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Implementation of a Mathematics Teaching Module with the PBL Model to Improve Grade 4 Students' Critical Thinking Skills at MI Kahasri Probolinggo

Rizka Kurnia[1]✉, M. Syahri[2], Dyah Worowirastri Ekowati[3]
(1,2,3) Universitas Muhammadiyah Malang, Kota Malang, Indonesia

✉ **Corresponding author**
ririskurnia97@webmail.umm.ac.id

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ABSTRACT

Critical thinking is a key outcome of mathematics learning, yet teacher-centered instruction leaves little room for students to question, reason, and justify solutions. This study describes how a Problem Based Learning (PBL) mathematics teaching module on area and volume measurement was implemented in Grade 4 at MI Kahasri Probolinggo and which critical thinking indicators emerged among students. A qualitative descriptive case study involved 30 students in eight groups and the Grade 4 teachers. Observation, interviews, and documentation were analyzed using Miles, Huberman, and Saldaña's interactive model and four of Facione's indicators: interpretation, analysis, inference, and evaluation. The module was enacted following the five PBL phases, and teachers reported that students became more active and confident in discussion. Fifteen of the 30 students showed all four indicators; interpretation (28 students) and analysis (26) appeared most often, whereas inference (20) and evaluation (18) were less evenly developed. The findings suggest that a PBL-based module can create opportunities for critical thinking in primary mathematics, particularly for interpretation and analysis, while evaluation needs sustained scaffolding. Because the design involved one class without a baseline measure, the findings do not establish effectiveness.

Berpikir kritis merupakan capaian penting pembelajaran matematika, tetapi pembelajaran yang berpusat pada guru memberi ruang terbatas bagi peserta didik untuk bertanya, bernalar, dan membenarkan jawaban. Penelitian ini mendeskripsikan penerapan modul ajar matematika berbasis Problem Based Learning (PBL) pada materi pengukuran luas dan volume di kelas 4 MI Kahasri Probolinggo serta indikator berpikir kritis yang muncul pada peserta didik. Penelitian menggunakan studi kasus deskriptif kualitatif dengan 30 peserta didik yang bekerja dalam delapan kelompok dan guru kelas 4. Observasi, wawancara, dan dokumentasi dianalisis dengan model interaktif Miles, Huberman, dan Saldaña serta empat indikator Facione: interpretasi, analisis, inferensi, dan evaluasi. Modul diterapkan sesuai lima tahap PBL, dan guru melaporkan bahwa peserta didik menjadi lebih aktif dan percaya diri dalam diskusi. Lima belas dari 30 peserta didik menunjukkan keempat indikator; interpretasi (28 peserta didik) dan analisis (26) paling sering muncul, sedangkan inferensi (20) dan evaluasi (18) berkembang kurang merata. Temuan ini mengisyaratkan bahwa modul berbasis PBL dapat menyediakan kesempatan berpikir kritis secara berkelanjutan dalam matematika sekolah dasar, terutama untuk interpretasi dan analisis, sedangkan evaluasi memerlukan pendampingan yang konsisten. Karena penelitian ini melibatkan satu kelas tanpa pengukuran awal, temuan tidak membuktikan efektivitas.

Keywords: Problem Based Learning, teaching module, critical thinking skills, madrasah ibtidaiyah

Introduction

Mathematics underlies the natural sciences, technology, and economics, yet its abstract concepts are often difficult for students to grasp thoroughly (Zulmaulida et al., 2024). Learning mathematics is therefore expected to develop not only procedural skill but also more careful and critical ways of thinking (Saputra & Zulmaulida, 2025). Critical thinking can be understood as purposeful, reasoned judgment that involves interpreting, analyzing, evaluating, and drawing inferences from information (Facione, 2013; Qohar & Sulandra, 2021). It overlaps with problem solving, but it additionally requires the ability to give reasons for a conclusion (Sipahutar, 2022).

