to the normalization formula, the posttest mean was slightly lower than the pretest mean. This result should nevertheless be interpreted cautiously because the absolute difference was very small (0.11 points). More importantly, the contrast with the experimental group indicates that the PBL

intervention was accompanied by a substantially greater increase in students' perceived capability to engage with numeracy tasks.

The pattern is consistent with Bandura's (1977, 1997) theoretical framework, which identifies mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states as important sources of self-efficacy. PBL creates opportunities for these sources to operate simultaneously. Students can experience mastery when they successfully identify, measure, and solve angle problems; observe peers developing solutions; receive feedback and encouragement from teachers and group members; and gradually become more comfortable with challenging mathematical tasks. Bandura (1986) further explains these processes through reciprocal interactions among personal factors, behavior, and environmental conditions.

The indicator-level findings provide additional insight into this overall N-Gain. The largest improvement was observed in students' confidence in communicating their work, with an increase of 0.667, followed by confidence in identifying problem-solving strategies (0.590) and confidence in completing numeracy tasks (0.519). In contrast, the smallest increase occurred in students' ability to control fear and anxiety (0.361), followed by willingness to try new approaches (0.417). This pattern suggests that PBL may produce relatively rapid changes in behavioral and cognitive aspects of self-efficacy—such as communicating solutions and selecting strategies—while affective aspects may require a longer period of sustained intervention.

This interpretation is supported by Pajares (2006), who identifies successful experiences in mathematical contexts as an important source of mathematics self-efficacy. It is also consistent with Wulandari, Kartono, and Waluya (2023), who reported that the strength dimension of self-efficacy can increase through PBL, particularly because students are required to persist during investigations in which solutions are not immediately available. Similarly, Mahmud, Pulukadang, and Halidu (2025) reported that consistent implementation of PBL in elementary education can support not only academic competence but also students' independence and confidence, as reflected in active participation and willingness to express ideas during group discussions.

The findings also correspond with Zakariya (2022), who emphasized the importance of mathematics self-efficacy in students' academic achievement and highlighted the role of progressive successful experiences in encouraging students to engage with challenging mathematical tasks. Arifin, Arif, and Tueno (2024) likewise reported that active student

involvement in problem solving can contribute to increased confidence in subsequent learning activities.

3.4 Integrated Interpretation of Numeracy and Self-Efficacy Gains

Taken together, the N-Gain results reveal a consistent pattern across the two dependent variables. The PBL group achieved a moderate normalized gain in both numeracy (0.6264) and self-efficacy (0.4762), whereas the control group achieved low gains in numeracy (0.1436) and self-efficacy (−0.0053). The simultaneous direction of these changes is noteworthy because the intervention was not associated with improvement in only the cognitive dimension. Rather, the data show concurrent improvement in students' numeracy performance and their perceived capability to undertake numeracy-related tasks.

This pattern can be interpreted through Bandura's (1986) concept of reciprocal determinism. Improvements in competence may provide students with successful experiences that strengthen self-efficacy, while stronger self-efficacy may encourage greater persistence when students encounter difficult problems. In a PBL environment, these processes can operate repeatedly through investigation, discussion, solution development, presentation, and reflection. The resulting interaction provides a plausible explanation for why improvements were observed in both outcomes. The thesis also relates this integrated development to learner-centered instructional environments, in which students are given opportunities to experiment, communicate, make mistakes, and learn from the problem-solving process (Isnanto, 2022).

3.5 Analytical Contribution of the Present Study

The principal contribution of this analysis is its emphasis on **normalized improvement rather than solely on posttest differences**. Although the same dataset demonstrates statistically significant differences between the experimental and control groups, the N-Gain analysis provides an additional perspective by quantifying the extent of improvement relative to the students' starting points. This distinction is important because two groups with different posttest scores may have achieved different proportions of their potential improvement. In the present data, the moderate N-Gain values for both numeracy and self-efficacy in the PBL group contrast with the low gains observed in the control group.

Accordingly, the findings should be interpreted as evidence of a substantial difference in the magnitude of normalized improvement between the two instructional conditions. The N-Gain analysis provides an additional perspective on learning improvement by considering students'

progress from their initial performance to their posttest achievement. This approach highlights not only the final level attained by students but also the proportion of the possible improvement achieved during the intervention. Overall, the results indicate that PBL was associated with moderate normalized improvement in both numeracy skills and self-efficacy, while conventional instruction produced only low normalized improvement. The findings are theoretically consistent with constructivist learning, mastery-based development of self-efficacy, and contextual problem solving. However, the results should be interpreted within the study's boundaries: the sample comprised only 36 students from one elementary school, the intervention lasted two meetings, and the quasi-experimental design did not involve full random assignment. These factors limit the extent to which the magnitude of normalized gains can be generalized beyond the study context and indicate the need for longer-duration studies involving larger and more diverse samples.

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