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The Role of Problem Based Learning in Improving Self-Efficacy, Self-Regulation, and Algebraic Problem-Solving Ability: Evidence from Secondary School Students in Makassar

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***Abstract*:**
This inquiry investigated how Problem-Based Learning (PBL) impacts students' algebraic problem-solving skills, self-regulation, and self-efficacy. Utilizing a quantitative quasi-experimental approach with a pretest-posttest control group design, the study involved 53 eighth-graders Bajiminasa Junior High School in Makassar City, Indonesia. The subjects were divided into an experimental cohort taught via PBL and a control cohort under conventional methods. Data gathering relied on three highly reliable instruments: the Self-Efficacy Questionnaire (SEQ, α = 0.85), Self-Regulation Questionnaire (SRQ, α = 0.88), and Algebraic Problem-Solving Test (APST, α = 0.92). Analytical methods comprised descriptive statistics, independent and paired-samples t-tests, normalized gain (N-gain), and Cohen's d. Initial findings showed no meaningful baseline differences between the groups ($p > 0.05$). Post-intervention, however, the PBL group substantially outpaced the control group ($p < 0.01$), achieved a higher normalized gain (0.59, moderate-to-high) than the control group (0.35, moderate), and a substantial effect size (Cohen's d = 1.32). Consequently, PBL proves to be an effective pedagogical tool for bolstering these academic outcomes. Mathematics educators are encouraged to adopt PBL, while future researchers should expand the sample size and diversity to ensure broader generalizability.

Keywords: PBL, Self-Efficacy, Self-Regulation, Algebraic Problem Solving, Mathematics Education

Introduction

Mathematical problem solving abilities are essential skills for students, as they form the foundation for logical reasoning and analytical thinking, which are crucial in today's rapidly evolving technological world (Ahdhianto et al., 2020; Anggalia et al., 2020). Enhancing students' mathematical problem-solving skills is crucial for deepening their conceptual comprehension and boosting academic outcomes, while also empowering them to utilize these capabilities in practical contexts (Beitzel & Staley, 2015). For this reason, upgrading these skills represents a primary objective within mathematics curricula, particularly in secondary schools.

Recent educational literature highlights a burgeoning interest in the psychological factors driving students' problem-solving skills, identifying self-efficacy and self-regulation as critical core constructs (Zimmerman & Schunk, 2001). Student academic achievement, particularly in the domain of mathematics, is significantly influenced by two psychological factors: self-efficacy and self-regulation (Isoda & Katagiri, 2012). The former refers to a person's belief in their own capability to succeed in specific tasks (Bandura, 1977), whereas the latter involves the capacity to manage one's thoughts, behaviors, and feelings to attain defined objectives (Panadero, 2017).

Notwithstanding the extensive body of literature dedicated to self-efficacy and self-regulation, a scholarly vacuum persists regarding how these two constructs interactively converge to shape the mathematical problem-solving proficiencies of secondary school students. Extensive empirical research has firmly demonstrated that self-efficacy positively correlates with general mathematics achievement; nevertheless, the underlying combined mechanisms behind this relationship remain insufficiently investigated (Pajares & Graham, 1999; Usher & Pajares, 2007), the mechanisms through which self-regulation strategies enhance problem-solving remain underexplored, especially in non-Western educational contexts (Cleary & Zimmerman, 2004). This gap in the literature necessitates a deeper investigation into how self-efficacy and self-regulation jointly contribute to students' success in mathematics.

Furthermore, deconstructing this intricate relationship is of paramount importance for educators and policymakers alike, as it offers empirical benchmarks to guide the design of instructional frameworks. Such frameworks can simultaneously cultivate students' self-efficacy and self-regulatory capacities, ultimately augmenting their overarching problem-solving competencies (Boekaerts, 1995; Britner & Pajares, 2006; Corte, 2019). To address this gap in the literature, the current study focuses on empirically investigating how self-efficacy and self-regulation interactively influence and develop the mathematical problem-solving skills of secondary school learners. In doing so, this inquiry intends to offer meaningful insights that enrich the existing scholarly landscape surrounding effective mathematics education.

Prior literature has demonstrated that students possessing elevated levels of self-efficacy exhibit a greater propensity to confront complex mathematical tasks. Furthermore, these learners display heightened cognitive resilience when encountering academic obstacles and employ significantly more sophisticated problem-solving strategies (Jacinto & S. Carreira, 2016; Jamali et al., 2020). Research indicates that learners with high self-efficacy generally establish more ambitious targets, track their own learning advancement systematically, and show stronger persistence when encountering obstacles (Anderson & Betz, 2001). Nonetheless, although self-efficacy serves as a primary determinant of mathematics performance, its influence on problem-solving proficiency is frequently mediated by additional variables, including self-regulation (Marcou & Philippou, 2005).

