Al-Ishlah: Jurnal Pendidikan
Vol.16, 2 (June, 2024), pp. 1374-1382
ISSN: 2087-9490 EISSN: 2597-940X, DOI: 10.35445/alishlah.v16i2.4740

Enhancing Students' Geometry Learning Outcomes and Critical Thinking Skills through the Implementation of Problem Based Learning Model

Dewi Indrapangastuti[1], Murwani Dewi Wijayanti[2], Achmad Basari Eko Wahyudi[3]

[1] Universitas Sebelas Maret, Surakarta, Indonesia; dewiindrapangastuti@staff.uns.ac.id
[2] Universitas Sebelas Maret, Surakarta, Indonesia; murwanidewi@staff.uns.ac.id
[3] Universitas Sebelas Maret, Surakarta, Indonesia; Achmadbasari88@staff.uns.ac.id

ARTICLE INFO

Keywords:

critical thinking;
learning results;
primary school teachers;
problem based learning

Article history:

Received 2023-11-11
Revised 2024-02-14
Accepted 2024-06-28

ABSTRACT

To enhance students' critical thinking abilities, it is essential to adopt an interactive learning model where students actively participate, and the instructor acts as a facilitator. This can be achieved through the implementation of the Problem-Based Learning (PBL) model in the teaching and learning process. This study aimed to evaluate the improvement of learning outcomes and critical thinking skills through the application of the PBL model among students. Conducted as classroom action research, it involved 40 students from Yogyakarta State University. The research comprised two cycles, each consisting of two sessions. Instruments used included observation sheets for learning implementation, critical thinking assessment sheets, and tests. Data analysis was performed quantitatively using descriptive analysis methods. The findings revealed that (1) the learning process was effectively implemented, with observation data from both cycles rated as good, with a mode of 4 (good); (2) students' learning outcomes improved, with the average post-test scores increasing from 70.85 in Cycle 1 to 80.63 in Cycle 2; (3) students' critical thinking skills also enhanced, with the average score rising from 68.54 in Cycle 1 to 82.08 in Cycle 2. The conclusion of this study is that implementing PBL in the learning process can significantly enhance both critical thinking and learning outcomes. The research implies that teachers' professional competence can be developed through the application of PBL. It is recommended that teachers integrate the PBL model into their teaching practices to foster students' higher-order thinking skills, such as critical thinking, creativity, and scientific reasoning abilities.

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Corresponding Author:
Dewi Indrapangastuti
Universitas Sebelas Maret,Surakarta,Indonesia;email; dewiindrapangastuti@staff.uns.ac.id

1. INTRODUCTION

Continuous improvement and education are crucial for enhancing the quality and potential inherent in each individual. The development of human resources is paramount, particularly in the era of globalization (Tinio, 2003). There is a clear need for high-quality human resources capable of

realizing their full potential and effectively addressing future challenges. Higher education plays a significant role in enhancing the quality of human resources, as demonstrated by the implementation of the Tri Dharma of Higher Education, which encompasses three fundamental roles. However, universities face challenges in improving the quality of human resources. Ideally, university-level education should develop both hard skills and soft skills in students. In reality, however, it often focuses primarily on strengthening hard skills. Hard skills pertain to the mastery of academic material (theory), while soft skills aim to complement and enhance these hard skills. According to Wagner (2008), critical thinking is one of the essential soft skills. This skill involves identifying, analyzing, and solving problems creatively and logically, leading to appropriate judgments and decisions (Tinio, 2003). Therefore, fostering both hard and soft skills in higher education is essential for producing well-rounded, capable graduates.

Fisher (2011) argues that critical thinking encompasses the ability to analyze, interpret, and evaluate ideas and reasoning. Today, critical thinking is considered a fundamental skill, on par with reading and writing. Foster and Pikket (Susiyati, 2014) suggest that critical thinking goes beyond mere memorization, involving the application and manipulation of information in new learning contexts. Similarly, Abdullah (2016) asserts that critical thinking is a higher-order thinking skill that education should aim to develop. The level of critical thinking ability varies among individuals, depending on how much they practice and hone these skills. Observations of students in the Primary Teacher Education program (Pendidikan Guru Sekolah Dasar, PGSD) at the Faculty of Teacher Education and Educational Sciences, UNS Kebumen, reveal that they often focus on theoretical learning in the Solid Geometry course without sufficiently developing critical thinking skills. Their responses to instructor questions are limited and theory-focused, hindering their ability to reach their full potential. Some students struggle with group work, communication, and problem-solving in real-world scenarios, leading to inadequate decision-making. Developing critical thinking skills is essential for PGSD students, who are future elementary school teachers, to effectively observe, analyze, and address the various challenges they will face in school environments. Therefore, higher education should emphasize not only understanding the material but also applying it in practical, work-related contexts to better prepare students for their future careers.

