Improving Mathematical Problem-Solving Ability Through Problem-Based Learning (PBL) Model Using Augmented Reality Media

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Abstract
The research aims to improve students' Mathematical Problem-Solving Ability (KPMM) by applying the *Problem-Based Learning* (PBL) model assisted by *Augmented Reality* media. This research was a collaborative or participatory classroom action research and involved researchers, mathematics educators, colleagues, and students in grade IX of SMP Islam Muallimin Kediri in the even semester of the 2023/2024 academic year. The research instruments consisted of learning devices and data collection instruments. The learning devices employed the *Lesson Implementation Plan* (RPP), *Student Worksheets* (LKPD), and AR-Build Space Media. Meanwhile, data collection instruments were observation sheets, interviews, and KPMM tests. Data analysis was conducted descriptively comparatively. The results indicated that implementing the *Problem-Based Learning* (PBL) model assisted by *Augmented Reality* media significantly increased students' KPMM, with the average class value increasing from 56.75 in cycle I to 73.87 in cycle II. In short, the implementation of the PBL model assisted by augmented reality media could increase the KPMM of SMP Islam Muallimin Kediri's students in grade IX.
Keywords: *Mathematical Problem-Solving Ability, Problem-Based Learning, Augmented Reality*

Introduction

Learning mathematics provides challenges in the form of problems that require the ability to solve problems logically, creatively, and systematically. Daimah et al. (2023:136) explain that learning mathematics encourages students to develop critical, logical, and creative thinking to apply knowledge in academic contexts and daily life.

There is a gap between the ideal and the reality. Based on the Regulation of the Ministry of Education and Culture Number 58 of 2014, mathematics learning activities include supporting the development of mathematical problem-solving. Ramadhani et al. (2024:728) reveal that KPMM is the ability to use any information to be applied to solve problems.

However, students' mathematical problem-solving abilities (KPMM) were still lacking. It is in line with national and international surveys. According to the results of the *2022 Program for International Student Assessment* (PISA) survey published by the OECD in 2023, Indonesia experienced a five-rank increase in mathematics skills (Yuda &

Rosmilawati, 2024:172). Indonesia's mathematics score was 366, 106 points from the world average (Farah et al., 2024:254). It revealed that students' abilities in Indonesia, including their problem-solving ability, were still below average and adequate.

The students' low ability to solve mathematical problems cannot be separated from their mathematics learning activities. Through observations, Mrs. Nadifah Tullayli, a mathematics teacher, noticed that learning tended to be *Teacher-centered*, emphasizing memorizing formulas. As a result, students' Mathematical Problem-Solving Skills (KPMM) were not fully competent yet. Students often faced difficulties in solving problems, lacked abilities, were reluctant to ask questions, and felt anxious and afraid of making mistakes. It resulted in decreased student motivation and abilities.

The researchers conducted an initial study by providing two mathematical problem-solving questions and obtained results from eight people. 25% had fairly good mathematical problem-solving ability, while the other 75% did not have good mathematical problem-solving ability. Figures 1 and 2 provide examples of student answers obtained from the initial study.

