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Application of Problem Based Learning Assisted by Polya to Improve Problem-Solving Ability of Grade IV Elementary School Students

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Abstract
The mathematical problem-solving ability of grade IV students on the topic of area and volume measurement is generally still low, while previous studies integrating Polya's steps into the syntax of Problem Based Learning explicitly on this topic remain limited. This study aims to describe the implementation of Problem Based Learning assisted by Polya's steps and to analyze the improvement of mathematical problem-solving ability of grade IV students at Sekolah Dasar Negeri Gadang 3 Kota Malang. This study is a Classroom Action Research using the Kemmis and Mc Taggart model, conducted in two cycles with three meetings per cycle involving 24 students. Data were collected through problem-solving tests at the pre-cycle, the end of cycle I, and the end of cycle II, then analyzed using normalized N-Gain and the Wilcoxon test. The results show that the average score increased from 37.38 in the pre-cycle to 58.33 in cycle I and 68.33 in cycle II, with an average N-Gain of 0.332 (moderate category) in cycle I and 0.515 (moderate category) in cycle II calculated from the pre-cycle baseline, as well as a statistically significant improvement from the pre-cycle to cycle II (Wilcoxon, $p < 0.001$; Cohen's $d = 1.76$). Classical mastery increased from 4.2% to 41.7% in cycle I and 54.2% in cycle II. Nevertheless, the 80% classical mastery target was not achieved by the end of cycle II, and the improvement was not evenly distributed among all students. This study concludes that the integration of Polya's steps into the syntax of Problem Based Learning contributes to a gradual improvement in mathematical problem-solving ability, but requires strengthened individual guidance at the stage of understanding the problem so that its benefits are felt more evenly.

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Introduction

Mathematics is one of the subjects that plays an important role in shaping students' logical, systematic, and analytical thinking skills from the elementary school level. One of the main goals of mathematics learning is problem-solving ability, which serves as the foundation for other mathematical abilities such as reasoning, connection, communication, and representation (Satuti, Fajriyah, & Damayani, 2023). This ability requires students not only to master computational procedures but also to understand the structure of non-routine problems and determine appropriate solving strategies (Divrik, Pilten, & Taş, 2020). However, the mathematical problem-solving ability of elementary school students in Indonesia is in reality still relatively low. This condition is consistent with the finding that students at the elementary level tend to rely on procedural memorization rather than conceptual understanding when faced with problems requiring gradual reasoning, as indicated by the tendency of students to repeatedly overlook the stage of checking back in the problem-solving process (Isnaini, Ahied, Qomaria, & Munawaroh, 2021). This is in line with the finding that most students are able to solve problems in the form of direct numbers but experience difficulties when faced with word problems requiring contextual understanding and the formulation of solving strategies (Cahya, Syamsuri, Santosa, & Mutaqin, 2022).

These difficulties are also evident in the topic of area and volume measurement in grade IV of elementary school. Several findings indicate that students tend to succeed on problems with a low level of complexity that only require the direct application of formulas, but experience significant failure on problems requiring analysis, spatial visualization, or transformation of geometric shapes. The main obstacle generally lies at the initial stage, namely understanding the problem: students have difficulty identifying the information known and the information asked, so that the subsequent solving stages are also disrupted. This pattern is consistent with the general tendency of elementary school students from various regions, who are more accustomed to problems based on direct formulas compared to contextual problems requiring spatial reasoning. This condition confirms that the issue of mathematical problem-solving is not merely a matter of formula mastery but also of students' readiness to think systematically in facing non-routine problems. In addition to cognitive factors, students' readiness for systematic thinking is also influenced by the quality of learning that places students as active subjects; learning that encourages experimentation and critical dialogue has been shown to foster reflective thinking habits that are a prerequisite for problem-solving (Gultom, 2025).

The Minimum Mastery Criteria is 70. Judging from the four indicators of Polya's steps, the pre-cycle field notes show that the majority of students were only able to write down part of the known information without formulating a clear solving plan, so that failure occurred in a chain at the stages of devising a plan, carrying out the plan, and looking back. This pattern is consistent with findings on grade IV students of other elementary schools, most of whom were only able to fulfill one to two of the four indicators of Polya's problem-solving, namely understanding the problem and devising a plan, while the stages of carrying out the plan and looking back were rarely achieved (Satuti, Fajriyah, & Damayani, 2023). Most of the students' errors in the pre-cycle stage occurred at the initial stage of solution analysis, namely when students were asked to identify relevant data from word problems before performing

calculations, a pattern also consistent with students' difficulties in generalizing geometric patterns from visual representations of shapes (Ambrus & Barczi-Veres, 2022). This needs analysis confirms that the problem faced is not merely the mastery of area and volume formulas but rather the inability of students to carry out the reasoning process in a gradual and systematic manner, so that the action provided needs to explicitly train all four stages, not just one of them.

