IJOLAE Indonesian Journal on Learning and Advanced Education

http://journals.ums.ac.id/index.php/ijolae

Strategies for Integrating Problem-Based Learning, Teaching Modules, and Formative Assessments to Enhance Learning Outcomes and Critical Thinking Skills

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DOI: 10.23917/ijolae.v7i2.8612
Received: February 6th, 2025. Revision: March 1st, 2025. Accepted: March 3rd, 2025
Available Online: March 8th, 2025. Publish Regularly: May 2025

Abstract

In an ideal educational setting, students actively engage with content, apply critical thinking to solve real-world problems, and consistently demonstrate improved learning outcomes. However, many educational environments lack integrated strategies that connect theoretical knowledge with practical applications, leading to passive learning and underdeveloped critical thinking skills. This study addresses these gaps by developing and implementing a novel framework—Problem-Based Learning, Teaching Modules, and Formative Assessments (PLTMFA)—designed to enhance learning outcomes and critical thinking skills, particularly in the context of Magnitudes, Units, and Measurements. Grounded in instructional design principles, the PLTMFA approach emphasizes active learning and continuous, meaningful assessments to ensure student engagement and cognitive development. Given the increasing demand for critical thinking and problem-solving skills, there is an urgent need to explore and validate such innovative teaching methods. The study's primary objectives are to develop the PLTMFA framework, apply it in a classroom setting, and evaluate its effectiveness. Data collected through comprehension tests, questionnaires, and observations were analyzed to assess the impact on student performance. Findings indicate that PLTMFA significantly improves both learning outcomes and critical thinking skills, demonstrating its potential as an effective solution to current educational challenges.

Keywords: blended learning, critical thinking skills, digital education, digital literacy, learning outcomes, project based learning, teaching modules

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1. Introduction

Today's Education has shifted towards using digital technology in learning (Al-Abdullatif & Gameil, 2021; Kyaw et al., 2019; Loderer et al., 2020). Digital education, including online modules, tutorials, and virtual patient simulations, shows no significant difference in skills between digital learning groups and traditional learning groups. Moreover, research by (Charania et al., 2021; Kron et al., 2017; Sulisworo et al., 2019) highlights the use of computer simulations in teaching communication skills among medical students. Meanwhile, research by (Fitriani et al., 2022) demonstrates that conceptual problem-based learning on biology learning tools are effective in training students' critical

thinking skills. Additionally, the aspect of digital module development is also important, as shown by research by (Matsun et al., 2021; Yunita et al., 2021), which developed an Arduino-based electrical practicum module effective in improving student learning outcomes. Furthermore, research by (Bahreini et al., 2014; Cortázar et al., 2021) emphasizes the importance of introducing technology that enables emotion recognition in online learning environments.

In the context of digital learning, it is important to pay attention to digital literacy, as discussed in research by (Reddy et al., 2023; Zainal Abiddin et al., 2022), which highlights community-based strategies to enhance digital literacy to improve learning experiences. Moreover, research by (Cortázar et al., 2021; Fahmi et al., 2021; Sulisworo et al., 2019) stresses the importance of critical thinking in using technology for personal, professional, and social change. Integrating digital modules, critical thinking skills, assessments, and problem-based learning has emerged as a new research focus aimed at improving the effectiveness of learning experiences. A more interactive, problem-based, and relevant learning environment for students can be created by developing technology-supported problem-based digital modules and formative assessments. This approach leverages digital technology not only to facilitate learning but also to incorporate problem-based learning elements and formative assessments to comprehensively enhance students' critical thinking skills (Rusiana et al., 2024).

The novelty of this research lies in the integrative combination of digital modules, critical thinking skills, formative assessment, and problem-based learning (PBL) within a comprehensive approach to enhance students' learning outcomes and learning experiences. Although various studies have examined these aspects separately, there have not been many studies that integrate them into a systematic learning model.

Several previous studies have shown the effectiveness of PBL and formative assessment in enhancing critical thinking skills and student learning outcomes. For example, research by Winarti et al. (2023) found that the implementation of technology-based PBL can enhance students' understanding better than conventional memorization-based methods. Additionally, the study by Setyaningsih et al. (2022) shows that the continuous use of formative assessments can help students understand concepts more deeply and improve their critical thinking skills. However, these studies are still limited to the implementation of individual aspects without integrating digital modules as a main component in the learning strategy.