Likewise, self-regulation is widely acknowledged as a fundamental pillar of effective learning, as it allows students to plan, track, and analyze their learning journeys (Panadero et al., 2017). Such learners show higher proficiency in utilizing cognitive and metacognitive approaches necessary for resolving complex math problems (Boekaerts, 1995; Cera et al., 2014; Dinsmore et al., 2008). However, how to cultivate these specific self-regulation strategies in the classroom to improve students' problem-solving skills remains an area that warrants further research, particularly in mathematics.

As a means to overcome these obstacles, Problem-Based Learning (PBL) has emerged as a widely recognized instructional approach. Rooted in the principles of constructivism, this method positions students as autonomous participants in their learning process, where the construction of knowledge is stimulated by engaging with authentic and significant problems. Instead of passively absorbing information, students collaborate to analyze issues, develop hypotheses, evaluate solutions, and reflect upon their learning pathways (Lestari et al., 2020; Ahmad et al., 2023).

As argued by Hmelo-Silver (2004), combining existing knowledge with novel ideas through exploration and discovery is fundamental to how PBL improves student understanding. Accordingly, the growth of algebraic problem-solving is strongly supported by PBL because it requires learners to carefully evaluate intricate situations, design and test alternative models, and offer logical justifications for their conclusions (Savery, 2006).

Study in meta-analysis by Dochy et al. (2003) indicates that this learning model has a deep influence on skill acquisition, particularly regarding knowledge translation and problem resolution. Additionally, English and Gainsburg (2016) point out that within mathematics education, problem-focused approaches provide valuable frameworks for developing analytical reasoning capabilities.

The success of PBL has been proven to optimize mathematics education across diverse mathematical topics, with learners in PBL environments demonstrating better critical thinking performance than those in conventional settings (Maharani & Laelasari, 2017). Evidence from meta-analytic studies confirms that PBL reliably improves students' mathematical proficiency, with a notable impact on algebra (Nugraha & Suparman, 2021). Additionally, Izzaroh et al. (2025) highlighted that this model fosters critical thinking skills throughout diverse mathematical areas by structuring opportunities for systematic reasoning, collaborative exchange, and personal reflection. Furthermore, the capacity of PBL to favorably influence psychological constructs like self-regulation and self-efficacy has been substantiated in the literature (Panadero et al., 2017; Purnomo et al., 2024).

There is a strong correlation showing that highly self-efficacious students are more adept at utilizing self-regulation strategies, including goal formulation, self-monitoring, and reflective practices, thereby enhancing their capacity to solve problems (Artz & Armour-thomas, 2009; Beitzel & Staley, 2015; Winne & Hadwin, 1998). However, the literature still calls for more empirical investigations to clarify the degree to which these factors impact secondary school students' mathematical problem-solving skills in diverse backgrounds. This is supported by recent meta-analytic data and literature overviews, which uniformly highlight that stronger self-efficacy and self-regulation correspond to enhanced performance in mathematics (Street et al., 2024; Suparman & Juandi, 2025).

While individual contributions of self-regulation and self-efficacy toward mathematical performance are well-documented, holistic investigations exploring the joint relationship between self-efficacy, self-regulation, and algebraic problem-solving skills in the context of PBL are still noticeably absent from the current literature. Most studies focus on self-efficacy, self-regulation, and algebraic problem-solving ability separately, without considering how these constructs interact to influence problem-solving outcomes in PBL (Azevedo & Gašević, 2019; García-García et al., 2022). Furthermore, research on how these factors operate within the unique learning environment of middle school students is limited, highlighting the need for further investigation (Li et al., 2020).

Numerous studies indicate that suboptimal mathematics achievement stems not only from environmental and instructional variables but also from psychological traits within the students, specifically self-regulation and self-efficacy. Many students struggle to grasp mathematical concepts in algebra because they have low confidence in their mathematical abilities and are hesitant to engage with challenging tasks. Furthermore, when students lack adequate self-regulation skills, they face difficulties in establishing learning objectives, organizing study schedules, tracking their comprehension, and critiquing their academic growth. These obstacles are frequently intensified by conventional, teacher-centered instructional approaches, which restrict students from building independence and engaging dynamically in the PBL framework (Huang et al., 2024; Landa et al., 2025). Therefore, strengthening students' self-efficacy, self-regulation, and algebraic problem-solving abilities through a student-centered PBL approach is crucial for improving mathematics problem-solving abilities and overall academic achievement.

To strengthen the novelty of this research, a summary of previous research is presented in Table 1 as follows.

Table 1. Summary of Previous Research

Authors	Research Focus	Key Findings	Research Gap
Ahdhianto et al. (2020); Anggalia et al. (2020); Beitzel & Staley (2015)	Mathematical problem-solving	Problem-solving is essential for mathematical	Limited research links psychological factors to problem-solving.

