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Improving Mathematical Critical Thinking Among Junior Secondary Students: A Problem-Based Learning Approach to Algebraic Content

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Abstract: The purpose of this research is to examine how the Problem-Based Learning (PBL) model can be effectively applied to foster critical thinking abilities in junior secondary students, particularly within the domain of algebra. This study employed a qualitative approach with a teaching experiment design conducted in Grade VII A (29 students) at SMP PGRI II Wajak over four sessions. Data were collected through observation, pretest-posttest, student worksheets (LKPD), and questionnaires about learning motivation. According to Facione, the tool used to evaluate critical thinking skills includes six indicators: The study's findings indicate notable progress in students' critical thinking skills across six core dimensions: interpretation, analysis, evaluation, inference (conclusion), explanation, and self regulation evident both in their problem-solving performance and throughout the learning process. Both the N-Gain results, which were categorized as high (62.07%) and medium (37.93%), and the observation results, which demonstrated the domination of the good to very good category during the third meeting, demonstrate this growth. These results suggest that using the PBL paradigm can enhance students' quantitative critical thinking abilities and possibly boost their enthusiasm to learn. This study suggests using PBL as an alternative learning approach focused on fostering the growth of higher order thinking abilities.

INTRODUCTION

Education in mathematics promotes societal advancement. Everyone ought to do well in their math studies. The National Council of Teachers of Mathematics states that the concept of learning is that students should learn mathematics well (NCTM, 2020), and the principle of effective teaching is that students should know and be aware of the necessity of studying mathematics to assist their learning of mathematics (Saleh Haji, 2019). Learning mathematics is crucial for everyday life and can help people build logical, mathematical, critical, and creative thinking abilities (Arti et al., 2020; Sariningsih & Purwasih, 2017).

Mathematics encompasses structured systems involving patterns, quantities, shapes, and related abstract concepts. It is commonly organized into three core domains: algebra, geometry, and analysis. While mathematics is sometimes perceived as progressing from simple to complex topics, in practice it constitutes a highly sophisticated mental discipline. It demands deep understanding of abstract ideas, symbolic representations, logical structures, and relational reasoning and the ability to apply these elements effectively to real-world situations (Kasmaja, 2016; Ramadan & Susilo, 2019).

Algebra is widely regarded as a challenging area of mathematics due to its abstract nature. Mastering algebraic concepts demands more than procedural knowledge; it requires well-developed mathematical reasoning and, crucially, strong critical thinking skills. Students must apply these abilities to thoughtfully examine the logic behind theorems, proofs, and algebraic definitions, while also remaining attentive to the contextual demands of each problem. To nurture such competencies, teachers are encouraged to integrate reading and writing into mathematics instruction. This literacy infused approach empowers students to move beyond rote memorization and instead actively question, analyze, solve, construct, interpret, and discuss mathematical ideas during learning activities (Zanthy, 2016). In contrast, critical thinking represents a higher level cognitive competency that students must develop. It encompasses the capacity to engage in reasoned, logical, and constructive thought, which can be applied to evaluate real world situations and arrive at well considered conclusions and decisions (Asmar & Delyana, 2020).

The learning paradigm that uses problem-based learning, or PBL, has the potential to improve students' mathematical effectiveness. PBL's goal is to make connections between the steps (Trullàs et al., 2022; Yew & Goh, 2016). Enhancing students' capacity to methodically explore issues or queries is the primary objective. Enhancing pupils' capacity for independent learning is the second objective. Acquiring or mastering content is the third, if not crucial, objective (Ratnasari, 2019).

Findings from interviews conducted at SMP PGRI II Wajak reveal that students perceive mathematics as the most difficult subject, often describing it as boring and unengaging. This perception contributes to a passive learning attitude, wherein students typically rely on rote memorization of formulas rather than engaging deeply with mathematical concepts. In particular, students struggle to grasp foundational algebraic ideas, which underpin much of the secondary mathematics curriculum. Both students and teachers regard the prevailing teaching approach as ineffective in addressing these challenges and fostering meaningful understanding.

