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The Effect of the Deep Learning-Based Problem-Based Learning (PBL) Model on the Critical Thinking Skills and Mathematical Disposition of Elementary School Students

Novita Martika Putri[1], Maria Goreti Rini Kristiantari[2], Riandi Marisa[3]
[1]Magister Pendidikan Dasar, Universitas Terbuka, Indonesia, putrihermansyah1806@gmail.com
[2]PGSD, Universitas Pendidikan Ganesha, Indonesia, mariagoretirini.kristiantari@undiksha.ac.id
[3]Magister Pendidikan Dasar, Universitas Terbuka, Indonesia, riandi.marisa@ecampus.ut.ac.id

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Abstract

This study aims to analyze the effect and effectiveness of the Deep Learning-based Problem-Based Learning (PBL) model on the critical thinking skills and mathematical dispositions of elementary school students. A quasi-experimental study with a non-equivalent control group design was employed. The population consisted of fifth-grade students in Gugus 3 Kuta, with a total sample of 168 students (84 in the experimental group and 84 in the control group) selected through purposive sampling. The experimental group was treated with the deep learning-based PBL model, while the control group followed conventional learning. Data were collected using a critical thinking skills essay test and a mathematical disposition questionnaire. Analysis included N-Gain tests, Mann-Whitney U tests, and correlation analysis using SPSS. The results indicated a significant difference in outcomes between the two groups. The experimental group achieved a significantly higher post-test average for critical thinking (83.85) compared to the control group (47.65). Statistical tests confirmed that the deep learning-based PBL model significantly improved both critical thinking skills and mathematical dispositions (Asymp. Sig. 0.001 < 0.05). Furthermore, the model was found to be effective in enhancing both variables simultaneously. The integration of deep learning strategies into the PBL framework—emphasizing conceptual understanding, reflection, and knowledge transfer—creates a more interactive and reflective learning environment. This synergy effectively addresses students' difficulties with contextual problems and fosters a more persistent, confident attitude toward mathematics. In conclusion, the deep learning-based PBL model is a potent alternative for developing 21st-century skills at the elementary level.

Keywords: Problem-Based Learning; Deep Learning; Critical Thinking Skills; Mathematical Disposition; Elementary School.

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INTRODUCTION

Entering the era of 21st century education, the paradigm of mathematics learning in elementary schools has undergone a fundamental shift from simply mastering calculation procedures to developing higher-level thinking competencies. The 21st Century Skills framework places critical thinking as a key competency that must be internalized from an early age so that students are able to navigate the complexity of information in the future. In Indonesia, this demand is emphasized through the implementation of the Independent Curriculum which emphasizes the dimension of critical reasoning as one of the Pancasila student profiles that must be achieved by elementary school graduates. Teachers are now required to design instruction that is not only outcome-oriented, but also able to trigger students to analyze, evaluate, and reflect on every mathematical argument they build [1]

Academic success is not only determined by the cognitive aspect in the form of critical thinking skills, but it is also greatly influenced by an affective aspect known as mathematical disposition. Based on the standards set by the National Council of Teachers of Mathematics (NCTM), mathematical dispositions include psychological attributes such as confidence, perseverance in the face of challenges, and a great curiosity about mathematical patterns. This disposition serves as a mental driver that determines whether a student will continue to persistently seek solutions or give up when encountering impasse in solving problems. Therefore, building a positive attitude and learning resilience is crucial to ensure that critical thinking skills can be applied consistently by students in a variety of learning situations [2].

The reality on the ground shows that there is a wide gap between the demands of the curriculum and the actual conditions in schools. Based on initial observations at SD Gugus 3 Kuta, mathematics learning is still dominated by a procedural approach that is memorized, where students tend to be confused when faced with problems in the form of story problems. This symptom indicates low critical thinking skills, where students have difficulty identifying relevant information and developing self-resolution strategies. In addition, weak mathematical disposition can be seen from the attitude of students who lack confidence and are reluctant to explore alternative solutions, so that the learning process becomes shallow and does not provide meaningful understanding [3].

