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ORIGINAL RESEARCH PAPER

Describing the effect of worksheet-assisted PBL on the students' critical thinking, numeracy, and responsibility

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Abstract
This study aims to describe the effect of the problem-based learning model on students' critical thinking skills, numeracy, and sense of responsibility. The research employed a quantitative approach using a one-group pretest-posttest design. The research subjects were seventh-grade students at SMP Negeri 4 Banguntapan, selected randomly. The instruments used included a critical thinking test, a numeracy test, and a responsibility questionnaire. Data were analyzed both descriptively and inferentially using the paired t-test and N-Gain calculations. The results showed p-values ≤ 0.05, indicating significant differences between pretest and posttest scores in critical thinking, numeracy, and responsibility following the intervention. Therefore, it can be concluded that the problem-based learning model assisted by student worksheets positively influences students' critical thinking skills, numeracy, and sense of responsibility. The improvements in these three aspects fell into the moderate to high categories. These findings indicate that the problem-based learning model is effective in fostering active student engagement, enhancing higher-order thinking processes, and developing positive attitudes toward mathematics learning.

Keywords: critical thinking skills, numeracy, problem-based learning, responsibility

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INTRODUCTION

Mathematics education at the high school level is currently facing the demands of a rapidly changing era, which necessitates a paradigm shift in instructional approaches. The digital age not only brings technological innovations but also drives a transformation in the competencies students must possess. In this context, mathematics education is no longer sufficient to focus solely on procedural mastery and formulas; instead, it must also foster the cultivation of higher-level thinking skills and character formation. For example, at the junior high school level, mathematics learning must extend beyond cognitive aspects to include the development of character and students' social-emotional skills.

In line with these demands, several studies emphasize that critical thinking skills, numeracy, and responsibility are three essential components that must be developed simultaneously in 21st-century mathematics education (Fajriyah, 2022; Janah et al., 2019; Saputra & Sumardi, 2024). Responsibility is an essential component, as the development of students' cognitive abilities is highly dependent on their readiness, active participation, and consistency throughout the learning process, beyond mere content mastery (Koh & Chapman, 2019; OECD, 2025; Tshering et al., 2024).

Critical thinking skills enable students to analyze, evaluate, and synthesize information or problems logically and deeply, especially when facing real-life situations (Novalina & Sembiring,

2025; Padmakrisya & Meiliasari, 2023). Meanwhile, numeracy plays an important role in supporting students' understanding, interpretation, and application mathematical information in real-life contexts, making mathematics more meaningful and relevant to everyday life. On the other hand, a sense of responsibility as part of character development significantly determines the extent to which students can manage their learning independently, with discipline and reflection. When developed integratively, these three components can enhance the effectiveness of mathematics education and equip students with the competencies needed to face 21st-century challenges.

Based on the results of the 2022 Programme for International Student Assessment (PISA) survey results show that Indonesian students' average mathematics score was only 366 on a scale of 1000, far below the OECD average of 472 (OECD, 2023). Indonesian students were reported to be capable only of recognizing and interpreting simple mathematical situations such as comparing distances between routes or converting currency (OECD, 2023). These findings reveal a significant gap between the goals of the national curriculum which places numeracy as a priority and the actual learning outcomes achieved by students. Moreover, current practices in mathematics instruction in schools are still largely dominated by conventional, teacher-centered approaches (Eka et al., 2020; Hermawan et al., 2023; Zulyadaini, 2017).

Teacher-centered approaches tend to position students as passive recipients of information who follow instructions without being actively involved in the thinking or problem-solving process. As a result, students struggle to build deep understanding, and their thinking skills are underdeveloped. This method also fails to foster a sense of responsibility, as students are not given opportunities to take an active role in managing their own learning process. These situations highlight the urgent need to adopt problem-based learning (PBL), a student-centered instructional model that empowers students to actively build and apply their knowledge and thinking skills to solve a problem.

