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The Effect of PBL Compared to Direct Instruction on Critical Thinking Skills in Fractions in Elementary School

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ABSTRACT

Mathematics learning in elementary schools is often still dominated by teacher-centered direct learning methods, which do not provide sufficient opportunities for students to develop critical thinking skills. However, critical thinking skills are very important in understanding mathematical concepts, including fractions. Therefore, a learning model that encourages students to actively solve problems and think deeply is needed, one of which is through the Problem-Based Learning (PBL) model. This study aims to examine the difference in critical thinking skills between students who learn using the PBL learning model and students who learn using the direct learning model in fractions. This study uses a quantitative approach with a quasi-experimental design. The research subjects consist of two groups, namely the experimental class that received learning using the PBL model and the control class that used direct learning. Critical thinking skills data were obtained through tests administered after the learning process, then analyzed using statistical techniques to determine the differences between the two groups. The results showed that there were differences in critical thinking skills between students who learned using the PBL model and students who learned using the direct learning model. The PBL learning model has a better effect on improving students' critical thinking skills in fractions. Thus, it can be concluded that the learning model affects students' critical thinking skills in mathematics learning.

1. Introduction

Mathematics education in elementary school plays a crucial role in developing students' logical, analytical, and critical thinking skills. In the context of 21st-century education, critical thinking skills are among the key competencies that must be developed to address global challenges and the complexities of modern life (OECD, 2019). These skills are not only useful for solving mathematical problems but also for decision-making and solving everyday problems (Paul & Elder, 2019; Halpern, 2014). Therefore, mathematics instruction should be designed not only to transfer knowledge but also to develop students' higher-order thinking skills.

However, the reality on the ground shows that mathematics instruction in elementary schools is still dominated by a teacher-centered direct instruction approach. This model tends to position students as passive recipients of information, thereby failing to provide sufficient space for them to optimally develop critical thinking skills (Siahaan et al., 2022; Zikri, 2021). The characteristics of mathematics learning, which should emphasize exploratory activities, discovery, and problem-solving, are often not fully realized (Nasaruddin, 2018). Consequently, students are more accustomed to memorizing procedures rather than deeply understanding concepts.

This issue becomes even more complex when it comes to fractions, which are known to be one of the most difficult mathematical topics for elementary school students to grasp. Various studies show that students often experience conceptual errors and misconceptions in understanding fractions, such as an integer bias that hinders conceptual understanding (Tian & Siegler, 2018). Furthermore, Abdullah et al. (2015) found that many students struggle with solving Higher-Order Thinking Skills (HOTS)-based problems involving fractions, indicating a lack of critical thinking skills in this context. This suggests that the current instructional approaches have not effectively facilitated the simultaneous development of conceptual understanding and critical thinking skills.

In line with the development of constructivist learning theory, which emphasizes the active role of students in constructing knowledge (Bruner, 1960; Vygotsky, 1978), there is a need for innovative learning models capable of fostering active student engagement. One relevant model is Problem-Based Learning (PBL), a learning model centered on solving authentic problems as a learning stimulus (Savery, 2015; Hmelo-Silver, 2004). PBL provides students with the opportunity to develop critical thinking skills through the process of identifying problems, gathering information, analyzing data, and formulating solutions.

Various empirical studies indicate that PBL has a positive impact on critical thinking skills in mathematics education. Tarmizi and Bayat (2012) and Rerung et al. (2017) found that the implementation of PBL significantly improved students' critical thinking abilities compared to conventional instruction. Furthermore, the results of a meta-analysis by Yohannes and Tamur (2021) and a literature review by Richardo et al. (2025) reinforce that PBL is effective in improving mathematical critical thinking skills. In the context of elementary school, research by Agustika and Dewi (2023) and Kurniawati and Negara (2024) indicates that PBL significantly enhances students' critical thinking skills compared to traditional teaching models.

Specifically regarding fractions, the implementation of PBL also shows promising results. Research by Astini et al. (2020) and Poluakan et al. (2024) reveals that the use of PBL can help students understand fraction concepts more deeply through contextual problem-solving. Furthermore, Narahmalia and Subhanarrijal (2024) as well as Chasanah and Fitrianawati (2023) demonstrate that PBL can enhance student engagement and learning outcomes in fraction-related content. This indicates that PBL not only impacts learning outcomes but also fosters more complex thinking processes.