Authors	Research Focus	Key Findings	Research Gap
		understanding and real-life application.	
Bandura (1977); Zimmerman & Schunk (2001); Panadero (2017)	Self-efficacy & self-regulation	Both positively influence mathematics learning.	Their combined effect on problem-solving is unclear.
Pajares & Graham (1999); Usher & Pajares (2007); Cleary & Zimmerman (2004)	Self-efficacy	Self-efficacy improves mathematics achievement.	The mediating role of self-regulation needs further study.
Boekaerts (1995); Cera et al. (2014); Panadero et al. (2017)	Self-regulation	Self-regulation supports effective learning and problem-solving.	Classroom strategies to foster self-regulation remain underexplored.
Hmelo-Silver (2004); Savery (2006); Dochy et al. (2003)	Problem-Based Learning (PBL)	PBL enhances reasoning and problem-solving skills.	The interaction between PBL, self-efficacy, and self-regulation is rarely examined.
Street et al. (2024); Suparman & Juandi (2025); Azevedo & Gašević (2019)	Integrated psychological factors	Self-efficacy and self-regulation improve mathematics performance.	Few studies examine their combined influence on algebra problem-solving in PBL.
Huang et al. (2024); Landa et al. (2025)	Mathematics learning challenges	Low achievement is associated with weak self-efficacy and self-regulation.	Student-centered PBL interventions require further empirical evidence.

Based on the literature review, there is a clear evolution in research positioning self-regulation, self-efficacy, and algebraic problem-solving abilities within PBL as pivotal psychological constructs that dictate student academic success. Previous studies consistently demonstrate that self-efficacy enhances students' confidence in completing academic tasks, while self-regulation supports the effective management of cognitive processes, motivation, and behavior. PBL can also improve students' mathematics learning achievement. Nevertheless, the majority of prior research evaluates these constructs independently or concentrates on broad educational outcomes. As a result, empirical documentation remains scarce concerning how PBL simultaneously fosters junior high school students' self-regulation, self-efficacy, and algebraic problem-solving abilities, which underscores the necessity of conducting deeper studies in this domain.

To address this specific limitation in current research, the present study aims to evaluate the effectiveness of a PBL framework designed to augment junior high school students' self-regulation, self-efficacy, and algebraic problem-solving skills. The novelty of this research lies in its exploration of the interactions between these constructs within a single study, providing a more holistic understanding of how they contribute to algebraic problem-solving ability. These findings offer valuable insights for educators, enabling them to design interventions that foster self-efficacy, self-regulation, and algebraic problem-solving skills in mathematics education..

Research Methods

To empirically test the impact of the PBL framework on junior high school students' algebraic problem-solving skills, self-efficacy, and self-regulation, a quantitative research design was implemented. This paradigm allows for the statistical analysis and objective assessment of core variables via validated measurement instruments. While qualitative research generally focuses on exploring the subjective perceptions and experiences of participants, a quantitative approach is more fitting for hypothesis verification and permits the generalization of findings across a broader target population (Creswell, 2009). Furthermore, data rigor, objectivity, and reliability are secured through the utilization of standardized metrics: the Self-Efficacy Questionnaire (SEQ), Self-Regulation Questionnaire (SRQ), and Algebraic Problem-Solving Test (APST). For a comprehensive breakdown of the operational steps, refer to Figure 1.