Karim and Normaya (2015) assert that to foster students' critical thinking skills, it is crucial to adopt a learning model that promotes active student engagement while instructors serve as facilitators. Problem-Based Learning (PBL) is an instructional model renowned for its ability to enhance critical thinking skills. PBL employs real-life topics as the foundation for learning concepts and information, utilizing critical thinking and problem-solving techniques. This approach involves a collaborative process where students build reasoning from their prior knowledge and the information gained through peer interactions. Sudarman (2007) describes this method as learning by doing. This perspective aligns with Nugraha and Mahmudi (2015), who highlight that PBL effectively cultivates critical thinking skills by enabling students to actively construct knowledge and understand learning concepts through collective problem-solving in groups. Therefore, integrating PBL into educational practices is essential for developing students' critical thinking abilities and preparing them for real-world challenges.

Research by Nuryanti et al. (2018) indicates that learning experiences that do not fully utilize students' thinking potential can lead to limited critical thinking skills. Additionally, Karim and Normaya (2015) emphasize that to enhance students' critical thinking abilities, a learning model must engage students actively, with the teacher serving as a facilitator. A well-known model for fostering critical thinking is Problem-Based Learning (PBL), which centers on real-world issues to develop knowledge and concepts through critical thinking and problem-solving. According to Sudarman (2007), PBL is a collaborative process where students build knowledge by leveraging prior knowledge and information gained from their interactions with others. Nugraha and Mahmudi (2015) further state that PBL effectively enhances critical thinking skills by encouraging students to actively construct their knowledge and understand learning concepts through group-based problem-solving activities.

One of the core elements in the Pancasila Student Profile within the Merdeka Belajar (Independent Learning) Curriculum is critical thinking. Consequently, PGSD students, who are future elementary school teachers, are expected to develop critical thinking skills, particularly for teaching Mathematics and spatial geometry at the elementary level. Problem-Based Learning (PBL) facilitates this by engaging students in the learning process through problem-solving activities, enabling them to draw conclusions based on their understanding. According to Hmelo-Silver and Barrow (2006), PBL problems do not have a single solution, requiring students to explore multiple solution paths through investigation. Implementing the PBL model aims to create a learning environment that goes beyond merely transferring information, fostering a process that emphasizes the construction of knowledge based on understanding and experiences, both individually and in groups. Therefore, PBL is a valuable approach for enhancing critical thinking skills in future educators.

Rusman (2013) notes that students' comprehension of concepts and principles begins through engagement with situations or problems presented via investigation, inquiry, and problem-solving. Students construct these concepts or principles by integrating their skills and previously acquired knowledge. Arends (2008) outlines the PBL model syntax as follows: 1) problem orientation and organizing students for learning, 2) guiding individuals or groups, 3) developing and presenting work results, and 4) analyzing and evaluating the problem-solving process.

The benefits of the PBL model include: 1) helping students understand lesson content more fully through problem-solving techniques; 2) allowing students to test their knowledge and gain a sense of accomplishment when learning new things; 3) improving learning activities through problem-understanding; 4) aiding students in comprehending real-life issues; 5) encouraging students to develop new knowledge, take ownership of their learning, and self-evaluate their learning process and outcomes; and 6) showing students that every learning material involves a way of thinking and understanding, rather than just learning from teachers or books (Sanjaya, 2011). Given that PBL fully immerses students in the learning process through problem-solving activities, it is expected to aid in developing critical thinking abilities. Students must hone their critical thinking skills as they navigate problems and make deductions based on their learning during these problem-solving exercises.

Learning outcomes refer to the mastery of knowledge or skills developed through subjects, typically indicated by test scores or grades given by educators (Depdiknas, 2008). This suggests that assessments provided by educators can be in the form of tests or non-test evaluations. According to Purwanto (2013), learning outcomes are changes in behavior that occur after the teaching and learning process, aligned with educational goals. Humans possess psychological potential that can be educated, allowing them to change their behavior across cognitive, affective, and psychomotor domains. Syah (2010) emphasizes that learning outcomes are the level of success students achieve in reaching set goals in a program, while Suryabrata (2006) mentions that learning outcomes are scores representing educators' final assessment of students' progress over a specific period. Based on these views, learning outcomes represent the ability to master knowledge acquired through the learning experience, which can change students' attitudes or behaviors. These can be assessed through tests or non-test methods to gauge progress, covering cognitive, affective, and psychomotor domains. In this research, the cognitive and psychomotor domains are measured using tests aligned with learning outcomes, with a minimum passing criterion (KKM) of 75 (Good). The affective domain is measured using an instrument to assess critical thinking skills.