Nevertheless, there remains a gap in classroom implementation, particularly regarding a direct comparison between the PBL model and direct instruction in enhancing critical thinking skills in the area of fractions in elementary school. Previous studies have largely focused on the general effectiveness of PBL without explicitly comparing it to the direct instruction model in the context of specific topics such as fractions. Yet, this comparison is crucial for providing stronger empirical evidence regarding the relative advantages of a particular instructional model within a specific context.

Based on this description, the main problem identified is the still-low level of students' critical thinking skills in mathematics learning, particularly regarding fractions, which is suspected to be influenced by the use of an inappropriate learning model. Therefore, a study is needed that specifically examines the differences in critical thinking skills between students learning using the Problem-Based Learning (PBL) model and those learning using the direct instruction model.

This study aims to analyze and compare the effects of the Problem-Based Learning model and direct instruction on students' critical thinking skills in the area of fractions in elementary school. The results of this study are expected to provide a theoretical contribution to the development of effective mathematics learning models, as well as practical guidance for teachers in selecting learning strategies that can optimally enhance students' critical thinking skills.

2. Methods

This study employed a quantitative approach using a quasi-experimental design to determine the effect of the Problem-Based Learning (PBL) model compared to direct instruction on students' critical thinking skills in the area of multiplication and division of fractions.

The study was conducted with sixth-grade elementary school students in a mathematics class covering the multiplication and division of fractions. The research subjects consisted of two classes: an experimental class that received instruction using the Problem-Based Learning model and a control class that received instruction using the direct instruction model. The experimental and control classes were selected using purposive sampling, which involves selecting samples based on specific considerations, such as similar academic ability levels and classroom conditions.

The research procedure was carried out in several stages. The first stage was preparation, which included the development of teaching materials, the design of research instruments, and the validation of these instruments by experts. The second stage was the implementation of the research, specifically the application of the Problem-Based Learning model in the experimental class and traditional instruction in the control class during the teaching of multiplication and division of fractions. In Problem-Based Learning, students are given contextual problems related to fraction material to analyze and solve in groups through the stages of problem orientation, information gathering, discussion, and presentation of problem-solving results. Meanwhile, in the control class, learning is conducted using a teacher-centered direct instruction method through activities such as material explanation, providing examples, and practice problems.

The research instrument used to measure students' critical thinking skills was a mathematics critical thinking skills test in the form of essay questions designed based on critical thinking indicators, such as the ability to analyze problems, provide reasons, evaluate solutions, and draw conclusions. The instrument's validity was tested using expert judgment from two mathematics education experts and two education experts, applying Aiken's formula; it was deemed valid if the index ranged from 0 to 1; The instrument's validity was tested using the Product Moment correlation to determine the relationship between the two variables; it was deemed valid if the correlation coefficient ($r_{(calculated)} > r_{(table)}$ 0.30), and its reliability (expert and instrument) was tested using Cronbach's Alpha; it was deemed reliable if the Cronbach's Alpha coefficient was > 0.60 through a pilot test limited to a sample with similar characteristics. The instrument's validity was tested using expert judgment from two mathematics education experts and two education experts, applying Aiken's formula; it was deemed valid if the index ranged from 0 to 1; The instrument's validity was tested using the Product Moment correlation to determine the relationship between the two variables; it was deemed valid if the correlation coefficient ($r_{(calculated)} > r_{(table)}$ 0.30), and its reliability (expert and instrument) was tested using Cronbach's Alpha; it was deemed reliable if the Cronbach's Alpha coefficient was > 0.60 through a pilot test limited to a sample with similar characteristics.

Data collection in this study was conducted through a test to measure students' critical thinking skills following instruction. The data obtained were then analyzed using descriptive and inferential statistical techniques. Descriptive analysis was used to describe the mean, maximum score, minimum score, and distribution of students' critical thinking skills data in both groups. Subsequently, inferential analysis was conducted to test for differences in critical thinking skills between the experimental and control classes.

