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Improving Mathematical Critical Thinking Skills through Problem-Based Learning in Correlation Analysis for High School Students

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ABSTRAK

Penelitian ini termasuk dalam jenis Penelitian Tindakan Kelas (PTK) dengan tujuan untuk mengembangkan kemampuan berpikir kritis matematis siswa melalui penerapan model pembelajaran Problem Based Learning (PBL) pada pokok bahasan Analisis Korelasi. Subjek penelitian yaitu 36 siswa kelas XI SMAN 16 Garut semester genap tahun pelajaran 2024/2025. Studi dilaksanakan selama dua siklus meliputi tahap perencanaan, pelaksanaan, observasi, dan refleksi. Pengumpulan data melalui tes serta non tes. Teknik analisis data dilakukan secara deskriptif kuantitatif dan kualitatif. Hasilnya menunjukkan bahwa skor rata-rata kemampuan berpikir kritis meningkat dari 69,4% pada siklus I menjadi 80,5% pada siklus II. Temuan ini menunjukkan bahwa model PBL efektif dalam meningkatkan kemampuan berpikir kritis matematis siswa sehingga layak menjadi alternatif strategi pembelajaran aplikatif di kelas.

Kata Kunci: *Problem Based Learning*; kemampuan berpikir kritis matematis; analisis korelasi; siswa SMA

ABSTRACT

This study is classified as Classroom Action Research (CAR) aimed at developing students' mathematical critical thinking skills through the implementation of the Problem-Based Learning (PBL) model on the topic of Correlation Analysis. The research subjects consisted of 36 eleventh-grade students from SMAN 16 Garut during the second semester of the 2024/2025 academic year. The study was conducted over two cycles, encompassing the stages of planning, implementation, observation, and reflection. Data were collected using both test and non-test instruments. The data analysis was carried out using both quantitative and qualitative descriptive techniques. The results revealed that the average score of students' critical thinking skills increased from 69.4% in the first cycle to 80.5% in the second cycle. These findings suggest that the PBL model is effective in enhancing students' mathematical critical thinking skills and is therefore suitable for use as an alternative instructional strategy in the classroom.

Keywords: Problem-Based Learning; mathematical critical thinking skills; correlation analysis; senior high school students

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1. INTRODUCTION

In response to the challenges and needs of education in the modern era, the government launched the Merdeka Belajar (Freedom of Learning) policy as an effort to reform the national education system. The Merdeka Belajar policy represents a strategic step in transforming education, aiming to shift the conventional approach towards a more flexible and creative system that aligns with contemporary needs (Lembong et al., 2023). Among other things, this involves eliminating the National Examination (UN) and introducing the Minimum Competency Assessment (AKM), which focuses on evaluating literacy and numeracy skills, seen as the foundation for supporting students' success in the next level of education and aligning with the demands of 21st-century education (Solekha et al., 2025).

In this curriculum, mathematics is a core subject that plays a crucial role at every stage of education (Simanjuntak & Murniarti, 2024; Ulfahyana & Herwandi, 2024). It is a mandatory subject for students at every stage of education (Suwanti & Maryati, 2021). Mathematics lessons provide students with important knowledge and skills, while also developing critical, logical, and analytical thinking abilities. In ongoing learning activities, students are guided to master concepts, understand principles, and solve problems in a structured manner. In addition, mathematics learning helps shape a positive attitude towards the subject and instills values such as independence, perseverance, accuracy, rational thinking, and creativity (Kemendikbud, 2025). Thus, mathematics not only serves as an academic measure but also plays a crucial role in the development of critical thinking skills.

Among the mathematical skills important in facing the challenges of the 21st century and necessary throughout a person's life is critical thinking (Zainal et al., 2025). Critical thinking is a mental activity that involves logical and in-depth reasoning to carefully assess aspects worthy of belief and serve as a basis for decision-making. (Ennis, 2011). Meanwhile, according to Facione (2018), critical thinking encompasses several essential abilities, including the capacity to interpret, analyze, evaluate, infer, and explain information or situations. He also emphasizes that decision-making in critical thinking must be based on clear evidence, concepts, methods, and criteria, while considering the objectives of the process stages. Critical thinking can also be described as a skilled and responsible form of thinking that encourages individuals to make appropriate decisions based on specific criteria while considering relevant contexts (Rosyadi, 2021). Critical thinking skills are essential skills that must be developed systematically, as they play an important role in preparing students for the future.