Dewey emphasizes that critical thinking involves an active, continuous, and thorough examination of beliefs or knowledge that are accepted without supporting reasons for rational conclusions (Sihotang, 2012). Ennis (1996) describes critical thinking as a process for making reasonable decisions about what to believe and do. He identifies 12 indicators of critical thinking skills, which are grouped into five aspects: elementary clarification, which involves focusing on questions, analyzing them, and asking and answering questions; basic support, which includes assessing the credibility of sources and evaluating observation reports; inference, which entails deducing and evaluating both deductive and inductive results, as well as making and determining value judgments;

advanced clarifications, which involve defining terms, considering definitions, and identifying assumptions; and strategies and tactics, which include determining actions and interacting with others. In conclusion, these aspects collectively contribute to the development of robust critical thinking skills, essential for rational decision-making and problem-solving.

Previous studies on critical thinking have predominantly focused on either enhancing students' learning outcomes or improving their critical thinking skills in isolation. However, this research aims to bridge that gap by simultaneously enhancing both learning outcomes and critical thinking skills. The focus of this study is on Mathematics, given its crucial role in developing critical thinking skills. Critical thinking in Mathematics is vital for understanding and solving problems that require reasoning, analysis, evaluation, and interpretative thinking, which effectively reduces errors when tackling complex issues. By fostering critical thinking skills in Mathematics, we can encourage student participation and active learning, thereby equipping them with essential problem-solving abilities.

The primary objective of this research is to explore the dual impact of implementing the Problem-Based Learning (PBL) approach on students' learning outcomes and their critical thinking skills. The central research question guiding this study is: How can the implementation of Problem-Based Learning (PBL) improve students' learning outcomes and critical thinking skills? This research aims to contribute theoretically to the development of new teaching models and offer practical benefits for enhancing the effectiveness of the teaching and learning process, with a specific focus on improving student learning outcomes and critical thinking skills. In conclusion, this study seeks to provide a novel approach by integrating both objectives and thereby fostering highly skilled and high-quality human resources.

2. METHODS

This study employs collaborative classroom action research involving peer educators (lecturers). The instructional model employed was PBL. The participants of the study were 40 second-year students from the 2I class. The research was conducted in May 2023. The research design adheres to the Kemmis & Taggart model of classroom action research design, as outlined by Arikunto (2017). The research was carried out over two cycles, each consisting of two sessions. Each cycle involved (1) Planning, the critical development of a teaching plan aimed at improving the current situation; (2) Execution, implementing the established teaching plan; (3) Observation, evaluating the impact of the implemented actions on the students in line with the established plan; (4) Reflection, the process through which researchers analyze, assess, and contemplate the outcomes of the conducted actions. Based on these reflections, researchers, together with fellow educators, make necessary improvements and develop the plan for the subsequent implementation. This collaborative classroom action research was executed to enhance the effectiveness of Problem-Based Learning, improve student learning outcomes, and cultivate critical thinking skills. The research followed a systematic approach aimed at ensuring meaningful educational progress.

Data collected from interviews, pre-implementation observation sheets, and field notes were analyzed descriptively. In contrast, data from the observation sheets during the teaching sessions and the critical thinking ability assessment sheets were analyzed quantitatively. The quantitative data obtained through the observation questionnaires during teaching implementation were analyzed using descriptive techniques as outlined by Mogey in his Evaluation Cookbook, LTDI Institute for Computer-Based Learning (Harvey, 1998). This technique was used because the instrument utilized a Likert scale questionnaire. The data regarding students' critical thinking abilities, which included responses such as agree or disagree, were measured by comparing the percentages. Learning outcomes were assessed by analyzing the average post-test scores to determine if they met the minimum passing criteria. Additionally, the improvement in learning outcomes was evaluated by comparing post-test scores from cycle 1 and cycle 2.

3. FINDINGS AND DISCUSSION

The research aimed to implement Problem-Based Learning to enhance learning outcomes and critical thinking skills among 40 students, specifically in class 2I. The selection of this class was based on considerations that the pre-test results for the geometry material were suboptimal, with an average score of 62. This motivated the researcher to introduce Problem-Based Learning as an instructional method, concurrently investigating whether it could lead to improvements in both learning outcomes and students' critical thinking abilities. The researcher conducted the observation phase, while a faculty member conducted the teaching sessions. This classroom action research consisted of two cycles, each comprising four key phases: planning, executing the intervention, observation, and reflection.