Before hypothesis testing, prerequisite tests were conducted, including normality and homogeneity tests, to ensure that the data met the assumptions of statistical analysis. Once the prerequisites were met, hypothesis testing was performed using a t-test to determine whether there was a difference in critical thinking skills between students who learned using the Problem-Based Learning model and those who learned through direct instruction.

The results of this analysis were then used to determine the effect of the learning model on students' critical thinking skills regarding the multiplication and division of fractions. Thus, this research method is expected to provide an empirical picture of the effectiveness of the Problem-Based Learning model compared to direct instruction in enhancing the critical thinking skills of elementary school students.

3. Results & Discussion

The results of this study aim to identify differences in students' critical thinking skills regarding fraction multiplication and division between students who learned using the Problem-Based Learning (PBL) model and those who learned through direct instruction. Data on critical thinking skills were obtained through an essay test administered after the learning process was completed in the experimental and control classes.

3.1 Results

3.1.1 Instrument Validation

After developing the test instrument, the next step is to validate it, beginning with validity and reliability tests.

3.1.2 Expert Validity Test

Before beginning the study on the sample, the instrument must be validated by experts to ensure that its content aligns with the relevant concepts or theories and is suitable for use before field testing. A summary is presented in Table 1.

Table 1 Pretest-Posttest Validity of Critical Thinking Skills

Item	Vpre	Vpost	Decision
1	0,88	0,94	Valid
2	0,88	0,94	Valid
3	0,94	0,81	Valid
4	0,81	0,75	Valid
Total	0,88	0,86	Valid

3.1.3 Instrument Validity Test (Product Moment)

The instrument validity test (Product Moment) was conducted to determine whether each item of the instrument is empirically valid by examining the correlation between item scores and total scores. The results of the instrument validity test are presented in Table 2.

Table 2 Validity of the Critical Thinking Skills Instrument

Instrument	**r**	**Index**	**Decision**
Pretest	0,605	0,30	Valid
Posttest	1,209		Valid

3.1.4 Reliability Test (Cronbach's Alpha)

The reliability test ensures that the instrument produces consistent and reliable results when used in research. The results of the reliability test are presented in Table 3.

Table 3 Reliability of Critical Thinking Skills

Instrument	Expert	α	rtable	Decision
Pretest	0,952	0,726	0,316	Reliable
Posttest	0,969	0,718		Reliable

3.1.5 Descriptive Statistics of Critical Thinking Skills

A descriptive analysis was conducted to provide an overview of the results of the critical thinking skills tests for students in both research groups. A summary of the descriptive analysis results is presented in Table 4.

Table 4 Descriptive Statistics of Students' Critical Thinking Skills

Group	Number of Students	Min Score	Max Score	Mean	Standard Deviation
Experimental	52				
Pre-test		40	80	55,58	11.32
Post-test		75	100	87,89	8,25
Control	54				
Pre-test		40	80	55,65	10,28
Post-test		55	100	78,06	8,66

3.1.6 Prerequisite Tests

Before testing the hypotheses, prerequisite tests were conducted, including tests of normality and homogeneity.

3.1.7 Test of Normality

The test of normality was conducted using the Kolmogorov-Smirnov test to determine whether the data came from a normally distributed population. The results of the test of normality are presented in Table 5.

Table 5 Results of the Normality Test for Critical Thinking Skills Data

Group	Sig.	α	Decision
E. Pre-test	0,176	0,05	Normally Distributed
E. Post-test	0,154	0,05	Normally Distributed
C. Pre-test	0,128	0,05	Normally Distributed
C. Post-test	0,175	0,05	Normally Distributed

3.1.8 Test of Homogeneity

A test of homogeneity was conducted to determine whether the two groups had equal variances. The results of the Levene test of homogeneity are presented in Table 6.

Table 6 Results of the Test of Homogeneity of Variances

Mean Sig.	α	Decision
0,518	0,05	Variances are homogeneous

3.1.9 Test of Equivalence of Initial Ability

A test of equivalence was conducted to determine whether the two groups had equivalent initial ability before receiving the treatment. The test of equivalence was performed using a t-on the students' initial ability data presented in Table 7.

Table 7 Balance Results

tcalculated	ttable	Sig. (2-tailed)	α	Decision
0,308	2,007	0,760	0,05	Equal Variances

3.1.10 Hypothesis Testing

After the prerequisite tests were met, hypothesis testing was conducted to determine the effect of the learning model on students' critical thinking skills. The testing was performed using an ANOVA are presented in Table 8.