In the context of mathematics learning, critical thinking skills can be defined as a structured and rational thinking process in examining concepts, procedures, and problem-solving strategies in mathematics, as explained in Piaget's (1972) constructivist theory framework, where individuals actively construct their knowledge through direct involvement and continuous interaction with their surroundings. This ability includes activities such as evaluating mathematical arguments, identifying patterns, connecting concepts, and constructing justifications based on evidence and logic (Schoenfeld, 2014). Thus, mathematical critical thinking requires not only mastery of concepts but also reflective and evaluative skills in solving mathematical problems meaningfully.

However, the results of an internal survey conducted at SMAN 16 Garut indicate that the level of students' mathematical critical thinking achievement, encompassing interpretation, analysis, inference, and explanation skills, remains suboptimal. The findings are shown in Table 1.

Table 1. Percentage of Critical Thinking Achievement

Critical Thinking Skills Aspects	Percentage
Interpretation Skills	30%
Analysis Skills	20%
Inference Skills	30%
Explanation Skills	20%

(Source: Author's documents)

Table 1 shows an overview of the average critical thinking skills of students at SMAN 16 Garut based on four main aspects. The data indicates that interpretation and inference skills received the highest scores, with a percentage of 30% each. This indicates that the majority of students have begun to demonstrate the ability to understand information and draw logical conclusions based on the available data. However, in the analysis and explanation aspects, student achievements remain at 20%, indicating challenges in deeply analyzing information and providing coherent explanations. The data indicate that students possess the potential for critical thinking; however, more targeted efforts are necessary in the learning process to develop their analytical and explanatory skills optimally and evenly. The low level of critical thinking skills is likely due to a less challenging learning approach. As a result, students are less actively engaged in higher-order thinking processes, such as analyzing, evaluating, and drawing conclusions from information in depth.

Based on these issues, it is necessary to implement a learning model that can encourage the development of advanced thinking skills. Problem-Based Learning (PBL) is considered to be one of the most effective models. Windari and Yanti (2021) state that the PBL model provides learning experiences through real and open problem situations, thereby motivating students to use critical thinking skills to solve these problems. The PBL learning model can be applied as a strategy to produce graduates with optimal critical thinking skills (Mayasari & Ramdiah, 2023). In the context of mathematics learning, PBL provides students with an environment in which they can construct meaning, explore concepts, and communicate their mathematical reasoning independently or collaboratively.

The Problem-Based Learning (PBL) model comprises five main stages, designed to encourage active student participation in problem-solving-focused learning. In the first stage, teachers introduce problems to students by explaining learning objectives, logistical requirements, and motivating students to solve the problems. The second stage involves the teacher guiding students to formulate and develop a learning plan relevant to the problem presented. In the third stage, students conduct independent or group exploration, such as searching for information, conducting experiments, and designing solutions to the problem at hand. The fourth stage requires students to compile and present their findings, either in the form of reports or through class discussions. Meanwhile, the fifth stage focuses on reflection and evaluation activities facilitated by the teacher to help students review the learning process they have undergone and learn lessons for future improvement (Upu et al., 2022).

This study aims to analyze the application of the PBL model in improving the mathematical critical thinking skills of grade XI students at SMAN 16 Garut in the subject of Correlation Analysis. The research focuses on the development of interpretation, analysis, evaluation, and inference. Unlike previous studies that tend to examine the effectiveness of PBL in general or other cognitive aspects, this study specifically investigates the influence of PBL on mathematical critical thinking based on Facione's framework, contextualized in the Correlation Analysis material for Senior High School (SMA). Thus, this study is expected to contribute empirically and practically to the development of learning strategies that foster students' mathematical critical thinking skills.

2. METHOD

This study is classified as Classroom Action Research (CAR), which aims to improve students' mathematical critical thinking skills by applying the Problem-Based Learning (PBL) model to correlation analysis material. In general, the implementation of CAR by teachers consists of four main stages, namely planning, action implementation, observation, and reflection (Machali, 2022). According to Parnawi (2020), PTK is a systematic effort by teachers to improve and enhance the quality of the learning process under their responsibility through planned and continuous reflective actions in the classroom, which is the scope of their duties.