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This problem is strengthened by objective data listed in the 2025 Education Report Card in the Cluster 3 area of Kuta District. In some sample schools, such as SD 1 Tuban, the numeracy score and the character value of "Critical Reason" showed a worrying achievement and was ranked at the bottom nationally. Meanwhile, in other schools such as SD 6 Tuban, although the learning scores are quite high, there is still a significant gap in advanced numeracy skills, which indicates that students only master routine skills without deep reasoning skills. These facts underscore the need for pedagogical innovations that are able to transform the way students learn mathematics in the region[4].

One of the learning models that is considered a potential solution to overcome these problems is Problem-Based Learning (PBL). This model works by placing authentic and contextual issues as the center of learning, which forces students to actively engage in group discussions, data analysis, and collaborative decision-making. Various literature has proven that PBL is consistently able to stimulate students' critical thinking skills because they are trained to formulate problems and find solutions independently. Nonetheless, the effectiveness of PBL is highly dependent on the depth of the cognitive processes that students experience during the problem-solving phase [5].

To strengthen the impact of PBL, the integration of deep learning approaches is very relevant to be implemented [6]. Unlike surface learning, which only focuses on memorizing facts for exam passing, deep learning emphasizes deep conceptual understanding, interconnectedness between ideas, and metacognitive reflection. Through this approach, students are invited to not only find the correct answer, but also understand the "why"

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and "how" a mathematical procedure works. The integration of deep learning into the structure of PBL is expected to create a strong synergy in building students' reflective mindset and intellectual resilience in the face of complex math tasks .

The novelty in this study lies in the specific combination of the PBL model with the deep learning pedagogical framework to measure two important variables simultaneously, namely critical thinking ability and mathematical disposition at the elementary school level. So far, many studies have examined the effectiveness of PBL independently or linked deep learning to learning outcomes in general, but it is still very rare to find studies that integrate the two in the context of developing critical reasoning and mathematical attitudes of elementary school students. This research also makes a unique contribution by using research subjects in Cluster 3 Kuta who have the characteristics of certain educational challenges based on the latest Education Report data [7].

This study aims to provide a new empirical foundation regarding the effectiveness of PBL and deep learning synergy in enriching the study of mathematics learning methodology in primary education[8]. This integration is expected to prove that an approach that emphasizes reflective activities, elaboration, and metacognition can significantly strengthen the quality of student understanding compared to conventional learning models. Thus, the results of this study can be an important reference for the development of learning theories that harmonize cognitive and affective dimensions in one coherent instructional framework.

This study was designed with the main objective of analyzing the significant influence of the deep learning-based PBL model on students' critical thinking skills. In addition, this study aims to evaluate the extent to which the model is able to improve students' mathematical disposition, so that they have better confidence and persistence in

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learning. The ultimate goal is to simultaneously measure the effectiveness of this model in creating a challenging and enjoyable learning environment, which in turn can improve numeracy achievement and the quality of critical reasoning in primary schools.

With the implementation of this research, it is hoped that educators will get concrete references regarding alternative learning models that are relevant to the demands of the 21st century. The implementation of this deep learning-based PBL not only aims to improve students' academic grades, but furthermore is to form positive and critical thinking habits that will become essential life provisions for them in the future. Through this approach, mistakes in learning are no longer seen as failures, but are transformed into valuable sources of information for the process of intellectual maturity of students.

RESEARCH METHODS

This study uses a quantitative approach with a quasi-experimental research type. The research design applied is a non-equivalent control group design, where the research subjects are not randomly selected but use a group that has already been formed (class) to be given different treatment between the experimental class and the control class.

The population in this study is all grade V elementary school students in Cluster 3 Kuta, Badung Regency. The research sample was selected by considering the characteristics of equivalent schools based on the 2025 Education Report data. The experimental class received treatment in the form of a Problem-Based Learning (PBL) model based on deep learning, while the control class used a conventional learning model.