One systematic approach that has been widely used to train mathematical problem-solving ability is Polya's steps, which consist of four phases: understanding the problem, devising a plan, carrying out the plan, and looking back (Murtiyasa & Wulandari, 2022). Polya's steps provide a thinking framework that helps students work systematically, rather than merely memorizing solving procedures (Al Kayyis, Tohir, & Muhasshanah, 2024). Empirical findings at the elementary school level indicate that a problem-based approach organized in stages and accompanied by strengthening metacognitive strategies helps fourth-grade students build problem-solving ability more meaningfully compared to conventional learning (Divrik, Pilten, & Taş, 2020). Accordingly, the application of a problem-based approach in mathematics learning has also been proven to have a positive impact on students' problem-solving performance at various levels based on meta-analytic studies, not limited to cognitive aspects alone (Suparman, Yohannes, & Arifin, 2021). Various studies indicate that the consistent application of Polya's steps can improve students' ability to solve mathematical word problems, both in the topics of plane figures and solid figures (Al Kayyis, Tohir, & Muhasshanah, 2024).

However, Polya's steps cannot stand alone optimally if not integrated into a learning model that places students at the center of learning. The Problem Based Learning model is considered suitable for integration with Polya's steps because Problem Based Learning exposes students to contextual problems from the beginning of learning and requires students to actively investigate, discuss, and present solutions independently or in groups, as demonstrated by research that developed problem-solving instruments based on the four Polya indicators in problem-based learning (Susino, Destiniar, & Sari, 2023). The application of Problem Based Learning that raises realistic and local contexts has also been proven to contribute to increasing students' self-confidence in solving mathematical problems (Shongwe, 2024), while reinforcement through Student Worksheets that encourage active discovery and concept development also supports the development of thinking skills relevant to the problem-solving process (Suhendar & Ekayanti, 2018). In a broader context, learning that integrates cultural contexts and students' local experiences has also been proven to strengthen their engagement and critical thinking skills, so that the selection of problem contexts in Problem Based Learning needs to consider the proximity of problems to students' world (Indawati, Wiraningsih, & Mulyanti, 2025).

Compared to the aforementioned previous studies, the position of this study needs to be clarified. The classroom action research of Widyasari, Hadiyanti, and Kriswanto (2023), for example, applied Problem Based Learning to improve the problem-solving ability of grade II elementary school students on the topic of solid figure patterns, but did not explicitly map each phase of the Problem Based Learning syntax to the four Polya stages; the success of the Polya stages therein was more implicit as part of the general problem-solving indicators. Likewise, the study of Susino, Destiniar, and Sari (2023) developed an assessment instrument based on Polya indicators but did not make the integration of Polya part of the learning syntax design tested

cyclically. On the other hand, studies focusing on Polya's steps independently, such as on the topic of systems of linear equations (Murtiyasa & Wulandari, 2022) and plane figures (Satuti, Fajriyah, & Damayani, 2023), are generally descriptive without accompanying learning actions explicitly designed to improve them. The gap identified from this description is the unavailability of classroom action research that explicitly maps and integrates the four Polya stages into each phase of the Problem Based Learning syntax, while simultaneously testing its impact in a measurable manner on the topic of area and volume measurement in grade IV of elementary school, a topic that demands a combination of numerical reasoning and spatial visualization. This study is directed to fill this gap, with the main novelty lying in the action design that maps each phase of Problem Based Learning to a specific Polya stage explicitly as described in Table 1, as well as in the presentation of quantitative evidence in the form of inferential tests of the improvement that occurred, not merely a description of the increase in average scores.

Table 1. Integration of Problem-Based Learning Syntax and Polya's Steps

Problem-Based Learnig Phase	Integrated Polya's Step	Primary Role
Orienting students to the problem	Understanding the problem	Students identify given and required information from a contextual problem involving area/volume measurement.
Organizing students for learning	Devising a plan	Students and their groups formulate strategies and determine formulas or solution approaches.
Guiding individual and group investigations	Carrying out the plan	Students execute the devised strategy to calculate area or volume.
Developing and presenting work products	Looking back (initial stage)	Students present their results and begin evaluating the reasonableness of their answers.
Analyzing and evaluating the problem-solving process	Looking back (consolidation stage)	The teacher and students jointly reflect on the accuracy of the strategies and the final outcomes.