Students instructed through traditional teaching methods consistently demonstrate lower performance compared to those taught using Problem-Based Learning (PBL), a model widely endorsed for its effectiveness in fostering and enhancing critical thinking skills in classroom settings (Gumisirizah et al., 2024; Hidajat, 2023; Molande et al., 2017). Problem-Based Learning (PBL) significantly influences students’ development of mathematical critical thinking, with this effect shaped by both their prior mathematical proficiency and their school level. The analysis further revealed a statistically significant difference in mathematics learning outcomes between students with high versus low critical thinking abilities. However, no significant difference was found between the experimental and control conditions in terms of overall learning gains. Moreover, the study detected no interaction effects either between the instructional approach and school level, or between students’ initial mathematical critical thinking ability and the type of learning approach employed (Crowley, 2015; Pratiwi & Setyaningtyas, 2020; Yu & Zin, 2023).

Research by Pramuditya et al. (2019) and Septiana et al. (2019) shows a clear link between students' mathematical ability and their critical thinking performance based on the FRISCO indicators (Focus, Reasoning, Inference, Situation, Options, and Conclusion). Students with high mathematical ability exhibited excellent critical thinking skills, as they fulfilled all FRISCO criteria. Those with moderate ability demonstrated good critical thinking by meeting several indicators, whereas students with low mathematical ability showed weak critical thinking due to their failure to satisfy many of the FRISCO components. The studies further identified key factors contributing to students' underdeveloped critical thinking: minimal participation in classroom questioning, limited understanding of core mathematical concepts, and insufficient exposure to practice problems that vary in complexity. Additionally, some students struggled with basic tasks such as determining surface area not because of conceptual confusion, but simply because they had forgotten the relevant formula. (Pramuditya et al., 2019; Septiana et al., 2019).

Herdiman et al. (2018) found that most students had difficulty on questions that assessed basic thinking indicators, and questions that targeted evaluation and conclusion indicators. Follow-up interviews revealed that students were uncertain about which mathematical formulas to apply when addressing conceptual problems. Based on these findings, the researchers recommend integrating instructional approaches that actively support deeper conceptual understanding into the teaching process, as such strategies are essential for fostering robust mathematical critical thinking skills (Herdiman et al., 2018).

This study aligns with prior research in its focus on strengthening mathematical critical thinking skills among junior secondary students, its consideration of the influence of foundational mathematical competencies, and its recognition that active learning approaches are essential to address gaps in conceptual understanding. This study differs from other Problem-Based Learning (PBL) teaching experiments in several key ways: it specifically focuses on developing mathematical critical thinking within algebra content for Grade VII junior secondary students, employs a teaching experiment design implemented in a real regular classroom (rather than an artificial or controlled setting), and integrates PISA style assessment instruments with in depth analysis of all six Facione based critical thinking indicators (interpretation, analysis, evaluation, inference, explanation, and self-regulation). Moreover, the researcher acted simultaneously as both teacher and investigator, making the intervention more authentic and responsive to actual classroom challenges such as students' difficulties in grasping algebraic concepts and their tendency to rely on rote memorization of formulas. This approach offers a strong contextual contribution compared to generic PBL studies that merely measure learning gains or are applied outside the domain of mathematics.

METHOD

This study adopts a teaching experiment design, implemented in three phases: (1) preparation, involving the development of lesson plans embedded with pretest and posttest items and grounded in the Problem-Based Learning (PBL) model; (2) implementation, carried out over four classroom sessions with 28 seventh grade students at SMP PGRI II Wajak, focusing on algebraic concepts such as variables, constants, and algebraic operations; and (3) analysis, during which the researcher reflects on and generalizes the learning outcomes.

The researcher assumed the dual role of both teacher and investigator, conducting the experiment within an existing regular classroom rather than creating an artificial experimental setting to authentically enhance students' mathematical critical thinking skills. A qualitative descriptive approach was employed to capture the nuanced dynamics of learning in this naturalistic context. Furthermore, the study integrates qualitative analysis with the principles of teaching experiment methodology to deeply explore how the PBL model fosters the development of critical thinking within algebraic instruction.

This study involved 60 seventh-grade students from SMP PGRI II Wajak during the odd semester, with 29 students from Class VII A selected as the primary participants. Data were collected from two main sources: (1) classroom observations conducted by trained observers, which yielded insights into students' critical thinking skills during learning activities; and (2) multiple assessment instruments including pretests, posttests, observation records, Student Worksheets (LKPD), and knowledge tests administered before, during, and after the learning process to evaluate students' critical thinking abilities in problem-solving contexts.