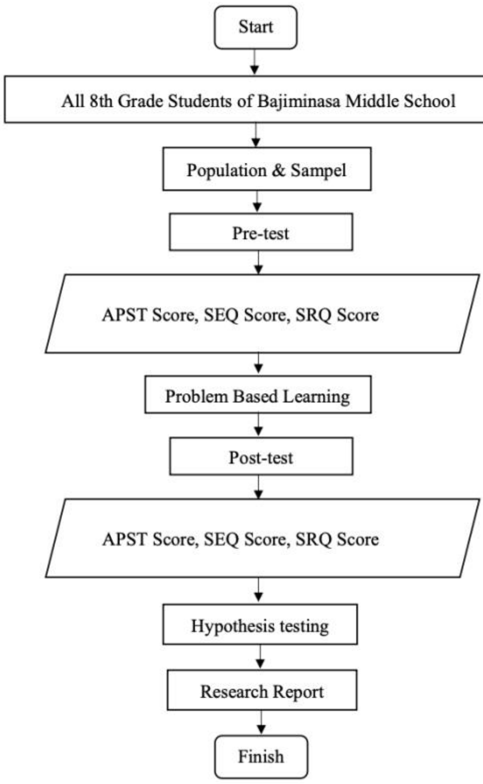

Figure 1. Research Flow

Based on the workflow in Figure 1, the study initiated its procedures by establishing the research population, encompassing all eighth-grade individuals at Bajiminasa Junior High School, Makassar City. Subsequently, the research sample was drawn from eighth-grade students within the 2025/2026 academic period. Of the three eighth-grade classes, two classes IX^A and IX^B were selected using a combination of random and purposive sampling techniques. Each class consisted of 28 and 25 students, respectively, resulting in a total sample of 53 participants. To fulfill the methodological criteria of this study and secure a representative sample from the broader population, a structured sampling approach was deployed. Data collection was carried out through three validated measurement instruments, comprising the Algebraic Problem-Solving Test (APST) to determine algebraic problem-solving proficiency, alongside the Self-Efficacy Questionnaire (SEQ) and Self-Regulation Questionnaire (SRQ) to capture students' self-efficacy and self-regulation, respectively. The scores obtained from these instruments were compiled as research data and further analyzed through hypothesis testing to examine the relationships and contributions between variables. Finally, the findings were documented and presented in the form of a research report as the final stage of the study.

To psychometrically evaluate the psychological constructs under investigation, two standardized instruments were adapted from established literature. Specifically, the Self-Efficacy Questionnaire (SEQ) was derived from the framework established by Laranang and Bondoc (2020) to gauge students' mathematics-specific self-efficacy. Concurrently, the Self-Regulation Questionnaire (SRQ) was modeled after the instrument developed by Brown et al. (1999) to assess learners' self-regulatory mechanisms within the mathematics domain. Both the Self-Efficacy Questionnaire (SEQ) and Self-Regulation Questionnaire (SRQ) utilized items derived from established instruments frequently applied in educational psychology studies, confirming that self-regulation and self-efficacy are evaluated with high precision and consistency. These instruments were selected because of their strong psychometric properties and their suitability for use with secondary school students.

To guarantee curricular alignment with junior high school competency standards, the development of the APST was anchored in standardized mathematics curricula and rigorous problem-solving frameworks. This instrument was explicitly designed to measure learners' capacities in conceptual application, logical reasoning, and systematic problem-solving. Furthermore, the empirical reliability of the research toolkit was substantiated by robust internal consistency coefficients, yielding Cronbach's alpha values of 0.85 (SEQ), 0.88 (SRQ), and 0.92 (APST).

All participants were enrolled in regular mathematics courses to ensure they received equivalent exposure to mathematical content. In alignment with ethical research codes, formal consent was granted by the institutional authorities, mathematics teachers, school administrators, and the students prior to conducting any data collection activities. In the pretest, the SEQ and SRQ were administered to both experimental and control classes during regular school hours in a supervised classroom environment to minimize distractions and encourage honest responses. To mitigate the confounding factors of cognitive overload and optimize measurement accuracy, the APST was administered across separate, dedicated testing sessions. This procedural fragmentation ensured that students' latent algebraic problem-solving capabilities were evaluated under conditions that maximize psychometric precision and reflective focus.

During the initial phase of the investigation, participants completed the SEQ and

SRQ. A total of 20 psychometric items made up each instrument, with options measured on a 5-point Likert scale ranging from a score of 1 ('Strongly Disagree') to 5 ('Strongly Agree'). The main operational purpose of the SEQ was to numerically capture students' personal beliefs concerning their capability to solve mathematical challenges. Conversely, the SRQ aimed to capture the frequency and depth with which learners deployed cognitive and metacognitive strategies, specifically focusing on self-directed planning, active monitoring, and reflective evaluation within their mathematics coursework.

The second phase involved the administration of the APST, which consisted of eight open-ended problem-solving tasks. These psychometric items were explicitly constructed to evaluate learners' capacities in dissecting intricate problems, determining optimal resolution strategies, and mobilizing mathematical principles to resolve high-complexity tasks. The problems covered multiple mathematical domains, including algebra, geometry, and word problems, ensuring a broad and comprehensive evaluation of students' problem-solving skills.

Each data collection session lasted approximately 60 minutes, providing sufficient time for students to complete the instruments without unnecessary pressure. Students were encouraged to attempt all items within the allocated time to capture their full range of abilities. This structured administration process helped ensure that the data collected were both reliable and representative of students' self-efficacy, self-regulation, and mathematical problem-solving performance.

The primary parameters measured in this study were students' self-efficacy scores obtained from the SEQ, self-regulation scores derived from the SRQ, and mathematical problem-solving scores from the APST. Self-efficacy scores were calculated by averaging each student's responses across the 20 SEQ items, producing a single composite score that reflected their overall confidence in solving mathematical tasks. In a similar manner, responses from the 20 items of the SRQ were averaged to obtain the final self-regulation score, yielding a metric that illustrates the degree to which learners successfully monitor and direct their own learning experiences throughout mathematical tasks.