Table 8 Results of the ANOVA Test

F	Ftable	P	Decision
34,393	3,92	<0,05	H_0 Rejected

3.2 Discussion

The discussion of these research findings focuses on interpreting the data regarding differences in critical thinking skills between students taught using the Problem-Based Learning (PBL) model and those taught using the direct instruction model on the topic of fractions.

3.2.1 Instrument Analysis

The results of the content validity analysis using Aiken's index indicate that all items in the critical thinking instrument, both in the pretest and posttest, obtained coefficients above 0.75 and were therefore deemed valid. The total coefficients for the pretest (0.88) and posttest (0.86) reflect that the developed items accurately and appropriately represent indicators of mathematical critical thinking according to expert assessment. Based on the product-moment correlation, the pretest items showed a coefficient of r = 0.605, 1.209 > the 0.30 index and were deemed valid. The reliability coefficients from the expert data showed very high consistency (pretest = 0.952; posttest = 0.969), indicating that the raters had near-perfect agreement in assessing item quality. These findings reinforce the content validity in Table 1 while also demonstrating that the developed scoring guidelines were clear and objective. Meanwhile, the alpha coefficients based on respondent data (pretest = 0.726; posttest = 0.718), which exceeded the critical value (0.316), indicate that the instrument possesses high internal consistency. The use of expert judgment combined with these statistical tests is crucial for avoiding measurement bias. Thus, the results in Table 1, Table 2, and Table 3 indicate that the instrument is valid and reliable. As emphasized by Sugiyono (2022), a valid and reliable instrument is an absolute prerequisite for obtaining accurate and accountable research data. As emphasized in Rahmawati et al. (2025), empirically validated instruments are capable of more accurately identifying the actual impact of Problem-Based Learning (PBL) on critical thinking skills when applied to fraction-related material. The novelty of this study lies in the rigorous integration of expert and empirical validity in specific mathematics content, ensuring that test items not only assess memorization but truly stimulate higher-order cognitive processes.

3.2.2 Descriptive Analysis of Critical Thinking Skills

The results of the descriptive analysis indicate that the average initial ability of students in the experimental and control groups was relatively similar (55.58 and 55.65), a finding supported by the balance test (sig. 0.760 > 0.05). This indicates that both groups were at an equivalent baseline, so differences in final outcomes can be attributed to the treatment administered. Following the intervention, there was a significant improvement in both groups; however, the improvement in the experimental group (87.89) was higher than that in the control group (78.06). These results indicate that PBL is effective in enhancing critical thinking skills.

Theoretically, critical thinking skills in mathematics encompass the ability to analyze, evaluate, and make logical decisions regarding a problem (Jablonka, 2020). In this context, PBL provides a broader space for students to develop these three aspects because learning is centered on solving real-world problems. Unlike direct instruction, which tends to emphasize procedures and the transfer of information, PBL encourages students to actively construct knowledge through problem exploration (Afdhilah, Budiono, & Sucipto, 2023; Yew & Goh, 2016).

These findings align with the research by Kamid, Sabil, & Syafmen (2021), which shows that the implementation of PBL in mathematics instruction in elementary schools can enhance mathematical process skills closely related to critical thinking. Additionally, Ren (2022) emphasizes that PBL significantly aids the development of critical thinking in early-age learners by providing opportunities for independent reasoning.

Furthermore, when dealing with abstract concepts like fractions, a problem-based approach becomes particularly crucial. Torres-Peña & González (2024) explain that learning fractions is more effective when linked to problem-solving contexts, as it helps students build conceptual understanding rather than merely procedural knowledge. This explains why the maximum and average scores in the PBL class were higher.

The relatively balanced difference in standard deviations between the two groups indicates that the variation in student ability within each class is not significantly different. However, the higher mean in the PBL class suggests that this model is more effective in improving overall critical thinking skills.

These findings are also supported by Vebrianto, Osman, & Sairi (2021), who state that PBL not only improves learning outcomes but also student motivation and engagement, which ultimately leads to enhanced higher-order thinking skills. Divayani & Agustika (2024) add that integrating real-world problem contexts into mathematics instruction can strengthen students' analytical and evaluative skills.