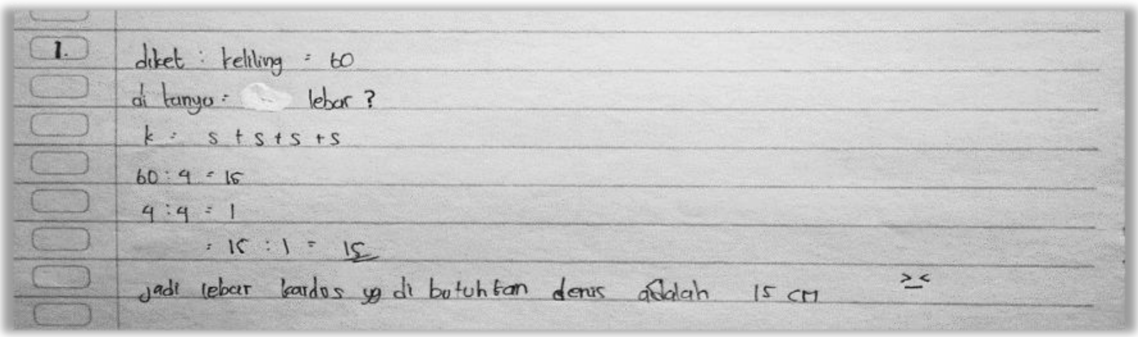

Figure 1. Example of Students' Answers to Question Number 1

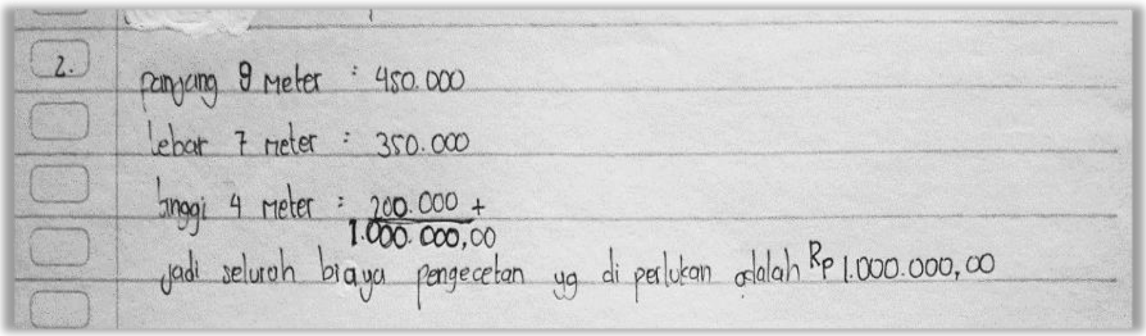

Figure 2. Example of Students' Answers to Question Number 2

Based on the student interview test results, several vital findings were obtained: (1) students considered the questions to be immensely complicated and did not understand how to solve them; (2) students worked on questions only based on memories of the teacher's explanation, without a deep understanding of the concept; (3) students were confused about the method of working; hence, they often use their methods without following the correct procedures. These findings indicated difficulties in understanding the material and applying strategies for solving mathematical problems.

Innovative learning models such as the *Problem-Based Learning* (PBL) model can be applied to increase student proactivity during learning activities and develop mathematical problem-solving skills. According to Suginem (in Rosita et al., 2023:3), *Problem-Based Learning* (PBL) is a learning model that focuses on student needs or is *student-centered*; thus, students are expected to be active and optimal in researching, investigating, solving problems, and evaluating the process.

Solikah & Aini (2023:38) emphasize that PBL allows students to practice formulating problems, finding solutions, and implementing knowledge and abilities in real-world contexts, which helps them to remember and apply learning in daily life. Karlina & Wirdati (2023:744) reveal that the PBLs' stages consist of (1) orienting students to the problem, (2) organizing students, (3) guiding students, (4) displaying work results, (5) analyzing and evaluating problem-solving stages. Therefore, PBL seeks students to learn deeply through direct experience solving problems, testing hypotheses, and applying knowledge practically (Faridah & Pertiwi, 2024).

Current technological developments encourage educators to utilize technology to develop ICT-based learning media. One of the latest innovations that can improve mathematics learning is *Augmented Reality* (AR). This model is also implemented and supported by *Augmented Reality* media or, more accurately AR Geometry Augmented Reality technology helps 3D virtual objects to be viewed interactively in the real world (Mustaqim et al., 2017:37).

When implementing the *Problem-Based Learning* (PBL) model assisted by *Augmented Reality* media, students must be active and able to communicate the results of their group assignments. As stated by Mitasari & Prasetiyo (2016:13-14), the presentation activities can train communication in conveying ideas and gaining a higher understanding. This research aimed to improve the students' *Mathematical Problem-Solving Abilities* (KPMM) of Junior High School in grade IX by applying the *Problem-Based Learning* (PBL) model assisted by *Augmented Reality* media.

Method

This research design was *Classroom Action Research* (CAR), which was collaborative or participatory, and the research design referred to Kemmis and Mc. Taggart's (1988) model, where activities in each cycle contain four stages: *initial plan*, *action*, *monitoring*, and *evaluation*. Figure 3 explains the process and steps of Classroom Action Research (CAR) activities based on the expanded approach of Kemmis and Taggart.