The APST scores were determined using a structured scoring rubric that evaluated the accuracy, complexity, and completeness of students' solutions. Each problem was assessed based on the correctness of the final answer, the appropriateness of the strategy used, and the clarity of the problem-solving steps, with a maximum total score of 100 points. This multidimensional scoring approach ensured that students were evaluated not only on whether they reached the correct answer, but also on how effectively they applied mathematical reasoning and problem-solving strategies. The experimental procedure commenced with a pre-test, followed by the integration of a PBL intervention. Finally, a post-test was conducted to determine the presence of any statistical growth in learners' algebraic problem-solving abilities, self-efficacy, and self-regulation post-treatment.

To examine the connections among algebraic problem-solving capabilities, self-efficacy, and self-regulation, data processing was conducted using SPSS 29.0, utilizing both descriptive and inferential statistics. Prior to hypothesis testing, the dataset underwent prerequisite diagnostic checks to satisfy parametric conditions. Data normality was verified via the Shapiro–Wilk and Kolmogorov–Smirnov procedures, and homogeneity of variance was assessed using Levene's test, proving that all requirements were met at $p > 0.05$. For the primary analyses, an Independent Samples t-Test compared post-test outcomes between the treatment and control groups, while a Paired Samples t-Test measured internal group growth over time. To better evaluate academic advancement, normalized gain (N-gain) scores were determined, with the effect magnitude quantified through Cohen's d. Throughout all statistical calculations, the significance threshold was strictly maintained at 0.05.

Rigorous ethical principles were upheld over the course of this study. Institutional approval was officially secured, and all participating students took part on a strictly voluntary basis. To protect respondent anonymity, all gathered data were treated with tight confidentiality, and individual identifiers were completely removed. Overall, the investigative framework was systematically designed to ensure seamless coherence among the pedagogical approach, the classroom environment, and the evaluated outcomes, establishing a robust basis for assessing how effectively Problem-Based Learning develops critical thinking skills within algebra instruction.

Results and Discussions

Statistical data analysis plays a fundamental role in educational research by transforming raw data into meaningful and interpretable information. Through systematic procedures, it enables researchers to summarize large and complex datasets, identify patterns, detect trends, and describe the characteristics of study variables in a precise manner (Creswell, 2009). Detailed baseline metrics concerning the participants' behavioral characteristics and academic execution are provided through descriptive statistical analysis, which encompasses frequency distributions, means, and standard deviations. Establishing this fundamental baseline is indispensable for conceptualizing the overarching profile of the empirical data prior to executing sophisticated inferential models.

An initial baseline analysis of the study's core constructs, including self-efficacy (SEQ), self-regulation (SRQ), and algebraic problem-solving test outcomes (APST), was established through the computation of descriptive statistics. These statistics summarize the central tendency and variability of the data, allowing researchers to understand the general level and distribution of students' responses. The descriptive outcomes showed a mean SEQ score of 3.75 (SD = 0.58), confirming that the student body generally maintained a solid, moderate-to-high level of math-related confidence. Correspondingly, a mean value of 3.60 (SD = 0.62) was recorded for the SRQ, pointing to the frequent utilization of self-regulatory behaviors by most participants during class sessions.

The APST yielded a mean score of 75.3 (SD = 12.4), which reflects a reasonable level of proficiency among the participants, although with noticeable variability. The relatively higher means of SEQ and SRQ compared to APST imply that while students perceive themselves as confident and capable of regulating their learning, this perception does not fully translate into equally high problem-solving performance. This pattern highlights the importance of examining not only students' self-beliefs and learning strategies but also how these factors interact to influence actual academic outcomes.

An overview of the number and average score of 53 students can be seen in Figure 2 and Figure 3. Below is presented Figure 2 regarding the total scores of 53 students.