This research was conducted in the even semester of the 2024/2025 academic year, specifically from April to May 2025, involving 36 eleventh-grade students at SMAN 16 Garut as subjects. The research activity consisted of two cycles, each cycle comprising two meetings. Each cycle of action implementation included four main stages: (1) planning stage, (2) action implementation, (3) observation or monitoring, and (4) reflection. The action flow diagram for each cycle is shown in Figure 1, which refers to the original model by Kemmis & McTaggart (Parnawi, 2020).

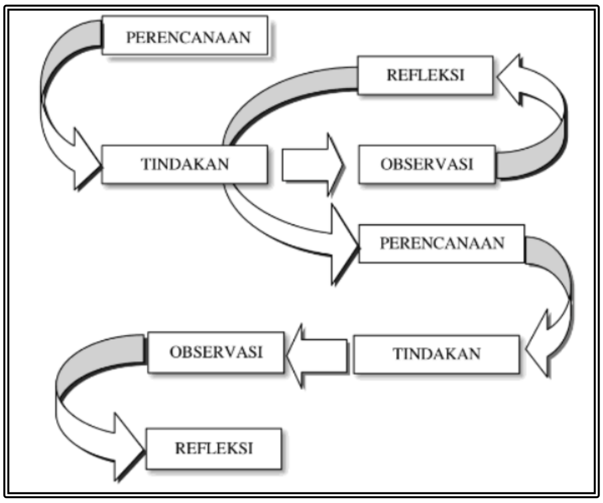

Figure 1. Kemmis & McTaggart PTK Model Design (Parnawi, 2020)

Data collection was conducted using two methods, namely tests and non-tests. Descriptive test instruments were used to measure the development of critical thinking skills in each cycle of this study. To ensure the validity of the instruments, content validation was carried out by two mathematics education experts. The validation process included assessing the relevance of the questions to the indicators, the clarity of the language, and the level of difficulty of the questions. The instruments were revised based on input from the validators before being used in the learning process.

Meanwhile, the non-test approach was implemented through the use of learning implementation observation sheets to monitor the progress of activities during each learning cycle. The data obtained were analyzed using both quantitative and qualitative descriptive techniques. The learning implementation data were analyzed using the following formula.

$$\%\ implementation\ of\ learning = \frac{total\ score}{maximum\ score} x\ 100\%$$

The percentage of learning process implementation will be adjusted according to the achievement criteria listed in Table 2.

Table 2. Criteria for Learning Achievement

Percentage (%)	Achievement Criteria
81 – 100	Excellent
61 – 80	Good
41 – 60	Fairly Good
21 – 40	Poor
0 – 20	Fairly Poor

The data from the students' critical thinking ability tests were analyzed using the following equation.

$$P = \frac{R}{SM} x\ 100\% \qquad \text{(Riduwan, 2009)}$$

P is the percentage value to be determined, R is the raw score obtained by the participant, while SM is the ideal maximum score for an exam or test. The percentage of students' critical thinking skills will be adjusted according to the classification of abilities listed in Table 3.

Table 3. Criteria for Critical Thinking Skills

Percentage (%)	Clasification
81 – 100	Excellent
61 – 80	Good
41 – 60	Fairly Good
21 – 40	Poor
0 – 20	Fairly Poor

This study was deemed successful based on measurements using three criteria, namely: (1) at least 75% of students obtained a score of ≥ 70 on the mathematical critical thinking test, (2) there was an increase in the average score between cycle I and cycle II, and (3) the implementation of the PBL model by teachers received a minimum rating of "good" based on observation results.

As part of its ethical responsibility, this study has obtained ethical approval from the school and the subject teachers involved. All students participated voluntarily after receiving an explanation of the study's purpose and procedures, and were assured that their data would be kept confidential for research purposes.

3. RESULT AND DISCUSSION

a. Research Findings

1) Planning Stage

In the planning stages of cycles I and II, the researcher prepared various tools and requirements to support the implementation of the learning action. In this classroom action research, the researcher directly implemented the mathematics learning process in class XI Merdeka L at SMAN 16 Garut. Meanwhile, fellow teachers acted as observers and were tasked with observing the learning process during the action.