This study utilized the following research instruments: (1) a set of critical thinking items adapted from PISA assessment materials (Dewantara et al., 2015; Sari et al., 2020). This study adopted a qualitative data analysis approach. Qualitative data were gathered from the scores assigned by research participants in response to questions on the Lesson plan (RPP) validation sheet, which focused on students' critical thinking competencies. Additionally, students' critical thinking skills were evaluated both prior to and following the implementation of the Problem-Based Learning (PBL) model, using the normalized gain (N-Gain) formula to measure development over time.

Validation Analysis of the Lesson Plan by a Mathematics Content Expert

The classification of validity is established through a percentage value obtained from the RPP validation process.

$$P = \frac{\sum Xi}{\sum X} \times 100\% \qquad (1)$$

Description:
P = Percentage
$\sum$Xi = Total validators score
$\sum$X = Ideal score number

Table 1. Percentage of RPP Validity Level

Percentage (%)	Level of Instrument Validity
80 – 100	Valid
60 – 79	Quite valid
40 – 59	Invalid
0 – 39	Invalid

(Arikunto, 2009)

Analysis of Students' Critical Thinking Skills Data

Evaluation of students' critical thinking skills following the use of PBL and project-based learning lesson plans.

$$P = \frac{\sum Xi}{\sum X} \times 100\% \quad (2)$$

Description:
P = Percentage
$\sum$Xi = Total score
$\sum$X = Maximum scores

Below are the criteria adopted for categorizing the levels of students' critical thinking abilities as observed during learning activities (Rusmini, 2019).

Table 2. Percentage of Students' Critical Thinking Skills in Learning

Value Scale	Critical Thinking Skills of Students
$0\% < g \leq 25\%$	Not good
$25\% < G \leq 50\%$	Pretty good
$50\% < G \leq 75\%$	Good
$75\% < G \leq 100\%$	Excellent

Considering the pretest and posttest findings whether or not students' critical thinking abilities have improved after receiving treatment will be discussed. The N-Gain formula is utilized to observe the rise (Nasution et al., 2020).

$$\text{N-Gain} = \frac{\text{skor posttest-skor pretest}}{\text{skor ideal-skor pretes}} \quad (3)$$

The outcomes of the analysis are organized in the table below.

Table 3. Interpretation Criteria for N-Gain Scores

Magnitude of Gain (g)	Classification
G ≥ 0.7	Height
0.3 ≤ G ≤ 0.7	Medium
G < 0.3	Low

(Syahfitri, 2008)

RESULT AND DISCUSSION

The purpose of this study is to describe how the Problem-Based Learning (PBL) model is enacted in classroom practice to support the development of students' critical thinking competencies. The results are outlined below:

Research Results

Critical Thinking Skills

Observed indicators of critical thinking skills demonstrated during learning activities. Table 4 below presents the operational indicators used to assess students' critical thinking skills during learning activities.

Table 4. Indicators of Critical Thinking in Learning

Meetings	Critical thinking in learning NG	PG	G	VG
I	1	16	11	1
	3.44%	55.17%	37.93%	3.44%
II	0	2	27	0
	0%	6.89%	93.10%	0%
III	0	0	24	5
	0%	0%	82.76%	17.24%

Description:
NG: Not Good G: Good
PG: Pretty Good VG: Very Good

As shown in Table 4, which summarizes observer ratings of students' critical thinking skills during learning activities, the initial observation revealed the following distribution: 3.44% of students were categorized as poor, 55.17% as moderately good, 37.93% as good, and 3.44% as very good. This mixed performance was largely attributed to several challenges faced by some learners particularly difficulties in clearly defining problem-related learning tasks, organizing their approach to such tasks, and providing relevant examples or responses that deepen rather than complicate the inquiry.

By the second meeting, a marked improvement was observed: 93.10% of students were rated as good, and 6.90% as moderately good (note: corrected from 6.89% for rounding consistency with standard percentage reporting). Further progress was evident in the third meeting, where observer ratings indicated that 82.76% of students fell into the good category and 17.24% achieved the very good level. This advancement reflects students' growing ability to: clearly articulate learning tasks tied to the problem, systematically organize their investigative approach, introduce relevant phenomena, demonstrations, or narratives to contextualize problems, and support their responses with illustrative examples or supplementary reasoning that enrich rather than obscure their answers. Collectively, these developments demonstrate a clear trajectory of growth in students' critical thinking competencies throughout the learning process.