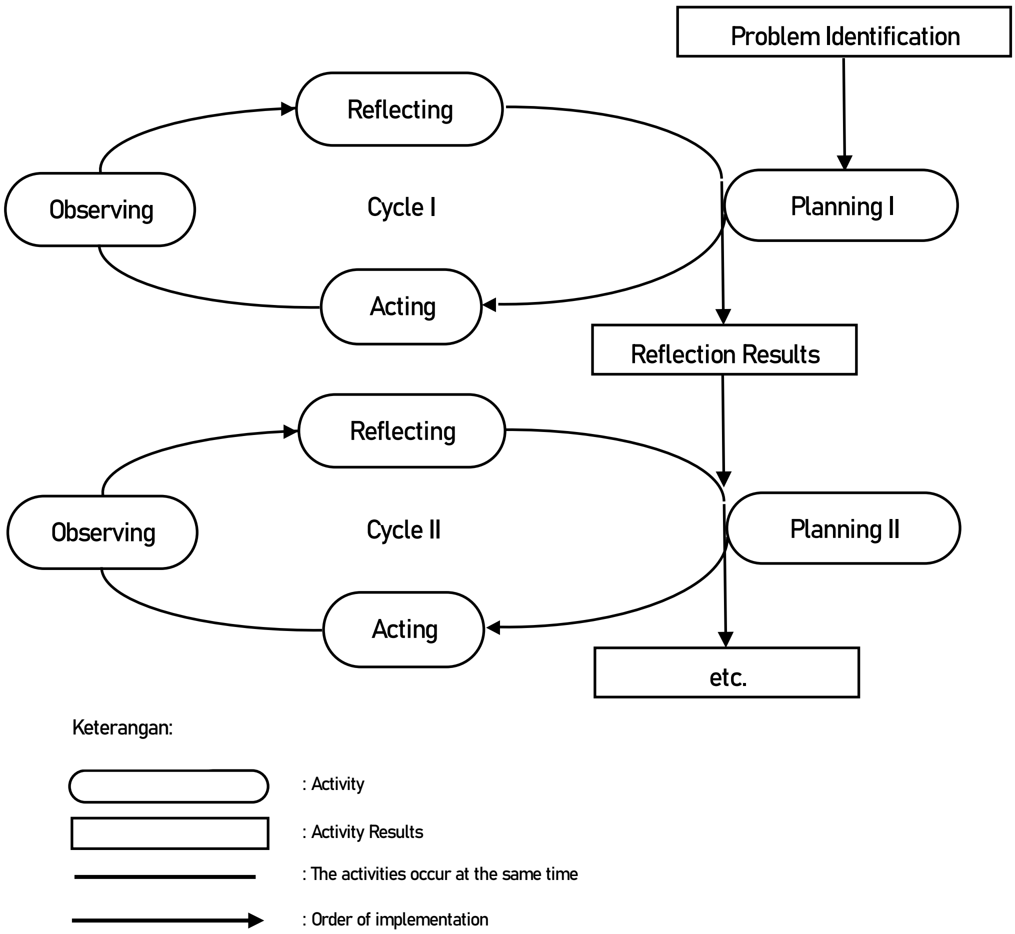

Figure 3. CAR Spiral Model
(*Kemmis and Mc. Taggart, 1988*)

The research was during the even semester of the 2023/2024 academic year, with eight students as subjects of grade IX. The research instruments consisted of learning devices and data collection instruments. The learning devices employed the *Lesson Implementation Plan* (RPP), *Student Worksheets* (LKPD), and AR-Build Space Media. The data collection instruments used observation sheets, interviews, and KPMM tests. Data were analyzed using comparative descriptive analysis.

This research procedure involved two cycles. Each consisted of two meetings. If the criteria of students' KPMM completeness had not been achieved in cycle I, the research would continue to cycle II with the same stages of activity but with improvements based on reflections from cycle I. Each cycle would experience improvements to overcome the difficulties and obstacles found previously. If cycle II reached the criteria for completion, then this classroom action research would be stopped.