Based on the results of observation and initial assessment in grade IV of Sekolah Dasar Negeri Gadang 3 Kota Malang, it was found that students' problem-solving ability on the topic of area and volume measurement was still far below the expected mastery criteria, with only 4.2% of students achieving the Minimum Mastery Criteria at the pre-cycle stage. Students were able to calculate when formulas and data were presented explicitly but had difficulty when they had to estimate or measure using non-standard units before switching to standard units, as

demanded in the applicable learning outcomes. A number of relevant studies have reported positive results of applying Problem Based Learning in elementary school mathematics learning, including on the topic of whole numbers (Dahlia, 2022), learning reinforced with simulation media or visual aids (Simanjuntak, Hutahaean, Marpaung, & Ramadhani, 2021), as well as on improving mathematics learning outcomes in general with a direct learning approach combined with Problem Based Learning (Winarno, Muthu, & Ling, 2018). Other studies have also shown that strengthening Polya's steps is effective in improving the literacy and numeracy of elementary school students (Afandi, Nafingah, Pusnawati, Wahyuni, Handayanto, & Kusumaningrum, 2024) as well as students' academic ability in student-centered learning (Bara & Xhomara, 2020). These findings are consistent with evidence that learning based on literacy and the context of students' lives is able to increase their interest as well as their learning outcomes (Putri, Nugroho, & Pratiwi, 2024), so that the integration of contextual problems in Problem Based Learning has an adequate empirical foundation. As previously described, these studies have not specifically targeted the topic of area and volume measurement in grade IV with the explicit integration of Polya's steps into the Problem Based Learning syntax, so this condition encourages the need for systematic and measurable learning improvement actions in that context.

Based on this description, this study aims to describe the implementation of the Problem Based Learning model assisted by Polya's steps, in which each syntax phase is explicitly mapped to a specific Polya stage as described in Table 1, and to analyze the improvement of mathematical problem-solving ability of grade IV students at Sekolah Dasar Negeri Gadang 3 Kota Malang on the topic of area and volume measurement, viewed from the learning outcomes of measuring and estimating area and volume using non-standard units and standard units in the form of whole numbers. The novelty of this study lies in the explicit integration of the four Polya stages into the Problem Based Learning syntax for the topic of area and volume measurement in grade IV, which has not been widely done in previous classroom action research, as well as in the use of inferential tests to test the significance of the improvement that occurred. Theoretically, this study is expected to contribute to the development of studies on the integration of Polya's steps as a metacognitive device in the Problem Based Learning syntax in mathematics learning in elementary schools, particularly on the topic of measurement. Practically, the results of this study are expected to benefit teachers as an alternative learning strategy to improve students' problem-solving ability, schools as consideration material for developing mathematics learning programs, and future researchers as a reference in developing classroom action research on similar topics.

Method

This study employed a Classroom Action Research (CAR) design based on the Kemmis and McTaggart model, which follows a self-reflective spiral comprising four stages: planning, action, observation, and reflection, implemented in two cycles (Utomo, Asvio, & Prayogi, 2024). The research was conducted during the Guided Field Experience Practice in the second and third cycles of the program, involving 24 fourth-grade students at Sekolah Dasar Negeri Gadang 3, Malang City, Indonesia, who were studying area and volume measurement. Cycle I consisted of three learning meetings held on April 15, 20, and 22, 2026, while Cycle II was conducted over

