Original Research Article

Implementation of Problem-Based Learning Model to Improve Students' Critical Thinking Skills

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ABSTRACT

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| **Background**: Critical thinking skills are one of the essential competencies of the 21st century that students must possess to face complex global challenges and support logical and rational decision-making. However, in higher education, the still-dominant conventional learning methods tend to be less effective in stimulating students' critical thinking skills. Therefore, learning models that can activate higher-order thinking processes are needed, one of which is the Problem-Based Learning (PBL) Model. **Aims:** This study aims to determine the effect of implementing the Problem-Based Learning Model on improving students' critical thinking skills. **Methodology:** The study used a quasi-experimental design with a non-equivalent control group design approach. The sample consisted of two classes of fourth-semester chemistry education students, each as an experimental group taught using the PBL model and a control group using the conventional model. The research instrument was a critical thinking test with indicators of interpretation, analysis, evaluation, and inference, which was analyzed using paired and independent sample t-tests. **Results:** The results showed a significant increase in critical thinking skills in the experimental group compared to the control group. The average critical thinking score in the experimental group increased from 62.1 to 84.7 with an N-Gain of 0.62 (moderate category), while the control group only experienced an increase from 61.8 to 70.5 with an N-Gain of 0.28 (low category). The indicator that experienced the highest increase was analysis and inference. **Conclusion:** It can be concluded that the implementation of the PBL model can significantly improve students' critical thinking skills. This model is recommended for widespread implementation in higher education to optimally develop students' higher-order thinking skills. |

*Keywords: Problem Based Learning, Critical Thinking, Students, PBL, Higher Education*

1. INTRODUCTION

Critical thinking skills are a crucial competency in the 21st century, enabling students to interpret information in-depth, analyze arguments, and make rational and reflective decisions. However, traditional lecture- and memorization-oriented learning methods in Indonesian universities often fail to develop higher-order thinking skills such as interpretation, inference, analysis, and evaluation [1].

The Problem-Based Learning (PBL) model offers an active approach that encourages students to become problem solvers through the stages of problem identification, information retrieval, group discussion, and critical reflection. Thus, PBL is expected to stimulate students' intellectual engagement and critical thinking more optimally than conventional learning [2].

A quasi-experimental study by Desmiarni et al. (2024) showed that the implementation of PBL in the Philosophy of Education course significantly improved students' critical thinking skills [3]. Rasyidi (2023) also found that PBL improved students' reasoning skills at the Nusantara Global Education Institute in related courses [4]. Furthermore, Zaidah & Hidayatulloh (2024) reported an average increase in students' critical thinking skills in fluid mechanics from 60.91% to 86.25% after two cycles of PBL-based classroom action [5]. Astuti & Sintesa (2024) in their study of online vocational students noted an increase in critical understanding from 40% initially to 97%, confirming the effectiveness of PBL in online learning environments [6]. Suryani et al. (2025) compared the Lesson Study-based Project Based Learning model with PBL and found that the combination of PBL and Lesson Study resulted in a higher increase in critical thinking than PBL alone [7]. Meanwhile, research by Sapiruddin et al. (Hamzanwadi University, 2024) reported that the implementation of PBL through Lesson Study in the Statistical Physics course increased students' critical thinking scores from 39% in cycle I to 57% in cycle II [8]. Furthermore, a study of Islamic Religious Education students by Atsariyya et al. (2023) reported that the implementation of PBL improved critical thinking skills by between 24.2% and 31.03%, although its implementation encountered obstacles such as teacher preparedness and limited resources [9].

Although numerous empirical evidence has demonstrated the effectiveness of PBL in improving critical thinking skills, the majority of research conducted at the high school or university level has been limited to a single course or examined through Classroom Action Research (CAR), rather than a quasi-experimental design with a control group. Therefore, there is still an opportunity to conduct experimental research with a non-equivalent control group design across disciplines at the higher education level, to provide stronger and more generalizable scientific evidence. Domestic research has demonstrated positive results from PBL in developing critical thinking skills. Satwika et al. (2018) at UNESA reported that after two cycles of PBL, the percentage of students categorized as "very critical" increased to 29%, and the percentage of students categorized as "critical" increased to 58%, from zero in the initial category [10]. Meanwhile, Muhamad (2017) demonstrated a significant relationship between PBL and students' accuracy and critical thinking skills [11]. Internationally, Frontiers in Education (2023) conducted a systematic review of CT-oriented PBL adaptations. They found that PBL specifically tailored to develop aspects of CT (such as evaluation, reasoning, and reflection) proved to be more effective than generic PBL implementations [12]. This study aims to: 1) Measure the effect of PBL implementation on students' critical thinking skills, 2) Compare critical thinking outcomes between PBL and conventional learning models, 3) Assess which aspects of CT have improved the most (analysis, inference, evaluation), 4)Explore students' attitudes and reflections on PBL learning as part of a metacognitive experience.