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A meta-analysis by Abrami et al. (2015) found that critical thinking instruction is more effective when it includes dialogue, authentic problems, and guidance from the teacher, which points to the importance of how classroom activities are designed.

In many Indonesian primary and madrasah classrooms, however, mathematics is still taught through conventional teacher-centered models (Zainal, 2022). An initial observation conducted on 1 October 2025 at MI Kahasri Probolinggo, together with the Grade 4 homeroom teacher, showed a similar pattern. Assessment items were mostly limited to low-level cognitive demands, students tended to memorize material rather than reason about it, and instruction relied on lectures, worked examples, and textual individual tasks. Students were generally passive, rarely asked questions, and found it difficult to give opinions or solutions to simple problems drawn from their surroundings. This is a particular concern for learners aged 7–10 years, who are in the concrete operational stage and need concrete experiences to make abstract mathematical ideas meaningful.

Problem Based Learning (PBL) is one alternative that responds to this situation. PBL places a real or contextual problem at the starting point of learning, so that students construct knowledge by identifying, analyzing, and resolving the problem rather than receiving a complete concept first (Barrows, as cited in Kusumawardani et al., 2022). Reviews of PBL suggest that it supports flexible knowledge, problem-solving, self-directed learning, and collaboration (Hmelo-Silver, 2004), and that its advantages are clearer for long-term retention and skill application than for short-term test performance (Strobel & van Barneveld, 2009). Its typical sequence comprises orientation to the problem, organizing students for learning, guiding individual and group investigation, developing and presenting work, and analyzing and evaluating the problem-solving process (Rahmawati et al., 2024; Siswanto & Rahayu, 2025; Putri et al., 2025)). The success of this sequence depends on how it is planned and documented, which is the function of a teaching module (*modul ajar*). A teaching module is a systematically arranged learning tool that links learning objectives, materials, methods, exercises, and assessment into one coherent unit (Putri et al., 2025; Rismawanda & Mustika, 2024).

Previous studies have examined PBL-based modules and PBL implementation in primary mathematics from several angles. Hariri et al. (2021) developed a PBL-based mathematics teaching module and reported gains in students' mathematical critical thinking, and Husniah and Azka (2022) developed a PBL mathematics module to facilitate mathematical reasoning. Rahmadana et al. (2023) reported a statistically significant difference in primary students' critical thinking before and after PBL in an ex post facto design, while Nashiroh et al. (2024) and Utomo et al. (2023) applied PBL in Grade 4 mathematics through classroom action research and reported improved critical thinking and learning outcomes across cycles. These studies establish that PBL is promising, but most of them focus on module development or on outcome gains. Less is known about how a PBL-based module is actually enacted, phase by phase, in a madrasah ibtidaiyah classroom, and about how the different components of critical thinking are distributed among individual students working in groups. Such descriptive evidence is useful because it shows which parts of critical thinking a module readily supports and which parts remain fragile.

This study addresses that gap through a qualitative case study at MI Kahasri Probolinggo. It asks two questions: (1) how is a PBL-based mathematics teaching module on area and volume measurement implemented in Grade 4, and (2) which critical thinking indicators, according to Facione's framework, appear among students during its implementation? The study contributes a detailed account of module enactment and an indicator-level description of students' critical

thinking, and it discusses the pedagogical implications for teachers who plan to use PBL modules in primary mathematics.

Methods

This study used a qualitative approach with a descriptive case study design to explore, in depth and in natural conditions, how a PBL-based mathematics teaching module was implemented in a primary-level classroom (Creswell & Poth, 2018). The researcher did not manipulate the learning process; the study began from a real problem in classroom learning and examined the implementation as it occurred. The case was a Grade 4 class at MI Kahasri, located on Jl. Mayjend Haryono No. 91, Mayangan District, Probolinggo City, East Java, Indonesia, during the 2025/2026 academic year. The school had 588 students, of whom 84 were in Grade 4.