three meetings on April 27, 28, and May 4, 2026. The instructional intervention integrated the Problem-Based Learning (PBL) model with Polya's four problem-solving stages: understanding the problem, devising a plan, carrying out the plan, and looking back. During the planning stage, the researcher prepared instructional materials, lesson plans, and research instruments, which were reviewed by the mentor teacher. In the action stage, the researcher implemented the PBL-Polya learning activities, while the mentor teacher observed classroom implementation and student participation. Students engaged in problem-solving activities, group discussions, worksheet completion, and post-tests. During the reflection stage, the researcher and mentor teacher collaboratively evaluated students' learning outcomes, classroom engagement, and implementation challenges to determine improvements for the subsequent cycle. The research success criteria comprised improvements in student engagement, problem-solving abilities, the number of students achieving the Minimum Mastery Criteria, and the class average score, with a target of at least 80% classical mastery. At the process level, each meeting was considered successful when at least 75% of students were classified as active based on the observation sheet. Data were collected through written pre-tests and post-tests administered at the pre-cycle and at the end of each cycle, classroom observation sheets completed by the mentor teacher, field notes, and documentation of learning activities. The problem-solving test was developed using a test blueprint based on Polya's four indicators, with equal weighting assigned to each indicator. The student activity observation sheet assessed four aspects: asking questions, group cooperation, participation in discussions, and accuracy in completing worksheets according to Polya's stages. Both instruments underwent qualitative expert review by the supervising lecturer and mentor teacher, focusing on item relevance, language clarity, contextual suitability for fourth-grade students, and alignment with the learning outcomes for area and volume measurement. Revisions were made based on their feedback before the instruments were administered. However, the study did not calculate the Content Validity Index (CVI) or statistically assess inter-rater reliability for the observation sheet; this is acknowledged as a methodological limitation. Quantitative test data were analyzed by comparing scores across the pre-cycle, Cycle I, and Cycle II, calculating normalized gain (N-Gain) to determine the magnitude of improvement in students' problem-solving abilities. N-Gain was calculated using the pre-cycle score as the baseline and each cycle's post-test score as the comparison, with high ($g \geq 0.70$), moderate ($0.30 \leq g < 0.70$), and low ($g < 0.30$) improvement categories. Score differences were further examined using the Wilcoxon signed-rank test for paired data, while the paired-samples t-test was considered when the normality assumption was satisfied based on the Shapiro–Wilk test. Meanwhile, observation data and field notes were analyzed descriptively and qualitatively to provide contextual explanations of changes in student engagement and problem-solving performance across the research cycles.

Results and Discussion

Results

Before the action was given, the researcher conducted initial observation and a diagnostic test to determine the condition of the mathematical problem-solving ability of grade IV

students on the topic of area and volume measurement. The test results showed that of the 24 students, only 1 student (4.2%) achieved the Minimum Mastery Criteria of 70, with a class average score of 37.38. Most students were able to calculate when data and formulas were presented directly but experienced significant difficulties when faced with word problems requiring the identification of information, the formulation of a solving plan, and the checking of results. This condition indicates the need for more structured learning actions that actively involve students in a gradual thinking process. The learning outcomes of students in the pre-cycle are presented in Table 4.

Table 2. Pre-Cycle Learning Outcomes

Indicator	Result
Amount of data worked on	24
Number of items	16
Average score	37.38
Highest score	85
Lowest score	3
Number of students who mastered (Minimum Mastery Criteria ≥ 70)	1 student (4.2%)
Number of students who did not master	23 students (95.8%)

In cycle I, the action was implemented through the application of the Problem Based Learning model assisted by Polya's steps in three meetings, with the topic of area measurement. Students were exposed to contextual problems and guided through the four Polya stages, namely understanding the problem, devising a plan, carrying out the plan, and looking back, which were integrated into the problem orientation and investigation phases of the Problem Based Learning syntax. The process of integrating Polya's steps into the Problem Based Learning flow proved to help students map key information and formulate strategies for solving area measurement problems in a more structured manner. Nevertheless, in cycle I some students still experienced obstacles when verifying answers and translating contextual problems into mathematical formula form. Therefore, improvements to the learning process in the form of emphasizing individual guidance and strengthening the understanding of basic concepts were carried out in the implementation of cycle II. These improvement efforts showed a significant positive impact on improving students' understanding and learning independence. The implication is that the improvement in mathematical problem-solving ability is not only visible from the accuracy of students' work procedures but is also reflected quantitatively through N-Gain scores that increased gradually from cycle I to cycle II. After the action was given, a post-test was conducted to measure students' problem-solving ability. The test results and the calculation of each student's N-Gain in cycle I and cycle II are presented in Table 3.

Table 3. Descriptive Statistics of Pre-Test, Post-Test, and N-Gain Scores of Students in Cycle I and Cycle II (n = 24)

Statistic	Pre-Test	Cycle I Post-Test	Cycle II Post-Test	Cycle I N-Gain	Cycle II N-Gain
N	24	24	24	24	24
Mean	37.38	58.33	68.33	0.332	0.515
Median	41.00	65.00	72.00	0.306	0.550
Standard Deviation	21.60	22.67	21.17	0.248	0.303
Minimum	3	16	28	-0.111	-0.273
Maximum	85	88	100	0.770	1.000

Based on Table 3, the class average score in cycle I increased to 58.33 (Standard Deviation = 22.67) compared to 37.38 (Standard Deviation = 21.60) in the pre-cycle, with 10 of 24 students (41.7%) achieving the Minimum Mastery Criteria. The average N-Gain value in cycle I was 0.332 (Median = 0.306; Standard Deviation = 0.248), included in the moderate category. Nevertheless, two students, namely FH and AD, showed negative N-Gain in cycle I, meaning that their post-test scores were actually lower than their pre-test scores. Field notes indicate that these two students had relatively high pre-cycle scores (69 and 55) compared to the class average, so they possibly experienced a decrease in answer consistency due to less than optimal concentration during the cycle I post-test, not because they did not understand the material from the start; this condition indicates that the improvement resulting from the action was not yet uniform among all students, particularly among students with relatively good initial ability. The learning outcomes of students in cycle I are presented in Table 4.