Studies have shown that educational technology, particularly those supporting scaffolding, can reduce cognitive load and assist students in learning complex subjects (Kim & Lim, 2019; Stollman et al., 2019). Moreover, blending problem-based learning with web technology has been found to positively impact student learning outcomes, emphasizing understanding over memorization (Adhelacahya et al., 2023; Bosica et al., 2021; Jin & Bridges, 2014). Incorporating digital technology in problem-based learning environments has been proven to enhance students' academic performance (Al-Abdullatif & Gameil, 2021). By engaging students in problem-solving activities, high-level abilities, and creativity can be nurtured, promoting active learning and critical thinking (Adhelacahya et al., 2023; Dewi et al., 2023). The use of

constructivist technology in PBL has been associated with the development of higher-order thinking skills and the ability to apply knowledge in new contexts (Braun et al., 2020; Charania et al., 2021). In the context of vocational education, the integration of technology through e-modules has been shown to increase student interest and practicality in learning activities (Fahmi et al., 2021; Vantieghem et al., 2020). The use of problem-based learning integrated with a design thinking approach has been found to improve students' critical thinking and creativity. Moreover, the implementation of the problem-based learning model in e-learning environments can enhance student learning outcomes and critical thinking skills (Albus et al., 2021; Naik et al., 2020).

Teaching modules in the Kurikulum Merdeka (the national standard curriculum in Indonesia) must be created by educators with guidelines for learning and assessment to guide the learning process according to students' needs. The development process of teaching modules involves various stages such as defining, designing, developing, and distributing the modules (Houghton, 2023; Sulisworo et al., 2019). These modules aim to enhance student learning by providing structured guidance and assessment tools (Habibaturrohmah et al., 2022; Yan & Pastore, 2022). Furthermore, the use of instruction-based interactive and differentiated electronic modules has been highlighted as beneficial for blended learning environments (Houghton, 2023; Rini et al., 2020).

Additionally, the importance of creating higher-order thinking skills questions to support the implementation of the Minimum Competency Assessment (MCA) in schools has been emphasized (Sulisworo et al., 2019). This aligns with the need for educators to develop literacy-based assessment instruments (Anisah & Aufa, 2022; Sudakova et al., 2022) and digital teaching materials (Bezanilla et al., 2019; Kurniawan et al., 2022) to improve education quality. Moreover, teacher involvement in module development has been shown to increase motivation, understanding, and the ability to create independent teaching tools (Kusumaningtyas et al., 2020). Training sessions for educators on using tools like the Problem Uncovering Tool (PUT) are recommended to effectively map student learning problems (Lah et al., 2024; Liu & Pásztor, 2022a; Waite et al., 2020). The development of teaching modules is crucial in enhancing education quality by providing structured guidance, and assessment tools, and fostering higher-order thinking skills among students. Educators need to adapt to modern teaching methods by incorporating interactive, differentiated, and digital resources to meet diverse learning needs and improve overall learning outcomes.

Formative learning, a hallmark of the Kurikulum Merdeka, aims to monitor student learning progress and assist in learning development. Effective science education should be contextual and involve real-life experiences to enhance students' critical thinking skills. However, at the particular junior school in Sikka, East Nusa Tenggara, learning remains conventional with a lack of learning media and laboratory experiments. To improve learning at this school, various innovative steps can be taken. One such step is utilizing learning media as suggested by Peday & Watini (2022), which highlights the importance of media implementation. Teachers need to use media in the learning process to enhance learning effectiveness. The use of learning media, such as interactive multimedia based on PowerPoint, has also been proven effective (Rakoczy et al., 2019; Sakiah & Effendi, 2021). In the context of

science learning, the use of educational videos can also be an effective solution, as shown by (Rupp et al., 2019). By utilizing various interactive learning media, teachers can improve student learning outcomes.

The integration of PBL, teaching modules, and formative assessments represents a novel approach to educational strategies aimed at enhancing learning outcomes and critical thinking skills (Abdurrahman & Setyaningsih, 2019; Janssen et al., 2019; Rusnawati et al., 2021; Wei et al., 2021). While each of these components has been individually recognized for its educational benefits, their combined application in a structured, synergistic framework remains underexplored. The novelty lies in the deliberate and strategic fusion of PBL with tailored teaching modules (Houghton, 2023; Sudakova et al., 2022) and continuous formative assessments.

This approach fosters an environment where students not only engage in active problem-solving but also receive ongoing, targeted feedback that reinforces their learning journey. By embedding formative assessments (Chevalier et al., 2022; Rakoczy et al., 2019).

In this research, it was developed teaching modules and created formative assessments based on problem-based learning to enhance the critical thinking skills of students at this school on the topics of Magnitudes, Units, and Measurements. Learning at these schools faces challenges in improving learning outcomes and students' critical thinking skills. This issue is caused by the lack of effective teaching methods and the lack of development of relevant teaching modules and formative assessments according to student needs. The research objective was to determine and describe the improvement in learning outcomes and critical thinking skills through the effective implementation of teaching with the module and formative assessment based on problem-based learning.