PBL is selected because it directs students to focus on problem-solving skills, which lie at the core of developing critical thinking and numeracy (Nasution et al., 2018; Yew & Goh, 2016). PBL encourages students to engage actively in solving authentic problems, directly cultivating their critical thinking and numeracy skills. A recent meta-analysis by Yohannes et al. (2021) revealed that the implementation of PBL has a positive effect on students' mathematical critical thinking skills. Furthermore, PBL also significantly improved numeracy skills of junior high school students through story problems (Wahyuni & Septiani, 2024; Andini & Siregar, 2024).

Other studies affirm that PBL can significantly enhance students' cognitive abilities for instance, by helping them understand the relevance of mathematical concepts in everyday life, strengthening analytical skills, and fostering collaboration (Hmelo-Silver, 2004). With its student-centered and collaborative characteristics, PBL provides space for students to actively engage in the learning process and take responsibility for achieving their competencies (Savery, 2006). Therefore, PBL is considered relevant for improving students' critical thinking, numeracy, and sense of responsibility in mathematics learning.

Consistent with this perspective, various empirical findings show that the implementation of the PBL model either independently or assisted by instructional tools such as student worksheets positively impacts student competency achievement. Salsabila et al. (2024), for instance, developed student worksheets to support the implementation of PBL in statistics material and found it not only practical but also effective in enhancing students' numeracy skills. Similar findings were reported by Hayati & Nuriyah (2023), who showed that the use of student worksheets in problem-based learning can significantly foster students' critical thinking skills. The synergy between PBL and student worksheets presents a strong instructional combination; PBL provides an authentic learning context based on real-life problems, while student worksheet serves as a structured guide that leads students systematically through the stages of learning.

In this process, student worksheet supports students in solving problems step by step, stimulates critical questioning, and assists them in developing higher-order reasoning in a more structured manner. Furthermore, numeracy is refined through student worksheets activities that connect mathematical concepts to relevant contextual situations. On the other hand, responsibility is cultivated through group work facilitated by student worksheets, where each member holds a clear role and responsibility in completing the task collaboratively. These findings indicate that implementing the PBL model assisted by student worksheets has strong potential to promote the integrated development of critical thinking, numeracy, and sense of responsibility among students.

Previous studies on the development of student worksheets and the implementation of PBL have made initial contributions to innovative instructional design. However, no study has yet comprehensively investigated the role of student worksheets as a supporting tool in implementing PBL to simultaneously enhance students' critical thinking, numeracy, and sense of responsibility. This research gap underscores the urgent need to develop a more integrative, contextual, and adaptive learning model that meets the demands of 21st-century education. Based on this identified gap, the main objective of this research is to analyze and measure the influence of PBL assisted by student worksheets on junior high school students' critical thinking, numeracy, and responsibility in mathematics learning. Specifically, this study aims to: (1) identify and measure the improvement in students' critical thinking skills following the implementation of PBL assisted by student worksheets; (2) evaluate the effectiveness of the model in enhancing students' numeracy; (3) assess the impact of PBL on the development of students' character, particularly their sense of responsibility; (4) formulate practical recommendations for implementing this learning model in junior high schools.

RESEARCH METHOD

This study is quantitative research employing a quasi-experimental design. This type of research is based on the condition that the researcher does not create a new class for the study but utilizes existing classes. The purpose of this research is to describe the effect of the PBL model assisted by student worksheets on students' critical thinking skills, numeracy, and sense of responsibility.

The research design used in this study is the one-group pretest-posttest design, with the following stages: (1) administering a pretest to measure students' initial abilities before the treatment; (2) applying the treatment by implementing the problem-based learning model assisted by student worksheets; (3) administering a posttest to measure students' abilities after the treatment. The one-group pretest-posttest design (Fraenkel et al., 2012) used in this study is presented in Table 1.