Critical Thinking Skills in Problem Solving

The following are the outcomes of LKPD students' critical thinking abilities in problem solving.

Table 5. LKPD Tabulation

Critical Thinking Engineers	Pert-1 Criteria for Critical Thinking Ability				Pert-2 Criteria for Critical Thinking Ability				Pert-3 Criteria for Critical Thinking Ability			
	NG	PG	G	VG	NG	PG	G	VG	NG	PG	G	VG
Interpretation	12	13	-	4	8	10	2	9	6	-	10	13
%	41.38	44.83	0	13.79	27.59	34.48	6.90	31.03	26.69	0	34.48	44.83
Analysis	10	8	2	9	9	5	8	7	5	3	12	9
%	34.48	27.59	6.90	31.03	31.03	17.24	27.59	24.13	17.24	10.34	41.38	31.03
Evaluation	8	-	10	11	-	-	12	17	-	-	8	21
%	27.59	0	34.48	37.93	0	0	41.38	58.62	0	0	27.59	72.41
Conclusion	-	4	12	13	-	-	12	17	-	-	8	21
%	0	13.79	41.38	44.83	0	0	41.38	58.62	0	0	27.59	72.41
Explanation	-	-	20	9	-	-	16	13	-	-	12	17

Critical Thinking Engineers	Pert-1 Criteria for Critical Thinking Ability				Pert-2 Criteria for Critical Thinking Ability				Pert-3 Criteria for Critical Thinking Ability			
	NG	PG	G	VG	NG	PG	G	VG	NG	PG	G	VG
%	0	0	68.97	31.03	0	0	55.17	44.83	0	0	41.38	58.62
Self-regulation	29	-	-	-	25	4	-	-	20	4	-	5
%	100	0	0	0	86.20	13.79	0	0	68.97	13.79	0	17.24

Description:
NG: Not Good G : Good
PG: Pretty Good VG: Very Good

Table 5 outlines the progression of students' critical thinking performance across three meetings, as reflected in their responses to the Student Worksheet (LKPD). In the interpretation indicator, the first meeting showed that 41.38% of students demonstrated poor ability, 44.83% exhibited good ability, and 13.79% achieved a very good level. By the second meeting, the distribution shifted: 27.59% remained in the poor category, while 34.44% were rated as moderately good, 6.90% as good, and 31.03% as very good. Further improvement was observed in the third meeting, with 26.69% classified as poor, 34.48% as good, and 44.83% reaching the very good level. This consistent upward trend suggests that students gradually developed a clearer understanding of how to approach and solve LKPD-based problems.

Regarding the analysis indicator, initial results indicated that 34.48% of students had weak analytical skills, 27.59% showed good ability, 6.90% demonstrated strong ability, and 31.03% performed at a very good level. In the second meeting, 31.03% were still struggling (poor ability), 17.24% were rated as moderately decent, 27.59% as well-able, and 24.13% as very well-able. By the third meeting, only 17.24% remained in the poor category, while 10.34% were rated as fairly good, 41.38% as well-able, and 31.03% as very well-able. Although the rate of improvement was more gradual than anticipated, the steady increase in analytical performance across all sessions confirms that students are increasingly capable of examining and deconstructing problem-solving tasks.

For the evaluation indicator, the first meeting revealed that 27.59% of students had weak evaluative skills, while 34.48% demonstrated excellent ability and 37.93% exhibited very strong ability. By the second meeting, all students performed at or above the "well-able" level 41.38% were well-able and 58.62% were very well-able. This trend continued into the third meeting, where 27.59% were well-able and 72.41% achieved the very well-able category. The consistent growth reflects students' increasing familiarity with evaluative processes, aligning with the expected development of this skill. These findings indicate that learners are now better equipped to assess the validity, relevance, and quality of information when addressing LKPD problem-solving tasks.