Table 4. Cycle I Learning Outcomes

Indicator	Result
Amount of data worked on	24
Number of items	8
Average score	58.33
Highest score	88
Lowest score	16
Number of students who mastered (Minimum Mastery Criteria ≥ 70)	10 students (41.7%)
Number of students who did not master	14 students (58.3%)

In addition to the test result data, the researcher together with peer observers conducted observations of the learning implementation and student activities during the process, covering the indicators of asking activity, group cooperation, discussion participation, and accuracy in completing Student Worksheets according to Polya's stages. Specifically, the indicators of group cooperation and completion of Student Worksheets showed the most visible development because students began to get used to discussing according to the flow of Polya's stages.

However, the activity of asking independently and the thoroughness in reflecting on work results still required more intensive encouragement from the educator. The observation results showed that students had begun to be actively involved although in general they were still in the moderately active category, as shown in Table 5.

Table 5. Observation of Student Activities in Cycle I

Activity Indicator	Average Score (Scale 4)	Category
Asking activity	2.4	Moderately Active
Group cooperation	2.8	Moderately Active
Discussion participation	2.5	Moderately Active
Accuracy in completing Student Worksheets	2.6	Moderately Active
Overall average	2.6	Moderately Active

Based on the test and observation results, the researcher together with the observer conducted a reflection on the implementation of the action in cycle I. This evaluation step aimed to identify the strengths that needed to be maintained and the obstacles that needed to be improved in the next cycle. One of the main obstacles found was that some students still had difficulty at the stage of understanding the problem. This obstacle was visible especially in identifying and sorting relevant information from area measurement word problems. In addition, some students also appeared hasty in determining formulas without mapping the relationships between mathematical elements. The group guidance process that was not yet evenly distributed was also suspected of making some students passive and dependent on their peers. As a result, individual conceptual understanding became less than optimal and had an impact on post-test scores. As a follow-up, the educator needed to adjust the time allocation and provide scaffolding that was more focused on the initial stages of problem-solving. This approach was designed to ensure that each group member received proportional guidance according to their level of understanding. Thus, students were expected to be more independent and confident in unraveling the contextual problems given. The various findings and notes from the reflection results are presented in full in Table 6.

All improvement points in the table were then used as a fundamental reference for perfecting the action strategy in cycle II.

Table 6. Cycle I Reflection

Strengths	Obstacles	Improvement Plan
Students began to be enthusiastic about the contextual problem of area measurement	Some students had difficulty identifying information at the stage of understanding the problem	The teacher provides explicit guiding questions at the stage of understanding the problem
Mastery increased from 4.2% to 41.7%	Some students were not yet optimal at the stage of looking back	The teacher adds more modeling examples at the beginning of the session

Based on the results of the cycle I reflection, the action in cycle II was refined by strengthening scaffolding at the stages of understanding the problem and looking back, as well as inserting more modeling examples of volume measurement at the beginning of learning. This improvement was implemented in three meetings with the topic of volume measurement, following the same Problem Based Learning syntax assisted by Polya's steps as in cycle I. After the action was given, a post-test was again conducted to measure the achievement of students' problem-solving ability.

The class average score in cycle II increased to 68.33 (Standard Deviation = 21.17), with 13 of 24 students (54.2%) achieving the Minimum Mastery Criteria. The average N-Gain value in cycle II, calculated from the pre-cycle score as the baseline, was 0.515 (Median = 0.550; Standard Deviation = 0.303), increasing from 0.332 in cycle I and remaining in the moderate category, approaching the high category boundary. The Wilcoxon signed-rank test showed that the increase in N-Gain from cycle I to cycle II was statistically significant ($Z = -2.935$; $p = 0.003$), indicating that the improvement in students' problem-solving ability actually experienced acceleration, not deceleration, as the number of meetings increased and students became accustomed to the Problem Based Learning syntax assisted by Polya's steps. Student AR showed negative N-Gain in cycle II despite showing positive N-Gain in cycle I, while FH and AD, who previously showed negative N-Gain in cycle I, showed improvement with a moderate N-Gain category in cycle II. The phenomenon in AR deserves attention because it is in a different direction from the general trend; field notes indicate that this student was absent from school at one meeting in cycle II so was left behind at the stage of strengthening the understanding of the volume concept, which likely contributed to the decline in his score. The learning outcomes of students in cycle II are presented in Table 7.