The planning phase for each cycle involved developing instructional materials such as content, teaching aids, observation sheets, questionnaires, and post-test questions. Each cycle's implementation process, adhering to the Problem-Based Learning approach, was conducted over two class sessions. The teaching activities were organized into three main phases: the introductory phase, the core content phase, and the concluding phase. Observations during these sessions were carried out by a designated observer. Following this, reflection was conducted based on the observations, questionnaires, and post-test results. The curriculum content for both Cycle 1 and Cycle 2 focused on spatial geometry. In Cycle 1, the emphasis was on the surface area of spatial structures, while Cycle 2 concentrated on exploring the volume of these structures.

The data from the observation of the teaching implementation during Cycle 1 and Cycle 2 is as follows:

Table 1. The observations result of the teaching implementation in Cycle 1 and 2

No	The observed indicators	Cycle score 1	Cycle score 2
1	Carrying out apperception activities	4	4
2	Demonstrating mastery of learning material	5	5
3	Carrying out geometry learning in accordance with the goals to be achieved and student characteristics	4	4
4	Carrying out geometry learning based on the PBL syntax	4	4
5	Fostering active student participation in discussions	4	5
6	Facilitating students to present the results of discussions	4	4
7	Involving students in making conclusions	3	4
8	Maintaining good communication with students	3	4
9	Reflecting by involving students	3	4
10	Carrying out the final assessment (posttest 1 and 2)	4	4
	Mode	4	4

Based on the data, the implementation of the Problem-Based Learning (PBL) model in both Cycle 1 and Cycle 2 has been executed effectively. The mode of the scores for both cycles was consistently rated at 4 (Good).

Moreover, the data regarding the post-test results for Cycle 1 and Cycle 2 are presented in Table 2.

Table 2. The mean scores of the post-tests for 40 students in Cycle 1 and 2

Mean scores in Posttest 1 (Cycle 1)	Mean scores in Posttest 2 (Cycle 2)
70.85	80.63

The research data indicate an increase in the average post-test scores of students from Cycle 1 to Cycle 2. This is evident in the rise in the mean post-test score from 70.85 in Cycle 1 to 80.63 in Cycle 2. The escalation of the mean post-test score from Cycle 1 to post-test 2 in Cycle 2 is 9.78. It means that the implementation of the problem-based learning model leads to an improvement in learning outcomes.

The data regarding students' critical thinking skills in Cycle 1 and Cycle 2 can be found in Table 3.

Table 3. The mean scores for students' critical thinking in Cycle 1 and Cycle 2

No	Indicators	Cycle score 1 (%)	Cycle score 2(%)
1	Students can know the intention of the questions	72.5	85
2	Students can analyse questions	67.5	77.5
3	Students can ask and answer questions	57.5	72.5
4	Students can consider whether the source is trustworthy or not	72.5	82.5
5	Students can deduct and consider the results of the deduction	70	85
6	Students can induce and consider the results of induction	62.5	82.5
7	Students can make and determine consideration values	70	85
8	Students can define terms and definitions of reconsideration	72.5	87.5
9	Students can identify assumptions	60	72.5
10	Students can determine an action	72.5	82.5
11	Students can observe and consider reports of observation results	67.5	85
12	Students can interact with other people	77.5	87.5
	Mean	68.54	82.08

The research data regarding the critical thinking abilities of 40 students from Cycle 1 to Cycle 2 show a notable improvement. This is evident in the average percentage increase in critical thinking abilities for the 40 students, 68.54% in Cycle 1 to 82.08% in Cycle 2, marking an increase of 13.54%. Furthermore, this significant increase demonstrates the impact of the structured PBL approach on student engagement and learning outcomes. Based on this data, it can be concluded that the problem-based learning model effectively enhances students' critical thinking abilities. The results underscore the potential of PBL in fostering essential skills that are crucial for academic and real-world problem-solving.

In the test analysis, students demonstrated the ability to identify the questions or issues within the problems presented. Schafersman asserts that critical thinkers can pose relevant questions, gather pertinent information, act efficiently and creatively based on that information, and draw trustworthy conclusions (Sadia, 2008). Based on this perspective, critical-thinking students should be able to identify a problem and formulate questions accordingly. However, the students' responses often did not accurately convey the meaning of the posed questions. Interviews revealed that students frequently appeared confused when trying to address the intent of a question. Only a few high-achieving students could adequately explain the purpose behind the questions. Throughout the learning process, very few students actively engaged and were willing to ask and answer the teacher's questions. Although some students had opinions or thoughts, they lacked confidence in expressing them orally.