Furthermore, the research data analysis employed the Miles and Huberman (2014) model, which included three steps: *data reduction*, *data presentation*, and *conclusion*. Data were presented descriptively at the presentation stage comparatively. The research data included problem-solving ability test results, interview sheets, and observation sheets. This research also employed success indicators to assess whether the research objectives had been achieved.

This research was considered successful if it met all aspects of the indicators. The research success indicators are listed in Table 1 below:

Table 1. Success Indicators

Success Criteria	**Instruments**	**Data Collection Techniques**
≥ 70% of students get a test score of ≥ 70	End-of-cycle test question sheets	Test
Percentage of educator activities ≥ 80%	Educator activity sheets	Observation
Percentage of student activities ≥ 80%	Student activity sheets	Observation
Percentage of positive student responses to the application of the *Problem-Based Learning* (PBL) model assisted by *Augmented Reality* media ≥ 70%	Student interview sheets	Interview

The data were analyzed using the following formula (Ainaya & Pertiwi, 2023):

$$\text{Percentage of mean score (SR)} = \frac{\Sigma \text{ score achieved}}{\Sigma \text{ maximum score}} \times 100\%$$

Guidelines for concluding data analysis and the actions' success level can be found in Table 2 below:

Table 2. Action Success Level Criteria

Percentage (%)	**Description**
81% – 100%	Excellent
61% – 80%	Good
41% – 60%	Quite Good
21% – 40%	Less
0 – 20%	Poor

(*Source*: Ainaya & Pertiwi, 2023)

The minimum success criteria in implementing the *Problem-Based Learning* (PBL) model assisted by *Augmented Reality* media was ≥ 70%.

The final cycle test assessed students' mathematical problem-solving ability on the curved-sided spatial structure material, which was then analyzed descriptively. The calculation methods regarding the percentage of mathematical problem-solving by students (Handayani et al., 2023:1221) can be seen below:

a. $\text{Individual absorption capacity} = \frac{\text{score obtained}}{\text{maximum score of the questions}} \times 100$

Students were declared to have completed learning if their mathematical problem-solving test scores reached ≥ 70. If it did not meet the criteria, the treatment was considered failed, and improvements were needed in the subsequent treatment.

b. $\text{Percentage of learning completion} = \frac{\Sigma NS}{\Sigma N} \times 100$

Where:

NS = Student completion

N = Number of students

To determine the mean score, the formula can be seen below:

$\bar{x} = \frac{\Sigma x}{N}$, where:

$\bar{x}$ = Mean

ΣX = Total value

N = Total subjects

Results and Discussion

The research results on the problem-solving ability of curved-sided spatial figures in grade IX students of SMP Islam Muallimin Kediri were analyzed descriptively comparatively by comparing student learning outcomes in each cycle. All cycles were presented and compared simultaneously to determine the development of students' mathematical problem-solving abilities.

Initial observations revealed that the teaching and learning process was not optimal, tending to be centered on educators (*Teacher Centered Learning*). Many students paid less attention because they were noisy and talked to their desk-mates. It happened because of the lack of student involvement in learning. In mathematics, students memorized more formulas without understanding the concept. The teaching and learning process emphasized listening to explanations, followed by practice questions that were often only copied and pasted from the internet without understanding the meaning of the questions. The solution required was applying the *Problem-based Learning* model, assisted by augmented reality media.

Students' problem-solving abilities in cycle I were still not optimal. However, student activity in learning increased compared to before the classroom action. At the beginning of cycle I, students were not accustomed to Problem-based Learning assisted by augmented reality media because teachers rarely used it. As a result, some students were still hesitant and embarrassed to ask questions or present their group work because they feared making mistakes.

During group discussions, each group needed to be given some distance; thus, they would not talk to each other. In cycle I, the researcher was not optimal in conditioning the students; some were still not focused and did not participate in the discussion. The researcher was also not optimal in directing and assisting students in groups. The researcher and students were required to improve cooperation in cycle II; hence, the implementation of the *Problem-Based Learning* model with *Augmented Reality* media could run more effectively. In the final cycle test, students had difficulty following the steps to solve problems, were less trained in dealing with complex math problems, and often stopped before the problem was solved.