Table 7. Cycle II Learning Outcomes

Indicator	Result
Amount of data worked on	24
Number of items	8
Average score	68.33
Highest score	100
Lowest score	28
Number of students who mastered (Minimum Mastery Criteria ≥ 70)	13 students (54.2%)
Number of students who did not master	11 students (45.8%)

The distribution of students' N-Gain categories in both cycles is presented in Table 10 to show the shift in the proportion of students between categories from cycle I to cycle II.

Table 8. Distribution of Students' N-Gain Categories per Cycle

N-Gain Category	Cycle I (n = 24)	Cycle II (n = 24)
High ($g \geq 0.7$)	3	5
Moderate ($0.3 \leq g < 0.7$)	9	13
Low ($0 \leq g < 0.3$)	10	5
Decreased ($g < 0$)	2	1
Total	24	24

Based on the table, the number of students in the high category increased from 3 to 5, the moderate category increased from 9 to 13, while the low category decreased from 10 to 5, and the decreased category decreased from 2 to 1. This distribution shift is consistent with the results of the Wilcoxon test which showed a significant overall increase in N-Gain ($p = 0.003$), and proves that most students who were previously in the low category in cycle I successfully moved to the moderate or high category in cycle II. This condition confirms that the application of Problem Based Learning assisted by Polya's steps consistently facilitates the learning progress of the majority of students as their learning experience with the same syntax increases. Nevertheless, there is still one student (AR) in the decreased category in cycle II, indicating that the even distribution of the action's impact on all students has not been fully achieved and requires further individual assistance. The description of the trend of increasing average scores from the pre-cycle to cycle II is presented visually in Figure 1.

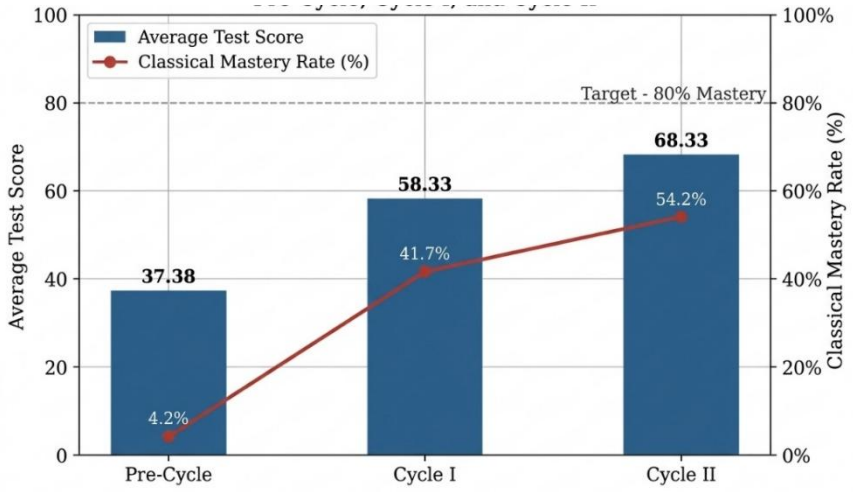


Figure 1. Trend of Average Scores and Classical Mastery from Pre-Cycle to Cycle II

In line with the improvement in test results, the observation of student activities in cycle II also showed improvement compared to cycle I, with students appearing more confident in asking questions and more systematic in applying Polya's stages when completing Student Worksheets. This indicates that the habituation of the Problem Based Learning model assisted by Polya's steps not only boosted academic achievement but also succeeded in building students' independence and structured mindset in learning, as shown in Table 11.

Table 9. Observation of Student Activities in Cycle II

Activity Indicator	Average Score (Scale 4)	Category
Asking activity	3.1	Active
Group cooperation	3.3	Active
Discussion participation	3.2	Active
Accuracy in completing Student Worksheets	3.3	Active
Overall average	3.2	Active

Because classical mastery in cycle II reached 54.2%, not yet meeting the success indicator set at a minimum of 80%, the researcher together with the observer and mentor teacher decided that follow-up in the form of an additional cycle or strengthened guidance at the stages of understanding the problem and looking back was still needed, although the implementation of the action in this study was stopped at the end of cycle II due to the time limitations of the Guided Field Experience Practice implementation. As a solution to this limitation, the improvement and strengthening of learning strategies are recommended to be continued by the mentor teacher in regular classroom learning activities. This step is expected to maintain the consistency of the improvement in students' problem-solving ability until reaching the set mastery target.