Finally, in the inference (conclusion-drawing) indicator, the first meeting showed that 13.79% of students had good ability, 41.38% demonstrated strong ability, and 44.83% performed at a very good level. During the second meeting, 58.62% were classified as very well-able, and the remaining 41.38% (equivalent to 12 students, assuming a class of 29) were well-able. By the third meeting, 72.41% reached the very well-able level, and 27.59% remained well-able. This progression suggests that repeated practice has fostered students' capacity to draw logical and well-supported conclusions. Consequently, it can be concluded that students are now more proficient in solving LKPD-based problems through reasoned judgment and critical reflection.

The first meeting's explanation indicator showed that 31.03% of students were very well-able and 68.97% of students were well-able. At the second meeting, 44.83% of pupils had very good abilities and 55.17% had good abilities. There were 58.62% of students with very good ability and 41.38% of students with good ability during the third meeting. This explanation indicator has increased, indicating that pupils are able to explain how they solve problems in LKPD.

100% of students did not comply with the first meeting regulation indication. During the second meeting, 13.79% of pupils had good ability and 86.20% had bad ability. At the third meeting, 17.24% of students had very good ability, 13.79% had good ability, and 68.97% had low ability. This is due to the fact that children are not accustomed to exercising self-control, and teachers frequently remind them of this skill, which leads to some students making an effort to do so successfully. Therefore, it can be said that when it comes to solving questions on the LKPD sheet, pupils are capable of making rules.

The knowledge exam results on students' critical thinking in problem solving are tabulated as follows:

Table 6. Tabulation of Knowledge Tests

Critical Thinking Engineers	Pert-1 Criteria for Critical Thinking Ability				Pert-2 Criteria for Critical Thinking Ability				Pert-3 Criteria for Critical Thinking Ability			
	NG	PG	G	VG	NG	PG	G	VG	NG	PG	G	VG
Interpretation	13	13	3	-	12	5	2	10	5	-	20	4
%	44.83	44.83	10.34	0	41.38	17.24	6.90	34.48	17.24	0	68.97	13.79
Analysis	11	9	6	3	8	5	8	8	4	3	6	16
%	37.93	31.03	26.69	10.34	27.59	17.24	27.59	27.59	13.79	10.34	26.69	55.17
Evaluation	9	2	5	13	4	2	9	14	-	-	16	13
%	31.03	6.90	17.24	44.83	13.79	6.90	31.03	48.27	0	0	55.17	44.83
Conclusion	-	20	-	9	-	-	2	27	-	-	-	29
%	0	68.97	0	31.03	0	0	6.90	93.10	0	0	0	100
Explanation	-	-	15	14	-	-	19	10	-	-	8	21
%	0	0	51.72	48.28	0	0	65.52	34.48	0	0	27.59	72.41
Self-Regulation	29	-	-	-	27	-	2	-	24	-	1	4
%	100	0	0	0	93.10	0	6.90	0	82.76	0	3.45	13.79

Description:
NG: Not Good   G: Good
PG: Pretty Good   VG: Very Good

Table 6 presents the progression of students' performance across three meetings, based on key critical thinking indicators.

Regarding the interpretation indicator, the first meeting revealed a mixed profile: 44.83% of students demonstrated poor ability, 44.83% showed good ability, and 10.34% exhibited strong ability. By the second meeting, the distribution shifted 41.38% remained at the poor level, while 17.24% were rated as quite good, 6.90% as good, and 34.48% as very good. Notable improvement was evident in the third meeting, with only 17.24% scoring in the poor range, 68.97% achieving good ability, and 13.79% reaching the very good level. This consistent upward trend suggests that students gradually developed the capacity to interpret and comprehend problem-solving tasks in knowledge assessments.

For the analysis indicator, initial results showed that 37.93% of students had weak analytical skills, 31.03% demonstrated decent ability, 26.69% displayed high ability, and 10.34% exhibited very strong ability. In the second meeting, 27.59% were still struggling (poor ability), while 17.24% were quite decent, and the remaining 55.18% were split evenly (27.59% each) between good and very good. By the third meeting, performance improved further: only 13.79% showed limited ability, 10.34% were rated as pretty excellent, 26.69% as able, and a majority 55.17% were classified as extremely capable. Although the growth was more gradual than expected, the steady increase across meetings confirms that students became increasingly skilled at analyzing problems.