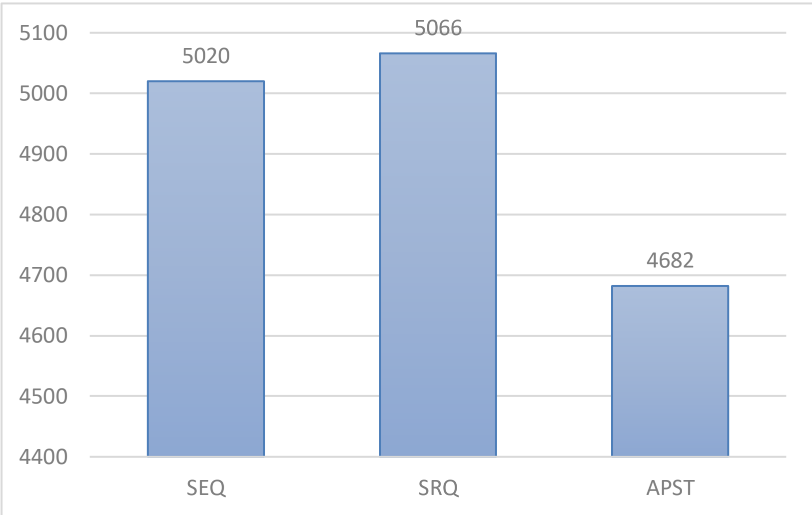

Figure 2. Total Value

The bar chart illustrates the total scores for three measured variables: SEQ, SRQ, and APST. Data analysis reveals that the SEQ achieved the peak aggregate metric with a total of 5066, closely followed by the SRQ at 5020. In sharp contrast, the cumulative score for the APST was substantially lower, remaining at 4682.

Interpreting these data indicates that participants' internal perceptions of their self-regulation and self-efficacy levels exceeded their practical execution when faced with mathematical problem-solving tasks. This discrepancy may indicate that while participants feel confident in their self-regulation and self-efficacy abilities, there is a notable gap between these perceptions and their practical application in mathematical problem-solving contexts.

Below is presented Figure 3 regarding the average score for each student out of 53 students.

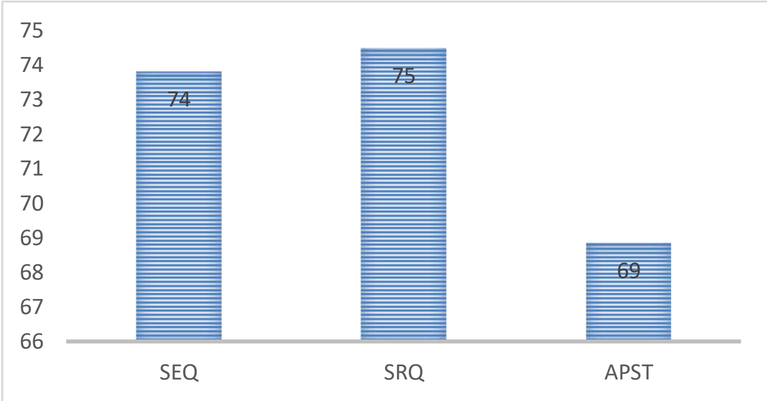

Figure 3. Average Each Student

The bar chart presents the average scores across three key variables: SEQ, SRQ, and APST. The data reveals that the average score for self-efficacy was 74, while self-regulation exhibited a marginally higher average score of 75. In contrast, the average score for the mathematical problem-solving test was substantially lower at 69.

Overall, 53 eighth-grade individuals served as the sample for this research, consisting of 25 male and 28 female students. The sample was distributed into an experimental class receiving Problem-Based Learning (PBL) treatments and a control class receiving traditional instruction. A pre-test was administered beforehand to verify baseline equality between the two cohorts. What follows is a comprehensive presentation of the statistical analysis results.

1. Assumptions Test

Prior to executing the main statistical evaluations, tests for homogeneity of variance and normality assumptions were conducted. Based on the Kolmogorov–Smirnov and Shapiro–Wilk outcomes, the pretest and posttest metrics for each group proved to be normally distributed ($p > 0.05$). To assess variance equality, Levene's test was applied across several metrics, yielding significance values well above the 0.05 threshold: 0.122 (mean), 0.163 (median), 0.156 (adjusted median), and 0.128 (trimmed mean). These outcomes indicate that the groups possess homogeneous variances. Meeting these twin prerequisites justifies the use of downstream parametric methods, specifically the independent samples t-test.

2. Independent Samples t-test

To ensure that the baseline abilities of both cohorts were statistically equivalent before analyzing the treatment's impact, an independent samples t-test was conducted on the pre-test data (see Table 2).

Table 2. Results Pre-test

Variable	Group Comparison	t	df	p-value	Interpretation
Pre-test	Experimental vs Control	0.35	51	0.723	Not significant

As illustrated by the data in Table 2, the pre-test metrics between the experimental and control cohorts did not vary significantly according to the independent samples t-test ($t(51) = 0.35$, $p = 0.723$). This evidence confirms that participants possessed comparable initial levels of self-efficacy, self-regulation, and algebraic problem-solving capabilities before undergoing the treatment, which strengthens the research's internal validity. To compare the post-intervention performance between the groups, a subsequent independent samples t-test was administered, the details of which are documented in Table 3.

Table 3. Results Post-test

Variable	Group Comparison	t	df	p	Interpretation
Post-test	Experimental vs Control	5.03	51	< .001	Significant difference

As outlined in Table 3, the post-test independent samples t-test revealed a statistically significant variance between both groups ($t(51) = 5.03$, $p < 0.001$). The higher mean score achieved by the experimental group indicates that the integration of Problem-Based Learning substantially enhanced the students' self-efficacy, self-regulation, and algebraic problem-solving abilities.