To provide a comprehensive picture of the development of students' problem-solving ability during the research, a recapitulation of data from the pre-cycle stage to cycle II was carried out. The data show that the class average score increased consistently at each stage, accompanied by an increase in the number of students achieving mastery and an increase in the average N-Gain from the moderate category in cycle I (0.332) to approaching the high category in cycle II (0.515). The complete comparison between the three stages is presented in Table 12.

To test the significance of the observed improvement, the Shapiro-Wilk normality test was first conducted on the pre-cycle scores, cycle I post-test, and cycle II post-test. The test results showed that the pre-cycle scores ($W = 0.956$; $p = 0.365$) and cycle II post-test ($W = 0.958$; $p = 0.392$) were normally distributed, while the cycle I post-test scores were not normally distributed ($W = 0.909$; $p = 0.034$), so the nonparametric Wilcoxon signed-rank test was used as the main test, supported by the paired t-test as a comparison. The test results showed that the score improvement from the pre-cycle to cycle I was statistically significant (Wilcoxon, $Z = -4.129$; $p < 0.001$; paired t-test, $t(23) = 6.06$; $p < 0.001$; Cohen's $d = 1.24$), the improvement from cycle I to cycle II was also significant (Wilcoxon, $Z = -2.935$; $p = 0.003$; paired t-test, $t(23) = 3.00$; $p = 0.006$; Cohen's $d = 0.61$), and the cumulative improvement from the pre-cycle to cycle II was also significant with a large effect size (Wilcoxon, $Z = -4.200$; $p < 0.001$; paired t-test, $t(23) = 8.61$; $p < 0.001$; Cohen's $d = 1.76$). These findings provide statistical evidence strengthening that the improvement in students' problem-solving ability in this study is not merely random fluctuation but a significant and consistent change at each stage of the action, with effect sizes generally classified as large according to Cohen's criteria. Nevertheless, this statistical significance needs to be interpreted proportionally considering that classical mastery at the end of cycle II (54.2%) is still below the set success target of 80%, so that the statistically significant improvement is not yet fully equivalent to the achievement of practical learning targets.

Table 10. Comparison of Classical Mastery in Pre-Cycle, Cycle I, and Cycle II

Aspect	Pre-Cycle	Cycle I	Cycle II
Class average score	37.38	58.33	68.33
Number of students who mastered (Minimum Mastery Criteria ≥ 70)	1	10	13
Classical mastery (%)	4.2	41.7	54.2
Number of students whose scores decreased from the previous cycle	—	2	1
Average N-Gain (from pre-cycle baseline)	—	0.332 (Moderate)	0.515 (Moderate)

Discussion

The findings of this study indicate that the integration of Polya's steps into the Problem Based Learning syntax is able to encourage a significant improvement in students' mathematical problem-solving ability and even tends to experience acceleration from cycle I to cycle II (N-Gain increased from 0.332 to 0.515; Wilcoxon, p = 0.003), although this improvement was not yet evenly distributed among all students and had not reached the 80% classical mastery target. This gradual improvement pattern is consistent with the results of the classroom action research of Widyasari, Hadiyanti, and Kriswanto (2023) which showed an improvement in problem-solving ability from the sufficient category (37.5%) in the pre-cycle to the moderate category (55%) in cycle I and the good category (70%) in cycle II through the application of Problem Based Learning without explicit integration of Polya's steps. The similarity of the improvement pattern in the two studies strengthens the conjecture that Problem Based Learning is generally effective in improving the problem-solving ability of elementary school students, while the explicit integration of Polya's steps in this study provides added value in the form of a reflective framework that helps students overcome obstacles at the stage of understanding the problem, as also emphasized by Yustinaningrum (2021) and Isnaini, Ahied, Qomaria, and Munawaroh (2021) who asserted that the obstacles to problem-solving in elementary and secondary school students generally originate from the most basic stage, namely when students fail to identify the information known and asked accurately so that it has an impact on the failure of the subsequent stages. Nevertheless, because this study did not use a comparison group without Polya integration, the claim regarding the specific added value of Polya integration above the contribution of Problem Based Learning alone is still tentative and needs to be tested further through an experimental design with a control group.