This study involved three main variables:

- Free Variable (X): Problem-Based Learning (PBL) learning model based on deep learning.
- First Bound Variable (Y1): Students' critical thinking skills
- Second Bound Variable (Y2): Students' mathematical disposition.

The implementation of the deep learning-based PBL model is carried out through stages that integrate problem-solving with cognitive depth:

- Problem Orientation: Presentation of authentic and contextual problems to spark curiosity.
- Self-Exploration: Students conduct in-depth investigations of relevant mathematical concepts.
- Collaborative Discussions: Group activities to analyze strategies and build arguments.
- Presentation and Critical Reflection: Students explain solutions and conduct metacognitive reflections on their thinking processes (deep learning aspects).
- Concept Connection: Connecting material to real-world situations to ensure meaningful understanding.

Data was collected using two main types of instruments that have undergone validity and reliability tests:

- Critical Thinking Ability Test: In the form of essay questions prepared based on Facione indicators, including interpretation, analysis, evaluation, inference, explanation, and self-regulation.
- Mathematical Disposition Questionnaire: Using the Likert scale to measure students' confidence, perseverance, curiosity, and thinking flexibility in mathematics.

Data analysis is carried out through several statistical stages:

- Prerequisite Test: Includes normality test and variance homogeneity test.
- Hypothesis Test: Using the N-Gain test to see the improvement in ability, as well as the Mann-Whitney test or t-test to compare differences between groups.
- Correlation Test: Used to analyze the relationship between critical thinking ability and mathematical disposition after treatment.

RESULT AND DISCUSSION

Result

The data analysis in this study was focused on comparing the achievement of critical thinking skills and mathematical disposition between the experimental group using the deep learning-based Problem-Based Learning (PBL) model and the control group with conventional learning. Based on the pre-test scores, the two groups departed from a relatively equal starting point, where the control class had an average of 45.06 and the experimental class of 51.01. However, after the treatment, there was a very significant improvement in the experimental class compared to the control class.

The data from the post-test results showed that the experimental class achieved an average critical thinking score of 83.85, while the control class only reached 47.65. This striking difference is also seen in the affective aspect, where the average mathematical disposition of the experimental class (94.90) is much higher than that of the control class (85.86). The results of the Mann-Whitney statistical test confirm that this difference is statistically significant with the Asymp value. Sig. is 0.001, which means that the deep learning-based PBL model has a real influence on both variables.

The following is a summary of the data from the research results in the form of a table:

Table 1. Comparison of Average Scores of Critical Thinking Skills and Mathematical Disposition

Bound Variables	**Groups**	Pre-test average	Post-test average	**Improvement** (Gain)
Critical Thinking Skills	Exsperiment	51,01	83,85	32,84
	control	45,06	47,65	2,59
Mathematical Disposition	Exsperiment	-	94,90	Signifikan*
	control	-	85,86	

*Based on the results of the Mann-Whitney test with a sig value. 0,001.

Overall, these findings suggest that the integration of deep learning into PBL syntax is effective in stimulating students' critical reasoning through reflective activities and in-depth exploration of problems. In addition, improved mathematical disposition proved that students in the experimental class showed stronger perseverance, confidence, and positive attitudes in the face of mathematical challenges than students in the control class. The results of the correlation test also showed a significant positive relationship between critical thinking skills and students' mathematical disposition after participating in this learning.

Discussion

The successful implementation of the deep learning-based Problem-Based Learning (PBL) model in improving students' critical thinking skills shows that the integration of problem-solving structures with cognitive depth is a very effective strategy. The results of this study confirm that when students are faced with authentic problems and given space to do deep exploration, their thought process no longer stops at the level of basic memory or understanding. This synergy allows students to deconstruct the problem, identify relevant variables, and build a logical solution synthesis. In this context, PBL acts as a container or vehicle, while deep learning principles serve as a driving force that ensures that each step in the learning syntax is carried out with high metacognitive awareness, so that the learning outcomes achieved become more permanent and meaningful.