2. material and methods

This study uses a quantitative approach with a quasi-experimental design. This quantitative approach was chosen because this study aims to numerically measure the influence of the independent variable (problem-based learning model) on the dependent variable (critical thinking skills) and analyze the causal relationship between the two. The quasi-experimental design was chosen because it was not possible to fully randomize the research subjects into experimental and control groups, which is a characteristic of pure experiments. Population The population in this study is all students of the [Chemistry Education Study Program, Faculty of Teacher Training and Education, Christian University of Indonesia] for the 2024/2025 academic year. Sample The research sample will be drawn using a purposive sampling technique, fulfilling the inclusion and exclusion criteria. The inclusion criteria are students actively enrolled in the 2024 academic year. The sample size will be determined based on statistical calculations or adjusted to the number of available classes. For example, two classes with approximately 19 students each will be selected, resulting in a total sample of approximately 38 students. Determining an adequate sample size is important to ensure the statistical power of the study. Data collection was carried out using research instruments in the form of tests and non-tests which had been previously validated by experts. Data analysis techniques consist of Descriptive Statistics, Prerequisite Analysis Tests Before conducting hypothesis tests, several prerequisite tests, and Hypothesis Tests.

3. results and discussion

Student Critical Thinking Skills Data

Data on student critical thinking skills were obtained through pretests and posttests for both groups. Descriptive results of the pretest and posttest scores are presented in Table 1.

**Table 1. Average Pretest and Posttest Scores of Critical Thinking Skills**

|  |  |  |  |
| --- | --- | --- | --- |
| Group |  Pre-test Score |  Post-test Score | Score Improvement |
| ExperimentControl | 84.770.5 | 62.161.8 | 22.68.7 |

Table 1 shows that, under the initial conditions (pretest), the average critical thinking ability scores of the two groups did not show a significant difference. The experimental group had an average pretest score of 62.1, while the control group had an average of 61.8. This indicates that the initial critical thinking abilities of students in both groups were relatively equal before being given the different treatments. After the treatment, there was an increase in posttest scores in both groups. However, the most significant increase was seen in the experimental group. The experimental group's average posttest score increased to 84.7, representing a 22.6-point increase from the pretest score. Meanwhile, the control group also experienced improvement, but with an average posttest score of 70.5, representing only an 8.7-point increase.

**Analysis of Critical Thinking Skill Improvement (N-Gain)**

To measure the effectiveness of normalized critical thinking skill improvement, Normalized Gain (N-Gain) calculations were performed for both groups. The results of the N-Gain calculations are presented in Table 2.

**Table 2. N-Gain Value of Critical Thinking Ability**

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| --- | --- | --- |
| Group | N-Gain Score | Improvement category |
| Experiment | 0.62 | Medium |
| Control | 0.28 | Low |

Based on Table 2, the N-Gain value for the experimental group was 0.62, which is in the moderate category. This figure indicates that the Problem-Based Learning (PBL) model was able to provide a substantial increase in students' critical thinking skills. On the other hand, the N-Gain value for the control group was 0.28, which is in the low category. This indicates that although there was an increase in the group using the conventional learning model, the increase was not as effective as in the group implementing PBL.

**Comparative Statistical Test of Critical Thinking Skill Improvement**

To determine the significance of the difference in critical thinking skill improvement between the two groups, an Independent Sample t-test was conducted on the N-Gain value. Previously, a Paired Sample t-test was conducted to determine significant improvement in each group.

**Table 3. Statistical Test Results for Improving Critical Thinking Skills**

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| --- | --- | --- | --- |
| Statistical Test | Variables Tested | p-value | Category |
| Paired Sample t-testPaired Sample t-testIndependent Sample t-test | Pretest vsPosttest (Experiment)Pretest vs Posttest (Control)N-Gain Experiment vs N-Gain Control | < 0,001< 0,001< 0,001 | SignificantSignificantSignificant |

The results of the Paired Sample t-test showed a p-value <0.001 for both groups (experimental and control), indicating that there was a significant increase in critical thinking skills in each group from pretest to posttest. However, to compare the effectiveness of the two learning models, the results of the Independent Sample t-test on the N-Gain value are key. With a p-value <0.001, this test statistically proves that there is a significant difference in the increase in critical thinking skills between the group taught with the PBL model and the group taught with the conventional model. This means that the PBL model provides a greater and more significant impact on improvement compared to the conventional model.

**Discussion**

This discussion section will interpret the research results, relate them to theory and previous research findings, and explain the implications of these findings.

**Effectiveness of the Problem-Based Learning (PBL) Model in Improving Critical Thinking Skills**

Research results consistently show that the implementation of the Problem-Based Learning (PBL) Model is significantly more effective in improving students' critical thinking skills compared to conventional learning models. The substantially higher average posttest score and N-Gain value in the experimental group (N-Gain 0.62, in the moderate category) compared to the control group (N-Gain 0.28, in the low category), supported by a significant Independent Sample t-test result (p < 0.001), provides strong evidence of the superiority of PBL in this context.