At this stage, the researcher carried out various preparations necessary to support the implementation of the research, including: (1) formulating learning objectives based on the learning outcomes in the Merdeka Curriculum, namely students' ability to analyze the relationship between two variables through the Correlation Analysis material; and (2) establishing the Problem-Based Learning (PBL) model as the primary approach in mathematics learning to encourage active student involvement in understanding concepts and applying correlation analysis in everyday life contexts. (3) Developing teaching modules and Student Worksheets (SW) based on Problem-Based Learning (PBL) tailored to the Correlation Analysis material to facilitate student-centered learning. (4) Preparing presentation materials in the form of PowerPoint to support the learning process and capture students' attention during the activity. (5) Develop test questions to measure students' mathematical critical thinking skills in Cycle I, and prepare observation sheets on the implementation of learning to be used by observers during the action process.

2) Implementation Stage

The implementation of learning in this study was carried out in two cycles, each consisting of two meetings. Cycle I was conducted on April 10 and 17, 2025, while Cycle II was conducted on April 24 and 30, 2025, with a total of four hours of lessons per cycle. The learning model applied was Problem-Based Learning (PBL), focused on enhancing students' mathematical critical thinking skills in the topic of Correlation Analysis.

In each cycle, the learning activities were divided into three stages: introductory activities (± 15 minutes), core activities (± 60 minutes), and closing activities (± 15 minutes). All 36 students in the 11th grade Merdeka L class at SMAN 16 Garut were the subjects of the study.

In Cycle I, students were divided into heterogeneous groups and encouraged to develop and present alternative solutions to contextual problems related to correlation analysis. Interaction between groups was facilitated through question-and-answer sessions and open discussions. In Cycle II, learning is conducted using the same approach, but is reinforced through active guidance by teachers during discussions and refinement of task instructions. The problems provided are also designed to be more complex, stimulating a deeper critical thinking process. To maintain a fun and focused learning atmosphere, icebreakers are inserted between activities.

3) Observation Stage

The learning process was observed by teachers using observation sheets, with a focus on student activity, group involvement, and the implementation of PBL steps. At the end of each cycle, students took a mathematical critical thinking test to evaluate their learning outcomes.

Table 4. Percentage of Mathematical Critical Thinking Ability Results

Percentage (%)	Clasification	Total Students	
		Cycle I	Cycle II
$81 < x \leq 100$	Very High	25	29
$71 < x \leq 81$	High	3	2
$62 < x \leq 71$	Medium	3	3
$43 < x \leq 62$	Low	5	2
$0 < x \leq 43$	Very Low	0	0

Based on the data in Table 4, there was a significant increase in students' mathematical critical thinking skills from Cycle I to Cycle II, as evidenced by the application of the Problem-Based Learning (PBL) model. The number of students who achieved the Very High category increased from 25 (69.4%) in Cycle I to 29 (80.5%) in Cycle II. Meanwhile, the number of students in the Low category decreased from 5 to 2, and no students were in the Very Low category in either cycle. The decrease in the number of students in the High and Moderate categories, each by one student, indicates a shift toward the higher category, Very High.

The results of observations of teacher activities during the implementation of learning in two cycles showed an improvement in the quality of teacher performance in implementing the Problem-Based Learning (PBL) model. In Cycle I, teacher observations reached a percentage of 78%, which was categorized as "fair." The strengths of this cycle included teachers conducting lessons by the lesson plans, motivating students, and using learning media. However, there were several shortcomings, including the failure to convey information about the next meeting, limited facilities (such as the unavailability of a projector), a lack of active involvement from all students, and suboptimal discussion time management. In Cycle II, the observation percentage increased to 88%, which falls into the "good" category. The learning process ran more smoothly and was more engaging; students showed enthusiasm in completing the worksheets according to the PBL stages, and overall student participation increased, although some students were not fully engaged in group work. These findings indicate significant improvement in the implementation of learning by teachers from Cycle I to Cycle II.

These findings are consistent with previous studies, which have shown that the implementation of PBL can improve the quality of teacher activities and student engagement during the learning process, thereby positively impacting traditional learning outcomes (Safitri et al., 2023). Additionally, a meta-analysis of various action research studies found that PBL significantly enhances students' critical thinking and collaboration skills, while also encouraging teachers to be more adaptive and reflective in designing and implementing instruction (Wahyudi et al., 2023).

b. Discussion

Thus, although the results achieved have met the success indicators, there is still room for improvement in the implementation of the PBL model so that students' critical thinking skills can be developed more optimally and evenly across all students. The diagram below (see Figure 2) shows the results of mathematical critical thinking skills after implementing PBL in cycle I and cycle II.