Tabel 1. One-group pretest-posttest design research design

Pretest	Treatment	Posttest
O_1 [a]	X [b]	O_2 [c]

[a] X : The worksheet-assisted PBL
[b] O_1: Pretest score before treatment
[c] O_1: Posttest score after treatment

This research was conducted in Class VII of SMP Negeri 4 Banguntapan, a public junior high school in Yogyakarta, with the population consisting of all seventh-grade students. The sample class was selected randomly. The researcher conducted the experiment over six sessions using the K-13 curriculum, in accordance with the curriculum implemented at the time of the study. The treatment in this research is the PBL model assisted by student worksheets, while the dependent variables are students' critical thinking skills, numeracy, and sense of responsibility.

This research employed both test and non-test techniques and instrument for data collection. All research instrument were developed based on theoretical foundations and relevant competency indicators. The critical thinking indicators, including the ability to identify problems, gather relevant information, formulate alternative solution and draw conclusion. The numeracy instrument was developed based on numeracy compentencies that emphasize the ability to understand, interpretasion and apply mathematical information in everyday contexts. Meanwhile, the non-test instrument in form of a responsibility questionnaire was design based on indicators of learning responsibility, such as readiness to participate in learning activities, active participation, awareness of fulfilling learning obligations, and task completion.

The test instrument consisted of multiple-choice item with four answer options to measure students' learning outcomes, as well as essay wuestions used to assess students' critical thinking and numeracy skills. In addition, the non-test instrument used in this was a questionnaire. In this study, instrument validity was examined through content validity. Both test instrument subsequently reviewed by subject-metter experts and subject teachers to measured indicators. The validation result indicated that the instruments were considered appropriate for use with minor revisons. Furthermore, instrument reliability was tested using Cronbach's alpha coefficient with the analysis result showed that the critical thinking and numeracy instrument demonstrated moderate reliability, with coefficient values of 0.060 and 0.68 respectively. Meanwhile, the responsibility instrument exhibited high reliability, with a Cronbach's alpha coefficient of 0.87.

The data analysis techniques used in this study included both descriptive and inferential statistical analyses. Descriptive analysis aimed to describe the characteristics of the research variables through calculations of the mean, standard deviation, variance, and to determine the percentage of overall student learning mastery. Meanwhile, inferential analysis was employed to determine the effect of the PBL model assisted by student worksheets on student learning outcomes using the paired sample t-test with the t-test function in the R program (Karadimitriou & Marshall, 2011). Furthermore, to examine improvements in students' critical thinking, numeracy, and responsibility, the N-Gain test was used.

RESULTS AND DISCUSSION

Results

In this study, data were obtained from the results of the pretest and posttest, which consisted of tests on mathematics learning outcomes, critical thinking skills, and numeracy. These two tests functioned to measure whether there was an improvement in students' abilities before and after the learning process. The presentation of the pretest and posttest results is shown in Table 2.

Table 2. Statistical data on students' learning outcomes

Variation	Learning Outcomes	
	Pretest	Posttest
Mean Score	58.89	70.97
Standard Deviation	10.83	15.73
Maximum Observed Score	85	95
Minimum Observed Score	45	40
Theoretical Maximum Score	100	100
Theoretical Minimum Score	0	0

Based on the table above, it can be seen that the average pretest score was 58.89 with a standard deviation of 10.83. Meanwhile, the average posttest score was 70.97 with a standard deviation of 15.73. The minimum score for the pretest was 45 and for the posttest was 40, while

the maximum pretest score was 85 and the posttest was 95. This indicates an increase in the average level of competency achievement, from a mean score of 58.89 to 70.97.

Next, before conducting the Paired Sample t-test, a normality test will be carried out using the Shapiro-Wilk test with the help of the R program to determine whether the obtained data are normally distributed. The results of the normality test for the pretest and posttest data are presented in Table 3.