In terms of the evaluation indicator, the first meeting showed that 31.03% of students had low ability, 6.90% had decent ability, 17.24% demonstrated strong ability, and 44.83% already performed at a very good level. By the second meeting, the proportion of students with weak evaluation skills dropped to 13.79%, while 6.90% remained at a decent level, 31.03% showed good ability, and 48.27% reached the very good category. In the third meeting, all students performed at or above the good level 55.17% were rated as good, and 44.83% as very good. This indicates that, through repeated exposure and practice, students became more accustomed to evaluating evidence and reasoning, leading to the anticipated enhancement in their evaluative skills. Consequently, it can be concluded that learners are now better equipped to assess and judge the components of problem-solving tasks in knowledge exams.

In the first meeting, students' performance on the inference (or conclusion-drawing) indicator showed that 31.03% demonstrated very good ability and 68.97% exhibited good ability. By the second meeting, this distribution shifted significantly: 93.10% of students were rated as very good, and 6.90% as good. By the third meeting, all students achieved the "very good" level, reflecting their growing familiarity with drawing logical conclusions. This consistent improvement suggests that repeated practice and instructional support enabled students to more effectively formulate expected conclusions, enhancing their capacity to address problem-solving items on the knowledge test.

Similarly, regarding the explanation indicator, 51.72% of students displayed good ability and 48.28% showed very good ability during the first meeting. In the second meeting, 65.52% were categorized as having high (or good) ability, while 34.48% reached the very good level. By the third meeting, performance further improved, with 72.41% achieving very good ability and 27.59% maintaining good ability. This upward trend indicates that students became increasingly capable of clearly articulating their reasoning when responding to problem-solving questions in the knowledge assessment.

Collectively, these findings suggest that students developed stronger competencies in both drawing valid conclusions and providing coherent explanations over the course of the intervention. During the first meeting, 100% of students demonstrated low performance on the self-regulation indicator. By the second meeting, this began to shift slightly: 6.90% of students exhibited good self-regulation skills, while the majority (93.10%) still showed weak abilities. Further improvement was observed in the third meeting, where 13.79% of students achieved a "very good" level, 3.45% reached a "good" level, and 82.76% remained in the "weak" category. This gradual development can be attributed to students' initial unfamiliarity with self-regulatory practices.

However, consistent reinforcement and reminders from the teacher appear to have supported some learners in applying this skill effectively. Consequently, it may be inferred that, over time, students began to internalize and apply self-regulation strategies such as setting personal guidelines when responding to problem-solving items on the knowledge test.

Table 7. Pretest and Posttest Tabulation

Critical Thinking Engineers	Pretest				Posttest			
	Criteria for Critical Thinking Ability				Criteria for Critical Thinking Ability			
	NG	PG	G	VG	NG	PG	G	VG
Interpretation	29	-	-	-	2	12	10	5
%	100	0	0	0	6.90	41.38	34.48	17.24
Analysis	29	-	-	-	-	-	-	-
%	100	0	0	0	0	0	0	0
Evaluation	29	-	-	-	-	-	25	4
%	00	0	0	0	0	0	86.21	13.79
Conclusion	29	-	-	-	-	2	2	25
%	100	0	0	0	0	6.90	6.90	86.21
Explanation	29	-	-	-	-	-	20	9
%	100	0	0	0	0	0	68.97	31.03
Self-Regulation	29	-	-	-	21	-	1	7
%	100	0	0	0	72.41	0	3.45	24.14

Description:
NG: Not Good G: Good
PG: Pretty Good VG: Very Good

As shown in Table 7, the pretest scores across all critical thinking indicators remained low, primarily because students were not yet accustomed to engaging deeply with problem-solving tasks. Instead, they tended to approach exercises mechanically focusing on completing answers rather than applying critical thinking processes. However, the posttest results indicate a shift: students began to make decisions more deliberately by referencing the specific dimensions of critical thinking. The following section presents the findings derived from the normalized gain (N-Gain) analysis, which compares pretest and posttest performance to assess improvements in students' critical thinking abilities in problem-solving contexts.