In cycle II, the condition of the students was much better. The teaching and learning process ran more smoothly, and group cooperation was more optimal. Students' enthusiasm for solving problems increased, as seen from the better discussion results. Students' attention was more focused, and activities of talking to themselves and joking were under control. Generally, students followed the learning well, were active, confident, and could work together. The researcher has also realized the shortcomings in cycle I and is more optimal in directing and guiding students. All planned activities have been carried out well without repeating previous mistakes.

Based on the description in each cycle, each cycle showed an increase. The classroom action research outcomes can be seen below:

Figure 4. KPMM Test Results

Figure 4 highlights that students' *Mathematical Problem-Solving Ability* (KPMM) increased from the pre-cycle to each cycle. In the pre-cycle, students' problem-solving ability did not meet the criteria; all students had not achieved a KPMM test score of ≥ 70. There was an increase after the action in cycle I, but success had not been achieved, with a percentage of 12.5% of students completing and 87.75% not achieving a KPMM test score of ≥ 70. In cycle II, after further action, it can be seen in Figure 4 that students experienced significant improvement and achieved the target, namely ≥ 75% of students achieving a KPMM test score of ≥ 70.

This analysis obtained facts that the problem-solving stages provided a structured and systematic framework, helping students understand and apply mathematical concepts effectively. The stages consisted of understanding the problem, preparing a strategy, implementing the strategy, and reviewing (Sembiring, 2020:47). By following these stages, students gained a clearer view of approaching and solving mathematical problems. Therefore, it allowed students to answer in detail and systematically according to the wishes of the educators.

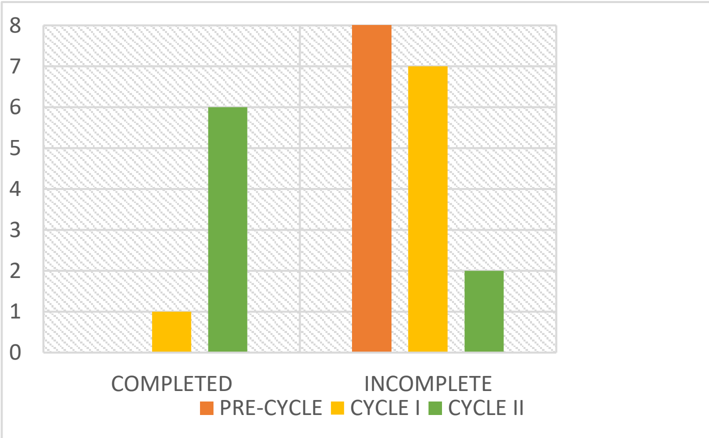

Figure 5. Learning Completeness

Based on the data, classically, there was an increase in completeness from the pre-cycle to cycle II. In the pre-cycle, no students had completed, with eight students not achieving a test score of ≥ 70; hence, the class had not achieved success because the completeness was still below 70%.

In cycle I, after the action, the class completeness reached 12.5% , with one student completing and seven students not completing; thus, it was still included as a 'not completing/ failed' class because the percentage of completeness was below 70%. In cycle II, completeness increased to 75%, with six students (completing) and two students (not completing).

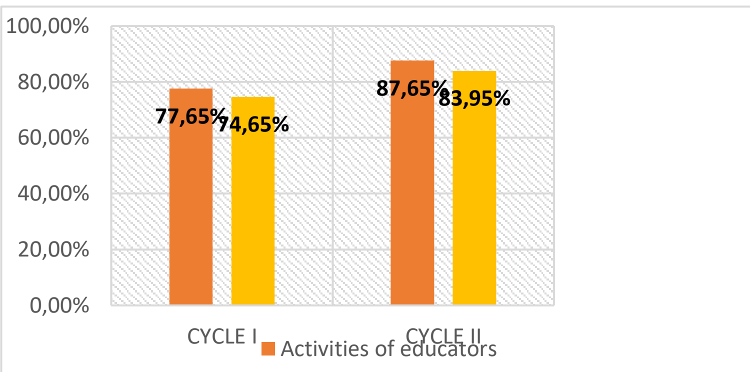

Figure 6. Results of Educator and Students' Activities

Figure 6 highlights that the activities of educators and students in the teaching and learning process increased, which tended to increase the average and classical learning completeness in mathematical problem-solving ability.