Table 3. Normality test results for pretest and posttest data

Variable	Shapiro-Wilk Test		Decision
	SW	p-value	
Critical thinking	0.947	0.122	Normal
Numeracy	0.945	0.109	
Responsibility	0.976	0.707	

Paired sample t-test

The t-test is conducted to determine whether there is a significant difference between the mean scores of students' critical thinking ability, numeracy, and responsibility before and after the treatment. The decision criteria are based on the results of the t-test and the p-value. If the t-value is greater than the critical value or the p-value is less than α (5%), then H_0 is rejected. This means there is a significant effect of the problem-based learning model assisted by student worksheets on students' critical thinking, numeracy, and responsibility. Conversely, if the t-value is less than or equal to the critical value or the p-value is greater than α (5%), then H_0 is accepted, indicating that the PBL model assisted by student worksheets has no significant effect on students' critical thinking, numeracy, and responsibility. The results of the paired samples t-test calculation using the R program for students' critical thinking, numeracy and responsibility are presented in Table 4.

Table 4. Paired sample t-test results for pretest and posttest data

Variable	Paired Sample T-Test		Mean Difference	Decision
	t	p-value		
Critical thinking	6.125	8.592e-07	21.718	H_0 is rejected
Numeracy	14.324	3.25e-15	10.209	H_0 is rejected
Responsibility	2.5572	0,01567	6.328	H_0 is rejected

Based on the calculation results, a p-value ≤ 0.05 was obtained, indicating a significant difference between the pretest and posttest data of critical thinking ability before and after the treatment. Therefore, it can be concluded that the PBL assisted by student worksheets has a positive effect on students' critical thinking ability.

Calculating effect size and N-Gain test

The calculation of effect size aims to determine the magnitude of the impact or effect of a treatment, while the N-Gain test aims to measure the effectiveness of the PBL model on students' critical thinking ability, numeracy, and responsibility by observing the increase in student scores after the learning process. The effect size analysis was carried out using the R program with the Cohen's *d*-function from the *effsize* package (Torchiano, 2020). Meanwhile, the N-Gain analysis was calculated manually using the following formula.

$$N\ gain = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score} \quad (1)$$

The categorization of effect size calculation results refers to Cohen (1988), while the categorization of N-Gain results refers to Hake (1998). Furthermore, the results of the effect size and N-Gain calculations for the pretest and posttest data are presented in Table 5.

Table 5. Results of effect size and N-gain calculations

Variable	Cohen's d	Category	N-Gain	Category
Critical Thinking	1.75	High	0.35	Moderate
Numeracy	0.63	Moderate	0.19	Low
Responsibility	0.57	Moderate	0.14	Low

Based on the effect size analysis, PBL demonstrated a strong effect on students' critical thinking (Cohen's d = 1,75), while its effects on numeracy and responsibility were classified as moderate. This difference indicates that PBL is more effective in enhancing critical thinking ability than in improving numeracy and student's sense of responsibility.

Meanwhile, the N-Gain analysis revealed that the effectiveness of the PBL model in improving student's critical thinking ability fell into the moderate category, whereas the gains in numeracy and responsibility were categorized as low. These findings suggest that although the learning intervention resulted in statistically significant improvements, the magnitude of the gains achieved by students particulary in numeracy and responsibility has not yet reached an optimal level. Furthermore, a visualization of the N-Gain values for each variable is presented in Figure 1.