3. Paired Samples t-test

To evaluate internal growth alongside between-group differences, a paired samples t-test was conducted, as outlined in Table 4.

Table 4. Paired Samples t-test Results

Group	Comparison	t	df	p	Interpretation
Experimental	Pre-test vs Post-test	13.71	27	< .001	Significant improvement
Control	Pre-test vs Post-test	9.14	24	< .001	Significant improvement

The paired samples t-test outcomes for both groups are presented in Table 4. Although significant pre-to-post-test gains were observed in both cohorts, the experimental group demonstrated a substantially higher t-value than the control group, reflecting a more pronounced advancement in critical thinking skills. This implies that while traditional teaching methods can foster academic growth, the Problem-Based Learning approach yields more impactful cognitive development.

4. Normalized Gain

To evaluate the magnitude of learning gains alongside statistical significance, a normalized gain (N-gain) analysis was conducted (Hake, 1999), with the findings detailed in Table 5.

Table 5. Normalized Gain

Group	Mean N-gain	Category
Experimental	0.59	Moderate–High
Control	0.35	Moderate

The data presented in Table 5 indicates that the normalized gain score for the experimental cohort (0.59, moderate-to-high) exceeded that of the control cohort (0.35, moderate), establishing the heightened capability of Problem-Based Learning. Moreover, a substantial effect size was confirmed through Cohen's d analysis ($d = 1.32$). This suggests that the discrepancy in student outcomes carries both statistical significance and practical educational value, emphasizing the profound impact of PBL on fostering advancements in self-efficacy, self-regulation, and algebraic problem-solving capabilities.

Correspondence is found between the current findings and established literature confirming that academic achievement, especially in mathematics, is heavily dependent on self-efficacy and self-regulation (Usher & Pajares, 2007; Zimmerman & Schunk, 2001). These conceptual frameworks posit that a student's internal belief regarding their capacity dictates their motivational levels, persistence, and active participation during instructional tasks. Within mathematical contexts, the presence of self-efficacy becomes paramount because navigating complex, highly challenging obstacles demands both unwavering confidence and prolonged effort.

Consistency is observed between current insights and international studies validating the effectiveness of PBL in developing high-level cognitive skills. As noted by Hmelo-Silver (2004), deeper learning pathways are cultivated via PBL by blending autonomous knowledge generation, cooperative group work, and inquiry-based activities. Furthermore, Dochy et al. (2003) substantiate that when measured against traditional lecturing, PBL offers superior efficiency in reinforcing how students utilize information and tackle multi-layered problems. Contemporary viewpoints, including those by Loyens et al. (2015), additionally indicate that PBL fosters autonomous learning regulation, an element essential to the growth of critical thinking capacities.

Although the outcomes are encouraging, the effectiveness of PBL is not uniformly guaranteed; unguided frameworks often induce cognitive overload among beginner learners (Kirschner et al., 2006; Leary et al., 2013). Nevertheless, while conventional approaches facilitate procedural understanding, they are less effective than PBL in cultivating self-efficacy, self-regulation, and algebraic problem-solving skills (Schmidt et al., 2006; Dolmans et al., 2013; Winne & Hadwin, 199). Accordingly, PBL ought to integrate with, rather than substitute, traditional teaching methods. In essence, positive results depend greatly on the caliber of execution and instructor scaffolding, which accounts for the robust achievements in the current research through well-structured mentorship during all PBL steps.

In addition, the fact that significant academic growth occurred in both cohorts introduces a noteworthy point of discussion. Even though PBL yielded superior results, traditional pedagogy also fostered learning progress. This aligns with the perspective of Mayer (2004), who posits that structured instruction is indispensable and that optimal educational setups frequently merge explicit direction with active learning techniques. Hence, instead of framing PBL as a total alternative to traditional education, it should be conceptualized as a cooperative method that enriches established pedagogical approaches (Arbo & Ching, 2022; Yuhana & Fajari, 2025).

Extant literature suggests that learners with robust convictions regarding their mathematical capabilities exhibit a higher propensity to undertake rigorous tasks, maintain resilience when encountering cognitive obstacles, and deploy adaptive problem-solving heuristics (Ahdhianto et al., 2020; Panadero et al., 2016, 2017; Landa et al., 2025). Direct alignment is observed between this behavioral trajectory and the current empirical evidence, which uncovers a significant positive correlation between a student's mathematical self-efficacy and their problem-solving capabilities. Such insights suggest that heightened self-efficacy is tightly interwoven with maximized problem-solving execution, further validating the theoretical premise that internal confidence in one's mathematical talents serves as a cornerstone for academic success.