The participants were 30 Grade 4 students (13 boys and 17 girls, aged about 9–10 years), who worked in eight small heterogeneous groups of three to four students, and the Grade 4 teachers who taught the lessons and served as key informants. The principal was designated as an additional informant for source triangulation. The learning topic was the measurement of area and volume, with the learning outcome that students can measure and estimate area and volume using non-standard and standard units with whole numbers. To protect confidentiality, students and teachers are identified by codes in this article (e.g., G2-S3 for the third student in Group 2, and T1 and T2 for the two teachers).

Data were collected through three techniques (Table 1). Observation (Daruhadi & Sopiati, 2024) recorded the teacher's preparation and use of the module, the enactment of each PBL phase, student activity, students' critical thinking behaviors, and classroom management. Interviews (Fadila et al., 2025) were held with teachers and students to obtain their understanding of PBL, their experience of the lessons, and perceived changes in students' thinking. Documentation collected the teaching module, the learning objective flow (ATP), student worksheets (LKPD), group work and presentation results, and photographs of learning activities. The researcher was the main instrument and used guides prepared for each technique.

Table 1. Data collection techniques and focus

Technique	Focus of the instrument	Sources
Observation	Teacher's preparation and use of the PBL module; enactment of PBL phases; student activity (asking, discussing, presenting); critical thinking behaviors; classroom management	Teacher, students, learning activities
Interview	Teachers' understanding and strategy of PBL; changes in students' thinking, participation, and learning results; students' experience and understanding of the material	Teachers, students, (principal as additional informant)
Documentation	Teaching module, learning objective flow (ATP), student worksheets (LKPD), group work and presentation results, photographs/video of activities	Teacher and student documents

Data were analyzed using the interactive model of Miles et al. (2014), consisting of data condensation, data display, and conclusion drawing and verification. Field notes and interview transcripts were condensed and coded deductively using four indicators from Facione's (2013) critical thinking framework: interpretation (understanding and giving

meaning to a problem), analysis (identifying relationships among information and concepts), inference (drawing reasoned conclusions from evidence), and evaluation (assessing the credibility and correctness of statements and solutions). The remaining two Facione skills, explanation and self-regulation, were not coded as separate categories. For each student, the observed behaviors were matched to the indicators, and the results were then summarized by group and for the whole class. The indicator counts reported below were tallied from these group-level records.

Credibility was supported by source triangulation (comparing the accounts of teachers, students, and the researcher's observation) and by cross-checking observation and interview findings against documentation, in line with the credibility criteria of Lincoln and Guba (1985). Rich description of the lesson activities and the use of authentic documentation were intended to make the interpretation traceable. Because this is a single-class case study, the findings are descriptive and context-bound.

Result

The findings are presented in three parts: the implementation of the PBL-based teaching module, the teachers' and students' accounts of learning, and the critical thinking indicators shown by students.

1. Implementation of the PBL-Based Mathematics Teaching Module

Observation showed that the teacher understood the principles of PBL, designed learning activities that matched them, and prepared relevant materials and resources. Before the lesson, the teacher prepared the teaching module, student worksheets, simple measuring tools, learning media, and trigger questions related to students' daily lives. The lesson opened with greetings, a joint prayer, and apperception. The teacher then asked everyday questions, such as the area of a classroom desk, the classroom floor, or the whiteboard, and the volume of water in a bucket, to link the topic to students' experience. The teacher also managed the class well and gave constructive feedback while the lesson was running. Table 2 summarizes how each PBL phase was enacted.