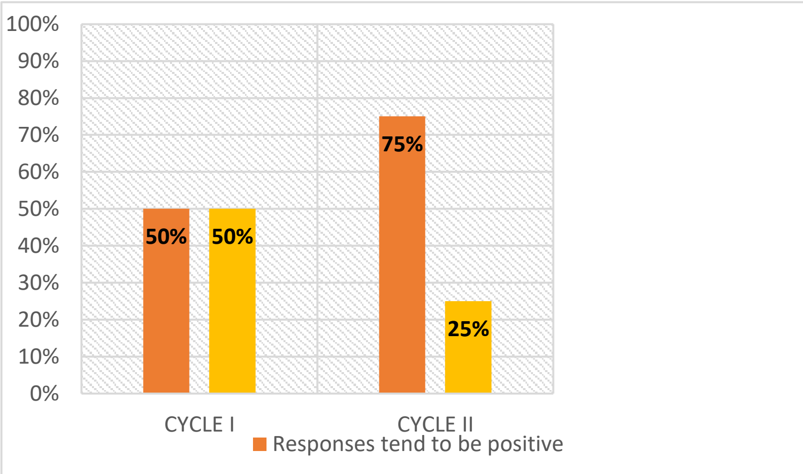

Figure 7. Positive Student Responses to the Implementation of the Problem-Based Learning (PBL) Model Assisted by Augmented Reality Media

The results of the interviews in cycle I obtained 50% positive responses from students. The main obstacles included a lack of interest in mathematics, low initiative to ask questions, minimal discussion participation, and boredom during lessons. After the action in cycle II, students' positive responses increased to 75%, due to the increase in students' understanding of solving problems.

Therefore, the class achieved success in completion and increased Mathematical Problem-Solving Ability (KPMM). This research success was in line with the results of research conducted by Mulianti et al. (2023), where learning by implementing the Problem-Based Learning (PBL) model assisted by Augmented Reality at SMK Negeri 1 Lebong could improve students' mathematical problem-solving ability.

Additionally, these findings are supported by relevant theories and recent research. According to the constructivist theories of Piaget and Vygotsky, Problem-Based Learning (PBL) allows students to build their knowledge through real-life experiences, which strengthens their understanding of mathematical concepts (Salsabila & Muqowim, 2024).

Recent research by Haryani et al. (2024) supports this, showing that using Augmented Reality in mathematics learning can enhance problem-solving skills. In this context, Augmented Reality media acts as a tool that enriches students' learning experiences by providing visualizations that make solving mathematical problems more interactive. Furthermore, a study by Sholikhah et al. (2023) found that combining Problem-Based Learning (PBL) with Augmented Reality technology can increase students' motivation and engagement during the learning process, ultimately improving their learning outcomes.

Therefore, the findings of this study confirm that Problem-Based Learning (PBL) supported by Augmented Reality media is not only effective in improving mathematical problem-solving skills but also aligns with existing learning theories and previous research, which highlight the positive impact of technology in mathematics education.

Conclusion and Suggestion

The implementation of the Problem-Based Learning (PBL) model assisted by *Augmented Reality Media* can improve the mathematical problem-solving ability of curved side space figures in SMP Islam Muallimin Kediri grade IX students. The mathematical problem-solving ability to apply the PBL model assisted by augmented reality media has increased from cycles I to II. In cycle I, there was one student who completed the KKM with a percentage of 12.5% of the eight students, and in cycle II, there was an increase of six students with a percentage of 75% of the eight students with a KKM of 70. The average KPMM value of students in cycle I was 56.75, increasing to 73.87 in cycle II.

To improve learning effectiveness, educators can help and encourage students to be more active in learning by providing more opportunities to be involved in activities and by implementing the PBL or other learning models. Hopefully, the use of augmented reality in the future will be more effective and complete, including containing game innovations based on the teaching materials.

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