Critical thinking theory encompasses the active, continuous, and meticulous evaluation of beliefs or knowledge, including the analysis of supporting reasons and rational conclusions (Sihotang, 2012). This indicates that students who engage in critical thinking can draw well-reasoned conclusions from problems by providing robust justifications. Interview results revealed that most student groups did not encounter difficulties in concluding the material. The Problem-Based Learning (PBL) model has proven effective in developing critical thinking and enhancing student learning outcomes. Interviews further supported these findings, showing that, on average, students found it relatively easy to define terms and explain the material. Throughout the PBL process, students engage in testing their thinking, questioning and critiquing their ideas, and exploring new concepts (Taufiq, 2010). In conclusion, the

integration of PBL into the curriculum significantly bolsters students' critical thinking abilities and academic performance, making it a valuable approach in education.

The interview results indicated that students struggled with identifying assumptions. Each student's reasoning ability varies, leading to different outcomes. Reasoning, the process of drawing conclusions, can be influenced by both subjective and objective factors. As a result, different understandings of a phenomenon can lead to diverse conclusions (Taufiq, 2010). This supports the theory that Problem-Based Learning (PBL) uses real-world problems as the context for students to develop problem-solving skills (Khoiri, 2013). Engaging with real-life issues allows students to think critically, making it easier for them to find solutions to problems. Interview data suggest that students are generally capable of determining a course of action effectively. In conclusion, while students may face challenges in identifying assumptions, the PBL approach equips them with the necessary skills to think critically and address real-world problems, highlighting the importance of incorporating PBL in educational settings.

This aligns with the theory that problem-based learning (PBL) as a teaching strategy fosters the development of thinking, problem-solving, and intellectual skills (Kusumaningtias et al., 2013). Nuryanti et al. (2018) demonstrated that learning experiences failing to maximize students' thinking potential result in limited critical thinking skills. Furthermore, Karim and Normaya (2015) found that to cultivate critical thinking abilities, the teaching model must facilitate interactive student engagement, with the teacher serving as a facilitator. PBL is well-regarded for its capacity to enhance critical thinking skills by immersing students in real-world problems that require active problem-solving and collaboration. By engaging students in these authentic learning experiences, PBL not only improves their critical thinking abilities but also prepares them for the complexities of real-world challenges. In conclusion, the integration of PBL in educational settings is crucial for developing well-rounded, critically-thinking individuals who are adept at solving problems and applying their knowledge in practical contexts.

The PBL learning process, enhanced by discussion and presentation methods, has proven to be highly successful. Discussion fosters critical and systematic thinking, encourages open-mindedness, and teaches students to value others' opinions (Zulfiani, 2009). In the initial problem orientation stage, students actively engage in solving geometry problems through group discussions and completing worksheets. Most students participate actively by asking and answering questions, although some less active students may lack the confidence to question the teacher directly. Additionally, some students find it challenging to express their opinions to their group members.

During the student organization for learning stage, students collaborate with peers to gather information related to the theories addressing the given problem. This collaboration not only deepens their understanding of the subject matter but also enhances their teamwork and communication skills. By working together, students learn to integrate diverse perspectives and develop more comprehensive solutions to problems. The interactive nature of PBL ensures that students are not passive recipients of information but active constructors of knowledge, which significantly boosts their engagement and retention of material. In conclusion, the PBL approach, when combined with effective discussion and presentation methods, creates a dynamic learning environment that cultivates critical thinking, collaboration, and practical problem-solving skills.

4. CONCLUSION

The research findings indicate that the implementation of the Problem-Based Learning (PBL) approach effectively enhanced both the learning outcomes and critical thinking abilities of the students. Specifically, the learning process was executed successfully, as evidenced by the observation data in cycles 1 and 2, which consistently scored well with a mode of 4 (good). Students' learning outcomes showed significant improvement, with average post-test scores increasing from 70.85 in cycle 1 to 80.63 in cycle 2. Additionally, students' critical thinking abilities improved markedly, with average scores

rising from 68.54 in cycle 1 to 82.08 in cycle 2. These improvements can be attributed to the active engagement of students in the PBL approach. Despite these positive outcomes, the research was limited to a specific group of students and subject matter, which may affect the generalizability of the findings. Future research should explore the application of PBL across different subjects and diverse student populations to validate and extend these findings. Moreover, longitudinal studies could provide deeper insights into the long-term effects of PBL on critical thinking and learning outcomes.

Acknowledgments: The author would like to thank the supervisors who have provided suggestions and materials in the completion of this article

Conflicts of Interest: the authors declare no conflict of interest.

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