Table 2. Enactment of the PBL phases in the area and volume lesson

PBL phase	Teacher's activity	Observed student activity
1. Orientation to the problem	Presented a real problem, e.g., finding the area of each student's desk by covering it with books	Became interested because they could imagine the use of the topic in daily life
2. Organizing students to learn	Divided students into small heterogeneous groups; distributed the worksheet (LKPD)	Discussed in groups to find solutions to the problem
3. Guiding investigation	Walked between groups, gave directions, and helped students who had difficulty	Measured classroom objects with rulers or simple tools, recorded results, calculated area and volume, and discussed them
4. Developing and presenting work	Gave other groups a chance to respond or ask questions	Presented solution steps; explained reasons for answers; respected and accepted input from peers
5. Analyzing and evaluating the process	Led reflection; reinforced concepts of area and volume; helped correct inaccurate answers	Reflected on the process and corrected answers

Several observations stand out. In the first phase, the problem was simple but concrete: students covered their own desks with their books to find the area, and this made the problem easy to imagine. During the investigation phase, students were more active than in earlier lectures. They asked one another questions, discussed, and tried to find answers with group

mates, and some students who were usually passive began to give opinions. In the presentation phase, students became more willing to speak in front of the class and began to explain why they chose a particular answer. They also learned to respect their peers' views and to accept input from other groups. In the final phase, the teacher and students reflected together, and the teacher strengthened the concepts of area and volume and helped students correct inaccurate answers.

2. Teachers' and Students' Accounts

The teachers interviewed regarded the model as beneficial for mathematics learning. T1 said that students found the material easier to understand because they were invited to solve real problems, either together in groups or independently, and that the aim was to see how they think and look for solutions. Regarding change in critical thinking, T1 stated: "Changes in students' critical thinking are very visible, especially among students who are often active in class; their way of thinking can also be seen from being more confident and able to express their opinions in class." T1 therefore linked critical thinking with active participation.

T2 agreed but added that students who were initially less active could also change when given opportunities. As an example, T2 described a group presentation task in which a student who usually did not speak explained ideas clearly. T2 concluded that, with the right support, all students can learn to think critically and confidently. A student offered a consistent perspective: mathematics was easier to understand in group discussion, and the student could express opinions more often when discussing with friends. Taken together, these accounts suggest that the learning conditions created by the module (small groups, shared problems, and presentation) increased students' opportunities to speak and justify their ideas. They are, however, perceptions reported by participants and cannot by themselves show how large the change was.

3. Critical Thinking Indicators among Students

Students' critical thinking during the PBL lessons was analyzed through four indicators: interpretation, analysis, inference, and evaluation. Table 3 shows the pattern by group, and Figure 1 shows how many students met each indicator. In total, 15 of the 30 students (50%) showed all four indicators. Groups 2, 4, and 8 were the groups in which every member did so. In the other five groups, indicators were distributed unevenly among members.

Table 3. Critical thinking indicators by group

Group	Students	All four indicators	Pattern observed
G1	3	0	Indicators distributed unevenly: one student showed interpretation and analysis, one analysis and evaluation, one inference, analysis, and evaluation
G2	4	4	All members showed interpretation, analysis, inference, and evaluation
G3	4	1	One student showed all four; others showed interpretation only, interpretation with analysis, or interpretation with inference
G4	4	4	All members showed all four indicators
G5	3	0	Interpretation only (one student) or interpretation with analysis (two); no inference or evaluation
G6	4	1	One student showed all four; two showed interpretation, analysis, and inference; one showed interpretation only
G7	4	1	One student showed all four; others showed interpretation with analysis and evaluation, with analysis and inference, or with analysis only
G8	4	4	All members showed all four indicators
Total	**30**	**15**	**Interpretation 28, analysis 26, inference 20, evaluation 18**

Group 2 illustrates the strongest pattern. Its members explained the problem in their own simple words, compared several solution strategies, drew conclusions from the group's data, and checked calculation errors (G2-S2, G2-S3). In Group 1, by contrast, no single member showed all four indicators; the group's skills were complementary rather than complete, with one student strong in interpretation and analysis, another in analysis and evaluation, and a third in inference, analysis, and evaluation. Group 5 was the group most in need of guidance: no member showed inference or evaluation, and the students mostly understood instructions and information in the worksheet and counted most unit squares correctly, but did not state or check conclusions.