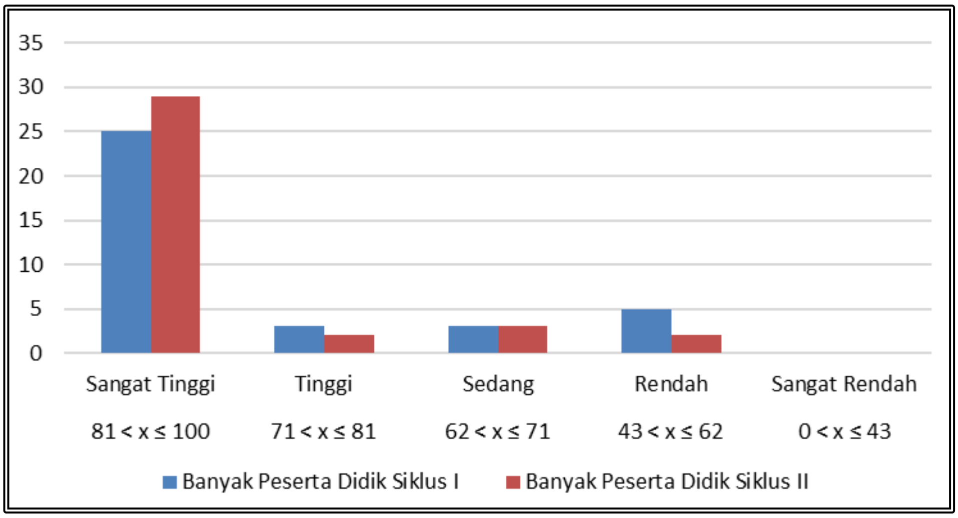

Figure 2. Results of mathematical critical thinking skills

The bar chart shows a significant increase in the critical thinking skills of Grade XI Merdeka L students at SMAN 16 Garut from Cycle I to Cycle II. In the Very High category ($81 < x \leq 100$), the number of students increased from 25 in Cycle I to 29 in Cycle II, reflecting a proportionate increase from approximately 71% to 83% of the total students. This is supported by the findings of Anggiana et al. (2024), who suggest that improvements in students' mathematical critical thinking skills can be attributed to the implementation of the Problem-Based Learning (PBL) model. This learning model encourages active student engagement through a series of problem-based learning stages, requiring them to observe, analyze, and draw conclusions independently.

Meanwhile, in the Low category ($43 < x \leq 62$), the number of students decreased from 5 to 2, indicating a clear improvement in the low-ability group. A decrease also occurred in the High and Medium categories, indicating that some students from these groups successfully moved up to the Very High category. There were no students in the Very Low category in either cycle, indicating that no students experienced extreme difficulties in critical thinking. Overall, this data shows an improvement in students' critical thinking skills due to the effectiveness of Problem-Based Learning (PBL) implementation, particularly in shifting the distribution of abilities toward higher categories in Cycle II.

4. CONCLUSION

Problem-Based Learning (PBL) has proven to be highly effective in teaching Correlation Analysis when implemented, as this model simulates statistical processes involving variable selection, relationship analysis, and concluding real data through group discussions and context-based solution presentations. By presenting real-world problems and requiring students to interpret, infer, and critically evaluate results, PBL sharpens the higher-order thinking skills necessary for Correlation Analysis. For example, research on statistical material found that PBL not only improves students' mathematical communication skills when interpreting correlation and regression results but also strengthens their conceptual understanding and ability to present mathematical arguments systematically and logically. In line with this, another study shows that PBL encourages students' creativity in solving statistical problems, including those related to interpreting correlation coefficients, making PBL an appropriate approach for strengthening mathematical critical thinking skills comprehensively in this subject matter.

The main limitation of this study lies in its relatively short duration, covering only two learning cycles within less than one month. This condition may significantly influence the results, particularly in measuring the long-term impact of implementing the Problem-Based Learning (PBL) model on students' mathematical critical thinking skills. However, the Problem-Based Learning (PBL) model has proven successful and effective in significantly developing students' critical thinking skills. The limited timeframe also prevents students from fully adapting to the new learning approach, meaning the potential for improved critical thinking skills may not yet be fully evident. Therefore, it is recommended that future similar studies be conducted over a more extended period and involve a broader range of materials to measure the impact of PBL implementation more profoundly and comprehensively. Additionally, time constraints make it challenging to collect broader data that covers other aspects, such as consistency in improvement across different materials or the long-term impact on learning motivation.

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