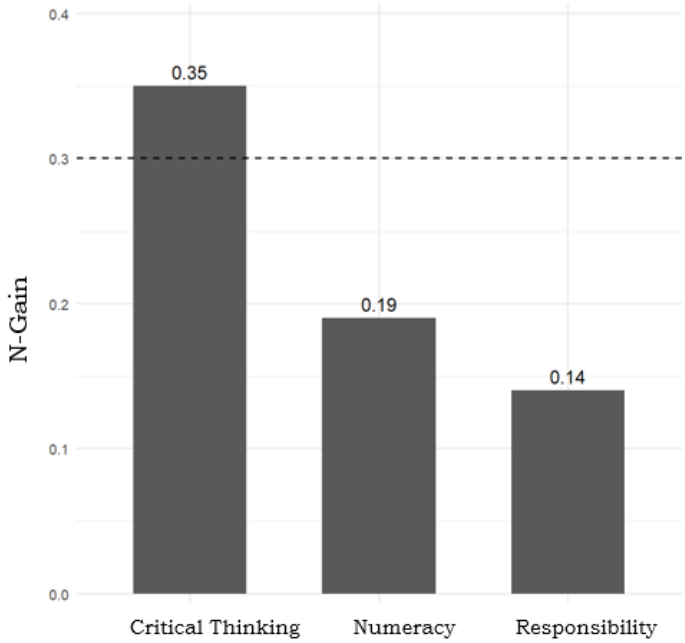

Figure 1. Comparison of N-Gain values for critical thinking, numeracy, and responsibility. The dashed line indicates the threshold between the low and moderate categories.

Discussion

Based on the results of the research conducted, this study successfully addressed the main objective regarding the influence of the PBL assisted by student worksheets on improving of junior high school students' critical thinking skills, numeracy, and responsibility in mathematics learning. The following discussion will comprehensively analyze each aspect based on the empirical findings obtained.

Effect of worksheet-assisted PBL on students' critical thinking, numeracy, and responsibility
This study shows that PBL assisted by student worksheets has a significant effect on improving students' critical thinking skills, numeracy and sense of responsibility. Statistical analysis revealed a significant difference between the pretest and posttest scores across all three variables, with p-values less than $\alpha = 0.05$. These finding are consistent with previous studies that highlight the effectiveness of PBL in developing students' higher-order thinking skills (Fakhriyah, 2014; Ningsih et al., 2023; Paillin et al., 2024; Rifai et al., 2019). The pretest and posttest analyses confirmed statistically significant differences across the three variabels (p-value < 0,05). However, the magnitude of improvement differed, with critical thinking demonstrating greater gains than numeracy and responsibility.

Effect of worksheet-assisted PBL on students' critical thinking
The results of the study indicate that the Problem-Based Learning (PBL) model assisted by student worksheets has a highly significant effect on students' critical thinking skills. This is evidenced by the statistical result of t = 6.125 and p-value = 8.592e-07, which is far below the significance level of $\alpha = 0.05$, thus rejecting H0. These findings are consistent with previous studies showing that students who participate in PBL have higher mathematical critical thinking skills compared to those who receive conventional instruction (Sianturi et al., 2018; Muahor & Yulianto, 2023).

An effect size of 1.75 indicates a high-level impact according to Cohen (1988) criteria. This value indicates that the PBL model assisted by student worksheets has a substantial practical impact on improving students' critical thinking skills. However, the N-Gain score of 0.35, categorized as moderate according to Hake (1998) classification, suggests that although the impact is considerable, the effectiveness of the improvement can still be further optimization.

The success of PBL in improving critical thinking skills can be explained by the characteristics of this learning model, which encourages students to actively analyze problems, evaluate information, and develop alternative solutions (Pratama & Mardiani, 2022). The student worksheets, as a supporting tool, plays a crucial role in facilitating the critical thinking process by providing a clear structure and systematic guidance for students in solving mathematical problems (Rosmana et al., 2024).

Effect of worksheet-assisted PBL on students' numeracy
This study demonstrates that the implementation of PBL assisted by student worksheets has a statistically significant effect on students' numeracy (t = 14.324; p-value = 3.25e-15). However, the effect size, which falls into the moderate category (0.63) and low N-Gain value (0,19) indicate that the improvement in numeracy has not yet been optimal. These findings suggest that the effectiveness of PBL in enhancing numeracy is strongly influenced by the alignment between the design of the worksheet and the instructional implementation (Purwati & Prasetyowati, 2024). Worksheet should not only be design to provide real life contexts but also include structured and repetitive numeracy activities, such as data interpretation exercises, calculations, dan conclution drawing at each stage of the problem-solving process, to strengthen students' numeracy ability (Yanti et al., 2022).