Table 8. Pretest and Posttest Critical Thinking Skills in Problem Solving

Magnitude of Gain (g)	Classification	Frequency	%
G ≥ 0.7	Height	17	62.79
0.3 ≤ G ≤ 0.7	Medium	12	37.21
G < 0.3	Law	0	0

Based on pretest and posttest data analyzed using the normalized gain (N-Gain) score, 37.93% of students fell into the moderate improvement category (0.3 ≤ g ≤ 0.7), while 62.07% demonstrated high improvement (g > 0.3 ≤ g ≤ 0.7), while 62.07% demonstrated high improvement (g > 0.7). These results suggest that students' mathematical critical thinking skills developed substantially, with the majority achieving either moderate or high gains between the pretest and posttest. Consequently, it can be concluded that learners are increasingly capable of applying critical thinking strategies to solve mathematical problems.

Discussion

Observations indicate that student learning has improved alongside the development of critical thinking skills. According to research by Asmar, Delyana, Septiana, and Zanty, students who possess strong critical thinking abilities are better equipped to reason logically and apply these skills to mathematical problems. This enables them to interpret concepts from multiple perspectives, thereby further strengthening their critical thinking capacity in learning (Asmar & Delyana, 2020; Septiana et al., 2019; Zanthy, 2016).

It can be reasonably suggested that students' analytical skills in problem solving have shown improvement, as evidenced by LKPD (Student Worksheet) outcomes. These results indicate that, across successive learning sessions, many students have begun to effectively interpret information, analyze problems, evaluate solutions, draw conclusions, articulate reasoning, and self-regulate their learning—although not all do so accurately or consistently. Supporting this observation, Pramuditya et al. (2019) and Septiana et al. (2019) found that students' critical thinking abilities correlate closely with their mathematical proficiency: those with high mathematical ability demonstrate excellent critical thinking by fulfilling all relevant indicators; those with moderate ability meet only some indicators, reflecting adequate skills; and those with low ability satisfy few or none, resulting in underdeveloped critical thinking. Contributing factors to this gap include insufficient understanding of the subject matter, limited engagement in asking questions, and inadequate exposure to practice problems of varying difficulty levels. Additionally, some students struggle with basic tasks such as calculating surface area due to either forgetting or never having learned the required formulas (Nainggolan, 2020; Pramuditya et al., 2019; Septiana et al., 2019).

The knowledge test outcomes from Meetings 1, 2, and 3 reveal a noticeable enhancement across all critical thinking indicators namely, interpretation, analysis, evaluation, inference, explanation, and self-regulation in problem-solving contexts. This improvement aligns with findings from prior studies, which similarly report gains in students' problem-solving competencies alongside better performance on knowledge assessments (Fatimah et al., 2019; Kusumawati et al., 2018; Maskur et al., 2020; Mustaffa et al., 2016; Nainggolan, 2020; Nasution et al., 2020).

Pretest and posttest results analyzed using the normalized gain (N-Gain) score are categorized as "high" when the gain value (g) is 0.7 or greater. This indicates that, particularly in addressing high-level problems, students demonstrated the most substantial improvement in critical thinking skills, reflected in their notably higher posttest scores. This approach aligns with the methodology employed by Coal, Rahayu & Hartono, and Syamsuddin, who administered critical thinking assessments twice once prior to instruction and again after instruction with results falling into the high category (Coal, 2017; Stuart & Scott, 2016; Syamsuddin et al., 2018).

CONCLUSION AND SUGGESTIONS

This study demonstrates that implementing Problem-Based Learning (PBL) in algebra instruction significantly enhances junior secondary students' mathematical critical thinking skills. Over four classroom sessions, students showed marked improvement across all six Facione based indicators interpretation, analysis, evaluation, inference, explanation, and self-regulation with 62.07% achieving high and 37.93% medium normalized gain scores. The findings confirm PBL as an effective, practical approach for fostering higher-order thinking in authentic classroom settings.

In view of the research findings' conclusions and descriptions, the investigator recommended the following actions: (1) the problem-based learning methodology can be used to evaluate students' critical thinking skills; (2) Future studies should evaluate students' critical thinking capabilities as well as their creative and advanced thinking abilities using the Problem Based Learning Model. Teachers can use the created lesson plans and test questions as a reference when developing new resources; (3) Even during a pandemic, it is preferable to dedicate extra time to education so that pupils can learn effectively and are not in a rush to return home; (4) It is intended that issues pertaining to contextual solutions will be further refined in further studies; (5) More research variables are anticipated for future studies.

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