To enhance self-efficacy, teachers can implement strategies such as providing constructive and positive feedback, setting attainable learning goals, and designing tasks that allow students to experience repeated success in mathematics (Alpacion et al., 2014; Anggalia et al., 2020). When learners recognize that their academic investments yield substantive advancement, their domain-specific mathematical self-efficacy is heightened. Driven by this psychological adaptation, students are inclined to interact actively with intricate problems and sustain their intellectual efforts through various academic challenges. Such experiences foster a more robust sense of personal competence among students, a vital factor for ensuring continuous participation in mathematical reasoning and problem-solving.

The significance of these outcomes is amplified when framed within the Indonesian context, where developing mathematical proficiency remains a persistent dilemma according to global benchmarks (OECD, 2014; Street et al., 2024). It has been substantiated by Huang et al. (2024) that the deployment of self-regulatory strategies advances problem-solving competencies in math, specifically through the refinement of planning, monitoring, and evaluating skills. Beyond conceptual misunderstandings, a lack of appropriate learning strategies and self-belief often hinders students during math tasks. Consequently, the strong interrelationships between mathematical problem-solving, self-efficacy, and self-regulation suggest that reinforcing these intrinsic components offers a critical pathway toward improving math outcomes for junior high school students in Indonesia.

Internationally, these outcomes correspond with modern educational goals that prioritize cultivating self-regulated students who can solve intricate problems on their own. The evident positive correlations between SEQ, SRQ, and APST suggest that comparable pedagogical methods could be integrated within diverse school systems to improve mathematical problem-solving capabilities. Given that mathematics forms the bedrock of global STEM disciplines, nurturing self-regulation, self-efficacy, and algebraic reasoning can play a pivotal role in equipping students with the vital competencies required for long-term career readiness and academic achievement (Li et al., 2020).

Schools can implement these findings by designing curricula and teaching practices that explicitly promote self-efficacy, self-regulation, and algebraic problem-solving abilities in PBL. To encourage students to take ownership of their learning, teachers can embed reflective activities, goal setting, and formative feedback into daily pedagogical practices. Implementing such a framework extends benefits beyond immediate mathematics achievement; it enhances comprehensive scholastic success by nurturing individual autonomy, internal motivation, and academic resilience among students.

In summary, the current study adds valuable insight to the accumulating evidence demonstrating how critical self-efficacy, self-regulation, and skills in algebraic problem-solving are to the field of mathematics instruction. Furthermore, it provides valuable theoretical and practical insights for educators and researchers. Addressing self-efficacy, self-regulation, and algebraic problem-solving in PBL simultaneously allows educational interventions to more effectively equip students with the confidence, motivation, and learning strategies needed to engage with challenging mathematics tasks and achieve higher academic outcomes.

According to the findings, the implementation of PBL successfully advances the algebraic problem-solving skills, self-efficacy, and self-regulation of lower secondary students. It is suggested that a strong belief in personal success combined with systematic support in managing the learning process encourages students to remain resilient, deploy efficient strategies, and achieve heightened performance within mathematical problem-solving environments.

Conclusions and Suggestions

The efficacy of Problem-Based Learning (PBL) in advancing the self-efficacy, self-regulation, and algebraic problem-solving abilities of junior high school students is substantiated by this research. Based on statistical data, students exposed to the PBL model achieved significantly greater post-test outcomes and heightened learning gains than those who underwent conventional instruction. These insights demonstrate that PBL acts as a supportive learning environment, empowering students to actively generate knowledge, control their instructional pathways, and gain confidence in resolving mathematical issues.

Additionally, the data validate that self-regulation and self-efficacy serve as critical psychological pillars linked to student achievement in solving algebraic problems. Learners possessing more robust strategic self-regulation and heightened confidence in their mathematical skills consistently displayed outstanding problem-solving execution. This inquiry expands upon prior literature by investigating these psychological dimensions concurrently within a Problem-Based Learning framework, thereby offering a more integrated insight into how psychological and cognitive elements cooperate to advance mathematics learning achievements.

From an applied standpoint, the outcomes imply that mathematics educators ought to merge Problem-Based Learning with pedagogical strategies designed to explicitly promote self-regulation and self-efficacy. This can be achieved through intentional goal setting, collaborative learning, self-monitoring, reflective exercises, and meaningful problem-solving tasks, which together cultivate self-assured, independent learners who excel at navigating complex mathematical scenarios. Nonetheless, certain limitations characterize this inquiry, particularly the small sample size restricted to a single lower secondary school in Makassar, which constrains the generalizability of the insights. Consequently, subsequent research should recruit broader, more heterogeneous cohorts across varying educational landscapes and utilize structural equation modeling or longitudinal methodologies to deeply dissect the causal connections linking Problem-Based Learning, self-efficacy, self-regulation, and mathematical problem-solving skills.

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