Development of student responsibility character
The results of this study indicate that PBL assisted by student worksheets has a significant effect on the development of student responsibility character with a t-value of 2.5572 and a p-value of 0.01567. However, the effect size of 0.57 is in the moderate category, and the N-Gain of 0.14 is in the low category. These findings are consistent with previous studies showing that PBL can develop students' sense of responsibility through collaborative activities and problem-solving tasks that require students to take an active role (Pasani & Basil, 2014; Supit et al., 2022). Cooperative learning in the context of PBL supports character development by placing students

in situations where they are accountable for both the learning process and outcomes (Supit et al., 2022).

The low N-Gain value in the responsibility aspect indicates the need for more explicit strategies in integrating character education into mathematics learning. Mathematics has great potential for character building by developing values such as discipline, perseverance, and responsibility (Husnul & Khairul, 2024; Lubis, 2022).

Implications of implementing worksheet-assisted PBL

Theoretically, this study strengthens the constructivist theory underpins the PBL model, where students actively construct their knowledge through problem-solving experiences (Muahor & Yulianto, 2023). Student worksheets serves as scaffolding that facilitates the process of knowledge construction in students (Fauziyah et al., 2025; Pasani & Basil, 2014).

From a practical perspective, these findings provide empirical evidence that PBL assisted by student worksheets can be effectively implemented in junior high schools to enhance students' critical thinking skills (Afifah et al., 2019; Purwati & Prasetyowati, 2024). However, the low gains in students' numeracy and responsibility suggest that the effectiveness of PBL is highly dependent on the quality of its implementation, including the alignment between worksheet design, instructional clarity, and teacher support in fostering student engangement and responsibility during learning.

Based on these conditions, the findings of this study have important implications for teacher training and curriculum development. First, teachers need to be equipped with deeper pedagogical understanding of how to design and facilitate PBL activities that explicitly target the development of students' numeracy ability and responsibility. Second, the curriculum needs to place greater operational emphasis on the integration of numeracy into mathematics learning activities, as well as to design the development of students' sense of responsibility as a continuous process rather than merely as an attitudinal outcome at the end of instruction. Dispite these implications, this study has certain limitations that should be acknowledged. The absence of a control group limits strong causal interpretation of the findings. Therefore, future studies are recommended to employ experimental designs with control groups to strengthen causal inference.

CONCLUSION

Overall, this study provides empirical evidence that the implementation og Problem Based Learning (PBL) assisted by student worksheets in improving students' critical thinking, numeracy, and responsibility. The findings indicate that the three competencies of critical thinking, numeracy, and responsibility have the potential to be developed in an integrated manner through a PBL approach assisted by student worksheets. Within a single learning sequance, social interaction in group work (responsibility), data-based problem-solving (numeracy), and the process of analyzing and evaluating solutions (critical thinking) occur simultaneously as part of a coherent learning experience.

Several recommendations can be proposed to enhance the effectiveness of the PBL model assisted by student worksheets in developing students' competencies. First, it is necessary to modify the PBL syntax to align with the of the student worksheet structure, so that each problem-solving stage explicitly facilitates the development of students' critical thinking ability, numeracy and responsibility. Second, the development of digital-based student worksheets can be a strategic alternative to increase student engagement and expand access to more contextual and engaging problem-based learning resources. Third, the development of more comprehensive assessment instruments is needed to measure students' numeracy and responsibility.

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DECLARATION

Author contribution
All authors contribute in the research and/or writing the paper, and approved the final manuscript.

Afifah Sausan Rahmawati	Conceptualizing the research idea, leading the investigation, setting up the methodology, analyzing the data, and writing the original draft.
Nur Anisa Fatonah	Assisting the investigation, reviewing the validity of the methodology, supervising the data collection, and assisting the data analysis.

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All authors declare that they have no competing interests.

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The use of artificial intelligence
We do not use any generative AI tools to write any part of this paper.

Additional information
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