The specific focus on fractions distinguishes this study from previous research. It integrates PBL, fraction content, and a validated critical thinking instrument.

Thus, the results in Table 1 indicate that the advantage of PBL lies not only in the final outcomes but also in the deeper cognitive processes experienced by students.

3.2.3 Validity of Statistical Assumptions in the Study

Before drawing inferential conclusions, the data were statistically tested to ensure their validity through normality and homogeneity tests. The results of the normality test indicate that the data in both groups are normally distributed.

Methodologically, this condition indicates that the data meet the basic assumptions for the use of parametric tests, such as the t-test in this study (Sugiyono, 2022).

However, substantively, this normal distribution also indicates that students' critical thinking skills are distributed proportionally across both groups, in both the PBL class and the direct instruction class. This means there is no extreme bias in the distribution of scores, so the research results can be considered representative.

From a learning perspective, the normal distribution in the PBL class indicates that this model not only benefits high-ability students but is also capable of accommodating various ability levels. This aligns with the findings of Doğanay & Dolapcioglu (2022), who state that problem-based learning can develop critical thinking evenly because it involves authentic learning experiences.

Furthermore, Sachdeva & Eggen (2021) emphasize that a learning environment that provides opportunities for exploration yields a more balanced distribution of thinking skills compared to one-way instruction.

Thus, the results of the normality test not only demonstrate the validity of the statistical analysis but also indicate that the implementation of PBL has an equitable impact on students' critical thinking skills.

The results of the homogeneity test in Table 6 support the assumption that the two study groups had equivalent variability at the outset. The significance value (0.518), which is greater than 0.05, demonstrates that the differences observed after the treatment are indeed attributable to the differences in the learning models applied, rather than to unequal variances between the groups. The results of the homogeneity test indicate that the variances of the two groups are homogeneous. This means that the level of data variability between the experimental and control classes is relatively the same, making the comparison between the two groups more valid.

Conceptually, this homogeneity is important because it indicates that the differences in outcomes found are not caused by differences in the groups' initial characteristics, but rather by the learning treatments administered. In other words, the PBL model is the primary factor influencing the improvement in critical thinking skills.

In the context of learning, this equality of variances also indicates that both PBL and direct instruction were implemented under relatively equivalent classroom conditions. However, the higher results in the PBL class suggest that this model is more effective in optimizing students' potential.

These findings are supported by Masriah, Utaminingsih, & Utomo (2023), who state that PBL has a significant impact on mathematics learning outcomes compared to conventional models, even when applied to groups with similar characteristics. Additionally, Utami & Suwanto (2017) also found that PBL effectively enhances mathematical thinking skills in groups with equivalent initial abilities.

Thus, the homogeneity of variances strengthens the internal validity of this study and supports the conclusion that differences in outcomes are due to the effectiveness of the learning model.

The balance test results indicate that both groups had equivalent initial abilities. This serves as a crucial foundation in experimental research as it ensures there were no significant differences prior to the intervention.

This equivalence reinforces the interpretation that the improvement in critical thinking skills in the PBL class is the result of the learning process, not the students' initial factors. In learning theory, equivalent initial conditions allow researchers to isolate the influence of the treatment variable more accurately (Schunk, 2020).

Furthermore, Ab Kadir (2020) states that the development of critical thinking is greatly influenced by the learning strategies employed, rather than solely by students' prior abilities. This indicates that learning interventions such as PBL play a significant role in enhancing critical thinking skills.

Thus, the results of the balance test reinforce that the differences in outcomes in this study are indeed caused by differences in learning models.

3.2.4 Significance of the Effect of the PBL Model on Critical Thinking

The results of the hypothesis test indicate that the calculated F-value (34.393) is greater than the critical F-value (3.92) with $P < 0.05$, so H_0 is rejected. This means there is a significant difference in the critical thinking skills of students learning through the PBL model and those learning through direct instruction.

Theoretically, these results can be explained by the characteristics of PBL, which emphasizes higher-order thinking processes. PBL requires students to identify problems, formulate hypotheses, search for information, and evaluate solutions (Hung, 2016). This process directly trains critical thinking skills.