More specifically, the improvement of critical thinking skills in the experimental class was triggered by the problem-orientation phase associated with the real context of students' lives in the Kuta area. Situationally relevant problems encourage stronger cognitive engagement because students feel they have a vested interest in solving the problem. At the investigation stage, the deep learning approach forces students to go beyond just looking for the right answer; They are encouraged to question assumptions and look for connections between mathematical concepts that were previously considered separate. This process is in line with the theory of constructivism, which states that knowledge is much more solid if it is built by the student himself through active and reflective experience, rather than simply receiving the passive transfer of information from the teacher.

The application of aspects of critical reflection and collaborative discussion in this model has also proven to be a key factor in sharpening students' reasoning power. Through peer-to-peer interaction in small groups, students are exposed to a variety of different perspectives and solutions strategies. This forces them to evaluate their own thinking and provide valid arguments to defend or revise their opinions. This kind of intellectual activity is crucial in developing indicators of interpretation and analysis in critical thinking. Thus, the classroom is no longer just a place to listen to lectures, but has been transformed into a thinking laboratory where each student actively tests the validity of their mathematical ideas collectively.

Regarding the variables of mathematical disposition, the findings of this study show that the learning environment created by PBL based on deep learning is able to foster a

positive attitude towards mathematics. Mathematical dispositions that include confidence, perseverance, and curiosity increase significantly as students feel given full autonomy in the learning process. When students succeed in solving complex problems through independent effort and collaboration, a strong sense of self-efficacy emerges. This feeling of being able is very important in math learning which is often considered daunting, because students who have a high disposition will tend to view challenges as opportunities to learn, not as obstacles to be avoided.

The dynamics between critical thinking skills and mathematical disposition in this study show a positive and mutually reinforcing reciprocal relationship. Students who have a good mathematical disposition tend to be more persistent in conducting critical analysis of difficult problems. In contrast, honed critical thinking skills provide tools for students to feel more competent, which ultimately strengthens their disposition. The use of deep learning strategies here acts as a bridge that connects these cognitive and affective aspects. By emphasizing the intrinsic value of knowledge and intellectual satisfaction when understanding a concept in depth, students not only learn mathematics technically, but also begin to love the thought process itself.

When compared to control classes using conventional models, the gap in learning outcomes is very visible in students' ability to handle non-routine problems. In the control class, students tend to get stuck on the formula given by the teacher and experience impasse when the context of the question is slightly changed. This happens because conventional learning is often stuck on surface learning that only touches the surface of the material. In contrast, students in experimental classes showed greater flexibility of thinking because they had become accustomed to exploring the "inner structure" of a mathematical problem. This difference in achievement confirms that to face the demands of numeracy on the Education Report Card which increasingly emphasizes reasoning, a change in the learning model from informative to investigative is a necessity.

To conclude this discussion, the integration of PBL and deep learning offers a robust pedagogical framework to overcome the low critical thinking skills at the elementary school level. This innovation not only answers the administrative challenges of the curriculum, but also touches the substance of education, namely humanizing students as active and reflective learners. These findings provide important implications for educators and policymakers in the region that improving the quality of mathematics education is not enough just by updating the content, but must be accompanied by a transformation of methodologies that are able to awaken students' intellectual capacity and mental toughness simultaneously. This model deserves to be replicated and further developed in a wider range of materials to create a generation that is critical thinking and has a love for science.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that the application of the Problem-Based Learning (PBL) model based on deep learning has a significant effect on improving critical thinking skills and mathematical disposition of

elementary school students. The advantage of this model can be seen from the achievement of the average score of the experimental class that surpasses the control class convincingly on both bound variables. The integration of PBL syntax with deep learning principles has been proven to be able to change students' learning patterns from mere mastery of technical procedures to reflective and independent conceptual understanding. These findings confirm that these learning innovations are effective in addressing the challenges of low numeracy and critical reasoning skills, while providing strategic implications for educators to transform instructional practices in the classroom towards a more comprehensive development of students' intellectual capacity.

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