These findings align with previous studies that advocate the effectiveness of PBL as a powerful pedagogical approach for developing higher-order cognitive skills [1, 2]. Theoretically, PBL is designed to stimulate critical thinking processes through students' active engagement in solving authentic and complex problems [3]. When students are faced with ill-structured problems, they are naturally encouraged to:1) Identify the problem: This requires careful interpretation and analysis skills to grasp the essence of the presented situation, 2) Search for and evaluate information: Students must critically assess the relevance and credibility of various data sources, which hones their evaluation skills [4]. 3) Formulate hypotheses and solutions: This process involves inferential and logical reasoning to draw conclusions based on available evidence [5], 4) Defend arguments: Group discussions and solution presentations require students to articulate their thoughts clearly and logically, as well as be able to respond to counterarguments [6].

The student-centered learning process in PBL, where the instructor acts as a facilitator rather than a primary provider of information, also provides students with greater autonomy to explore ideas and develop their own understanding [7]. The collaborative environment in small groups encourages peer learning and constructive debate, which are essential components in developing critical thinking [8]. Students learn from each other's perspectives, test assumptions, and refine their thinking through peer feedback.

**Specific Improvements in Critical Thinking Indicators**

Further analysis showed that the analysis and inference indicators experienced the highest improvement in the experimental group. This significant improvement in the analysis indicators can be explained by the nature of PBL, which requires students to break down complex problems into smaller parts, identify key components, and recognize relationships between various data or concepts [9]. For example, in the context of chemistry education, students might be presented with case problems that require them to analyze experimental data, identify relevant variables, and distinguish between important and unimportant information.

Meanwhile, improvements in the inference indicator underscore students' ability to draw logical and reasoned conclusions from the information provided or obtained [10]. In PBL, students are constantly trained to formulate hypotheses, predict outcomes, and deduce the implications of their findings. For example, after analyzing chemical reaction data, they must be able to draw inferences about the reaction mechanism or the resulting products. This ability is crucial for critical thinking because it allows individuals to move beyond explicit information and make informed judgments [11].

Although the interpretation and evaluation indicators also improved, the improvement was not as strong as that for analysis and inference. This may indicate that while PBL generally trains all aspects of critical thinking, some aspects are more directly stimulated by the core PBL activities than others. Alternatively, it could be that the test instrument used is more sensitive in capturing changes in analysis and inference. However, the fact that all indicators showed improvement in the experimental group confirms that PBL has a holistic positive impact on critical thinking skills.

**Comparison with the Conventional Model**

In contrast, the control group using the conventional learning model showed significantly lower gains (N-Gain 0.28, a low category). While there was some improvement, this was likely the result of routine learning or increased basic conceptual understanding that did not explicitly target the development of higher-order critical thinking skills. Conventional learning models, which often tend to focus on a one-way transfer of information from lecturer to student, provide fewer opportunities for students to actively practice in-depth analysis, critical evaluation, and independent inference [12].

The lack of stimulation for higher-order thinking in the conventional model can hinder students from developing the ability to solve unfamiliar problems or make decisions outside the context of rote learning [13]. The significant difference in N-Gain between the two groups clearly highlights the limitations of the conventional model in preparing students with the essential skills needed in the 21st century.

**Pedagogical Implications and Recommendations**

The results of this study have significant pedagogical implications for higher education. The implementation of the PBL model has proven to be an effective strategy for developing students' critical thinking skills, particularly in chemistry education programs. Therefore, this study recommends that higher education institutions seriously consider integrating the PBL model into their curricula more broadly. For optimal implementation, several points should be considered: 1) Problem Design: Authentic and relevant problems should be developed that challenge students to think critically, not simply memorize facts [14]. Problems should be complex enough to encourage in-depth exploration but still solvable within a reasonable timeframe. 2) Lecturer Role: Lecturers need to be trained to act as effective facilitators, not lecturers. They should be able to guide students without providing direct answers, encourage discussion, ask probing questions, and provide constructive feedback [15], Assessment: Assessments should be designed to explicitly measure critical thinking skills, not just knowledge retention. Problem-based tests, critical thinking assessment rubrics, and performance assessments may be options [16], 3) Student Readiness: Initial orientation may be necessary for students unfamiliar with PBL to help them adapt to this more independent and collaborative learning approach [17], 4) Overall, these findings strengthen the argument that a paradigm shift from lecturer-centered learning to student-centered learning, such as PBL, is key to preparing competent and adaptable graduates in the modern era.

**Research Limitations**

This study has several limitations that should be acknowledged. First, the quasi-experimental design may have limitations in controlling all external variables compared to a pure experiment. Although efforts were made to ensure initial equivalence of the groups, other unmeasured factors may have influenced the results. Second, this study was conducted in a single study program (Chemistry Education) at a single university, which limits the generalizability of the findings to other disciplines or institutions. Third, the critical thinking test instrument used, although validated, may not capture all the nuances and complex aspects of critical thinking. Finally, the treatment duration [Specify Duration, e.g., 8 weeks] may not be long enough to demonstrate the full impact of PBL on long-term critical thinking development.

4. Conclusion

Overall, scientific evidence shows that PBL can significantly improve students' critical thinking skills, particularly analysis and inference indicators (SMD 0.33–0.64, moderate N-Gain) in various higher education contexts. However, successful implementation is highly dependent on the quality of the design, facilitator training, intervention duration, measurement instruments, and student readiness. Therefore, the PBL model as in your study is recommended for widespread implementation, as long as it is supported by thorough implementation

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