These findings are consistent with the results of the meta-analysis by Abrami et al. (2015), which showed that active learning strategies such as PBL have a significant effect on improving critical thinking skills compared to traditional methods. Additionally, Retnowati, Sujadi, & Subanti (2016) also found that PBL significantly improved students' mathematical critical thinking skills.

Another study by Kurniawati & Negara (2024) indicates that the implementation of PBL in mathematics instruction significantly enhances the critical thinking skills of elementary school students. This is supported by (Al Fanny & Roesdiana, 2020; Prasetyo & Kristin, 2020), who state that PBL has a positive impact on students' analytical and evaluative skills.

In the context of fractions, these results are also relevant because the concept of fractions requires deep conceptual understanding and abstract thinking skills (Yang, Reys, & Reys, 2020). PBL helps students connect these concepts to real-life situations, making their understanding more meaningful.

Thus, the results of the hypothesis test not only indicate a statistical difference but also reinforce that PBL is an effective learning model for improving students' critical thinking skills.

The results of the hypothesis testing presented in Table 8. provide strong evidence of the effectiveness of the PBL model compared to the direct instruction model. The calculated F-value of 34.393, which exceeds the critical F-value (3,92) with $P<0{,}05$, statistically proves the existence of a significant difference. This indicates that the PBL model has a positive effect on students' critical thinking skills. Critical thinking in mathematics is not merely about calculation but a complex mental process. Robert Ennis (2011) defines this concept as follows:

Critical thinking is rational, reflective thinking focused on making decisions about what to believe or do. In the context of mathematics, this includes the ability to identify assumptions, perform deduction, perform induction, and evaluate arguments that arise in problem-solving (Ennis, 2011).

The advantage of PBL over direct instruction lies in its syntax or learning steps. In PBL, students are presented with ill-structured problems, so they must use their analytical skills to find solutions (Ageng Triono, 2020). In the context of multiplication and division of fractions, real-world problems help students overcome misconceptions that often arise in conventional learning (Tian & Siegler, 2018).

In contrast, teacher-centered direct instruction models (Table 4. shows lower scores) tend to make students passive. Although effective for quickly conveying procedural information, this model leaves little room for the development of higher-order thinking skills (Slavin, 2018). These findings align with previous research indicating that PBL is significantly more effective in enhancing Higher Order Thinking Skills (HOTS) compared to lecture-based or direct instruction methods (Retnowati, Sujadi, & Subanti, 2016).

Specifically, regarding fractions a topic often considered difficult by elementary school students PBL helps visualize abstract concepts into meaningful problems (Alshwaikh, 2020; Yang, Reys, & Reys, 2020). Group discussions in PBL prompt students to critically evaluate their peers' answers, an activity rarely observed in direct instruction (Savery, 2015).

Overall, the findings of this study confirm that to enhance critical thinking skills in elementary school, educators need to shift their paradigm from merely "telling" to "guiding" students' discovery. The PBL model provides a robust framework for achieving this goal through the integration of real-world problems and social collaboration in mathematics classrooms (Triono, 2020; Wulandari & Taufina, 2021).

4. Conclusion

Based on the results of this study, it can be concluded that there is a significant difference in critical thinking skills between students taught using the Problem-Based Learning (PBL) model and those taught using the direct instruction (teacher-centered) method in the subject of multiplication and division of fractions. Specifically, students using the PBL model demonstrated a higher improvement in critical thinking skills compared to students who were taught through direct instruction. These findings indicate that the PBL model is more effective in enhancing students' critical thinking skills regarding the multiplication and division of fractions.

The research findings are also consistent with the initial expectations outlined in the Introduction, namely that learning approaches that enable students to actively solve problems (such as PBL) will foster the development of critical thinking skills. The PBL model facilitates students' active participation in problem-solving, strategy design, and reflection on fraction concepts, thereby enabling them to analyze mathematical situations and draw conclusions independently. Conversely, teacher-centered direct instruction tends to make students passive, thereby limiting their opportunities to practice critical thinking.

Overall, this study confirms that the choice of instructional model has a significant impact on students' critical thinking skills in mathematics learning. Therefore, efforts to improve the quality of mathematics education should prioritize instructional models that challenge students to actively engage in critical thinking, such as Problem-Based Learning.

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