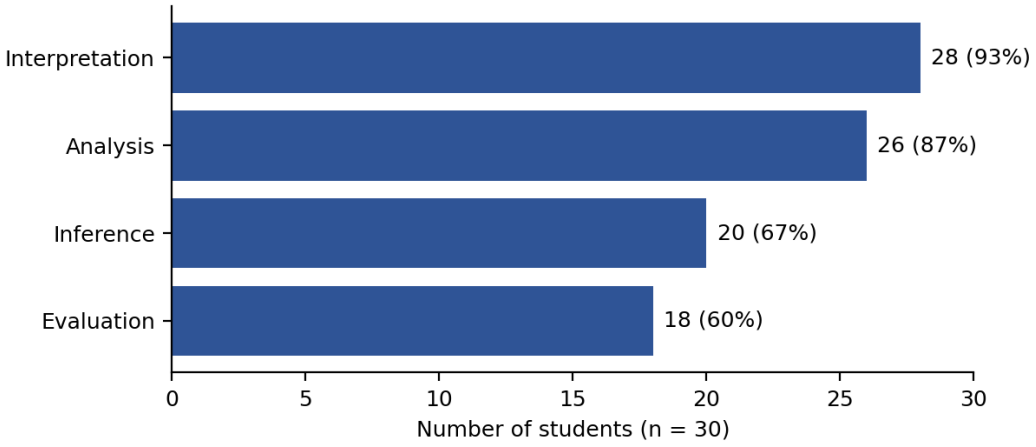


Figure 1. Number of students (n = 30) meeting each critical thinking indicator.

Across the class, interpretation was the indicator that appeared most often (28 students, 93%), followed by analysis (26 students, 87%), inference (20 students, 67%), and evaluation (18 students, 60%). Most students could understand the problem, identify the known information, and restate it in their own words, especially when it was connected to real objects in the classroom. Analysis was visible when students decided on a strategy, selected a suitable formula, connected data to mathematical concepts, and discussed alternative solutions. For example, when finding the area of the whiteboard, students first determined its length and width and then discussed which formula to use and how to carry out the calculation. When finding the volume of water, they recognized that length, width, and height were needed and connected the three values with the volume formula they had learned. In the discussions, students gave reasons for the steps they chose rather than only repeating formulas.

Inference was developing but uneven. Students who met it could conclude from measurement results, discussion data, or group calculations, but some still relied on group mates or the teacher to state the conclusion. Evaluation was the least frequent indicator. Students who met it were able to check the group's calculation, point out errors in another group's result, or correct an inaccurate answer; other students were reluctant to criticize or correct the work of other groups, and evaluation appeared mostly among students who also showed good conceptual understanding and active participation in the discussion.

Discussion

1. Enacting a PBL Module: Contextual Problems and Active Participation

The first research question concerned how the module was implemented. The findings show that the module functioned as a practical script that connected the PBL phases with concrete classroom activities: measuring familiar objects, working in heterogeneous groups, presenting results, and reflecting. This is consistent with descriptions of a teaching module as a coherent unit of objectives, materials, methods, exercises, and assessment (Putri et al., 2025;

Rismawanda & Mustika, 2024), and with the argument that the quality of a module partly depends on the teacher's pedagogical competence in using it (Salsabilla et al., 2023). It also supports literature reviews that identify PBL as a way to develop primary students' critical thinking (Aisyah & Gumala, 2025) and the observation of Sipahutar (2022) that PBL can place students in more active roles in which they develop critical and creative thinking, and the claim that PBL is suited to contextual and real-life problems (Fazryn et al., 2023; Tahsinia et al., 2022).

The shift from lecture-based to problem-based lessons also matters for the concrete operational learners in this class. Covering a desk with books or measuring a whiteboard allowed students to build the idea of area from physical experience before formalizing it, so the abstract concept was approached through materials they could touch and count. The teachers' accounts that previously passive students began to speak are in line with research that links PBL with higher engagement and collaboration (Hmelo-Silver, 2004; Nashiroh et al., 2024). Still, the data in this study are observations and perceptions, not pre- and post-measurements. The article therefore does not claim that PBL caused a measurable improvement in critical thinking; rather, it documents that the module produced classroom conditions in which critical thinking behaviors could be observed and talked about.