Theoretically, this finding strengthens the argument that the success of applying Polya's stages depends heavily on the quality of guidance and scaffolding provided by the teacher, especially at the stages of understanding the problem and devising a plan (Ambrus & Barczi-Veres, 2022). This finding is consistent with the view that the quality of learning is determined by the teacher's ability to design challenging learning experiences while providing proportional support, including in facilitating dialogue and student reflection during the investigation process (Gultom, 2025; Manobi, Sumadi, & Abdillah, 2024). The theoretical contribution of this study lies in strengthening the empirical evidence that the explicit integration of the four Polya stages in the problem orientation and investigation phases of the Problem Based Learning syntax can be applied consistently to the topic of area and volume measurement in grade IV, a context that has not been widely explored in previous studies as mentioned in the Introduction. Practically, these results indicate that teachers need to provide explicit guiding questions at the stages of understanding the problem and looking back, rather than merely asking students to go through the sequence of steps mechanically (Stacey, 2022), so that the benefits of this approach can be felt more evenly by all students, including students with low initial achievement. In addition, teachers also need to pay attention to the social-affective dimension of students, because social attitudes and discipline cultivated through modeling and habituation at school also support students' independence and perseverance in completing challenging problem-solving tasks (Lessnusa, Ritiauw, & Rusfadir, 2024; Tasane, Salamor, & Ritiauw, 2024).

Although the overall trend shows an acceleration of improvement, the variation in results between students remains an important note. One student (AR) who previously showed positive N-Gain in cycle I actually experienced a decline in cycle II, while two other students (FH and AD) who previously declined in cycle I managed to recover in cycle II. This non-uniform pattern is likely related to the characteristics of the material: the volume measurement problems in cycle II demand higher spatial visualization compared to the area measurement problems in cycle I, consistent with the finding that students experience significant difficulties in generalizing geometric patterns from visual representations of more complex shapes (Ambrus & Barczi-Veres, 2022). One alternative explanation worth considering is the possibility of cognitive overload in some students, namely a condition when students must process a relatively new and abstract volume concept simultaneously with the demand to carry out the four Polya stages explicitly, so that the working memory capacity of students with lower initial ability becomes burdened and has an impact on the decline in individual performance, although on average the class trend of improvement is maintained. This explanation is speculative because this study did not measure cognitive load directly, but it is quite reasonable considering that field notes indicate some students still needed repeated explanations at the stage of devising a plan when faced with volume problems. This variation in results indicates that the benefits of Polya's stages have not been fully felt evenly and possibly reflect differences in the intensity of individual guidance received by each student during learning, a limitation that needs to be overcome through worked examples and gradual release of responsibility in the next learning design, particularly at the initial stage of introducing volume material.

The classical mastery that has not reached the 80% target at the end of cycle II confirms that the two-cycle action is not yet sufficient to change the problem-solving ability of all students evenly, so that follow-up in the form of an additional cycle or strengthened guidance at the stages of understanding the problem and looking back, particularly for the volume measurement material, is still needed. The Classroom Action Research design with a single group without a comparison in this study also limits the possibility of separating the influence of the learning action from external factors such as the difficulty level of the test instruments between cycles, maturation, and testing effects, so that the interpretation of the results needs to be done carefully and not interpreted as a single causal proof of the effectiveness of the applied learning model.

Conclusion

The application of the Problem Based Learning model assisted by Polya's steps is proven to improve the mathematical problem-solving ability of grade IV students at Sekolah Dasar Negeri Gadang 3 Kota Malang on the topic of area and volume measurement, indicated by the increase in the average score from 37.38 in the pre-cycle to 58.33 in cycle I and 68.33 in cycle II, the increase in classical mastery from 4.2% to 41.7% and 54.2%, the average N-Gain of 0.332 in cycle I increasing to 0.515 in cycle II (both in the moderate category), as well as statistically significant improvement at each stage (Wilcoxon, $p < 0.01$, with a large effect size). Nevertheless, this study also shows that this model is not yet effective enough to achieve the 80% classical mastery target in two cycles, and the improvement that occurred is not yet evenly distributed because there are still students with low or negative N-Gain, particularly in the volume material

which demands higher spatial visualization; this condition indicates that the integration of Problem Based Learning and Polya's steps requires a longer adaptation time and explicit strengthening at the metacognitive stage, particularly the stages of understanding the problem and looking back, so that its benefits are felt more evenly by all students. Teachers are advised to allocate special time for guidance at the stage of understanding the problem through explicit guiding questions for students with low initial ability, before these students enter the group problem-solving stage; schools are advised to support the strengthening of teacher competence in designing problem-based learning integrated with systematic problem-solving strategies; and future researchers are advised to extend the number of cycles or the duration of the research and consider a design with a comparison group to strengthen the validity of the findings regarding the effectiveness of the applied model. The theoretical contribution of this study lies in the enrichment of instructional design that explicitly integrates Polya's heuristic strategy as a metacognitive device into the Problem Based Learning syntax framework, particularly on the topic of area and volume measurement in grade IV of elementary school.

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Authors' Note

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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