2. Why Interpretation and Analysis Were Stronger than Inference and Evaluation

The second question concerned which critical thinking indicators appeared. The descending order from interpretation to analysis, inference, and evaluation fits the nature of the tasks and the phases of PBL. Interpretation is the entry point of the framework, because it concerns understanding and giving meaning to information (Facione, 2013), and the orientation phase deliberately used concrete, familiar problems that students could easily restate. Analysis was supported by the investigation phase, in which students had to identify information, relate it to the formula, and justify their strategy within the group. These two indicators are also closest to the routine mathematical work of identifying given information and choosing a procedure, which may explain why they were widely shown.

Inference and evaluation are more demanding because they require students to take a position on their own or others' reasoning. Inference calls for rational conclusions based on evidence, and evaluation calls for judging the credibility of statements and the correctness of solutions (Facione, 2013). The reluctance to criticize other groups, and the finding that evaluation occurred mainly among students with firm conceptual understanding, suggests that confidence and conceptual mastery are preconditions. This agrees with the view that critical thinking is a trainable ability that develops through repeated opportunities (Qohar & Sulandra, 2021), and with Abrami et al. (2015), who emphasized dialogue and guidance. In practical terms, the presentation and reflection phases may need more explicit scaffolding, such as sentence starters for giving feedback ("I agree because…", "I found a different result because…"), checklists for verifying calculations, and a requirement that each group state a conclusion in its own words.

The group-level pattern adds a further point. Groups 2, 4, and 8 were uniformly strong, whereas Groups 1 and 5 contained students whose strengths did not overlap or who remained at the interpretation and analysis level. This indicates that heterogeneous grouping does not automatically spread critical thinking evenly: in some groups, the indicators were divided among members rather than shared. Teachers can respond by assigning rotating roles (for example, reader, calculator, checker, and reporter) so that every student has to practice inference and evaluation, and by providing targeted prompts to groups that do not yet show these indicators.

3. Implications and Limitations

For teachers, the results suggest that a PBL module is most useful when it specifies not only the problem and the steps, but also the questions and routines that elicit inference and evaluation. For schools, the findings support the provision of training and mentoring so that teachers can design and adapt PBL modules, as well as the provision of measuring tools and media that make concrete investigation possible. For future research, the descriptive evidence reported here can guide the design of studies with pre- and post-tests, comparison classes, or multiple cycles, in order to test whether the pattern is linked to improved outcomes.

Several limitations should be noted. The study involved a single class in one madrasah, so the findings cannot be generalized. The indicator coding was based on observed behaviors and records in one unit of instruction and used four of Facione's six skills. No baseline measure was available, and the improvement reported by teachers is a perception rather than a measured gain. Finally, the indicator counts were tallied by the researcher from group-level records, and independent coding by a second rater would strengthen their reliability.

Conclusion

This study described the implementation of a PBL-based mathematics teaching module on area and volume measurement in Grade 4 at MI Kahasri Probolinggo and the critical thinking indicators that appeared among students. The module was enacted in accordance with the five PBL phases and made students more active, enthusiastic, and confident in group discussion, according to observations and teacher accounts. Fifteen of the 30 students showed all four indicators; interpretation and analysis were the most frequent, while inference and evaluation were less evenly developed.

The findings imply that PBL modules can provide regular opportunities for critical thinking in primary mathematics, and that evaluation and inference need explicit scaffolding through structured feedback, role rotation, and reflection routines. Schools should support teachers with training and with learning media and measuring tools. Because the study is a single-class descriptive case without a baseline, further research using pre- and post-measures, comparison groups, and independent coding in other grades and topics is needed to test whether PBL-based modules improve critical thinking.

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