2. Method

This research design employs both quantitative and qualitative approaches to obtain a comprehensive understanding of the effectiveness of problem-based learning, teaching modules, and formative assessments (PLTMFA) in enhancing student's learning outcomes and critical thinking skills. The subjects of the research include teachers who teach the relevant subjects and students participating in the implementation of problem-based learning, teaching modules, and formative assessments. Research Instruments include questionnaires, comprehension tests, and observations. Questionnaires are used to gather data on students' and teachers' perceptions of the effectiveness of the PLTMFA. Comprehension tests are used to measure students' learning outcomes before and after the implementation of the teaching modules and formative assessments. Observations are conducted to monitor the learning implementation and the interaction between teachers and students during the learning process. Figure 1 shows the research activities.

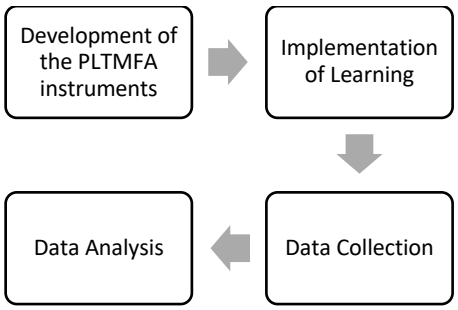

Figure 1. Research Activities

The development of teaching modules and formative assessments is conducted based on instructional design principles that align with the problem-based learning approach. This involves creating comprehensive, structured learning materials and assessment tools that encourage student engagement, problem-solving, and application of knowledge through real-world problems. Two key instruments are developed: the PLTMFA module and formative tests with problem-based learning to measure critical thinking skills. The module is validated by media experts and subject matter experts. Media experts validate components including learning outcomes and learning objectives (1 item), diagnostic assessments (2 items), teaching modules (5 items), types of assessments (3 items), and assessment instruments (6 items). Subject matter experts validate components such as material availability, concept, and principle alignment, and suitability for learner characteristics (6 items), as well as core components like learning objectives, triggering questions, and enrichment (6 items), and attachments like worksheets, glossaries, and reading materials (4 items). The module validation by learning experts includes ensuring the completeness of minimum components (3 items), the presence of essential and meaningful material with clear learning objectives and activities (11 items), continuity (4 items), and context (3 items). Additionally, the test is validated by learning experts focusing on content components (4 items), question construction (8 items), and language (4 items).

The PLTMFA approach was applied in teaching the topics of Magnitudes, Units, and Measurements. Students engaged in a series of learning problems meticulously designed within the modules, promoting active participation and hands-on experience. These problems not only cover the theoretical aspects of the subject but also require practical application, fostering a deeper understanding and retention of the material.

Data on students' learning outcomes and critical thinking skills were systematically collected through a set of tests. Comprehension tests were administered to measure students' grasp of the subject matter before and after the implementation of the PLTMFA. These data were analyzed using Paired Sample T-Test to find the effect of the learning model on student's achievement. Observations were made to monitor the implementation process and the interaction between teachers and students during the learning activities. Table 1 organizes the critical thinking indicators, their corresponding abilities, and the specific formative, summative, and Student Worksheet question items associated with each ability.

Table 1. The Rubric of the Instruments

Critical Thinking Indicator	Ability	Formative Question Items	Summative Question Items	Worksheet Question Items
Providing simple explanations	Able to calibrate questions from the CGS system to MKS	1, 2, 6	7	1
Developing basic skills	Able to analyze how to perform measurements when given practical tools and materials	3	6, 8, 9	3, 4, 5
Drawing conclusions	Able to answer problem-solving questions	7, 8, 9	1, 3	2
Providing detailed explanations	Able to conclude problems according to the given questions	4	2	6
Evaluating abilities	Able to evaluate story problems	9	5, 4	7

In this study, critical thinking skills are not measured directly but are incorporated as components within the test items, allowing students to engage with various critical thinking indicators. Thus, the measurement focuses on the learning outcome, which is an aggregate of the evaluation of each test item in the instrument.

The collected data were thoroughly analyzed using descriptive statistical techniques and normalized gain scores to identify any significant improvements in learning outcomes and critical thinking skills. This analysis aimed to evaluate the overall effectiveness of the PLTMFA in enhancing students' academic performance and cognitive abilities. The results were then interpreted to draw conclusions and provide recommendations for future implementation and development of modules and assessments.

3. Result and Discussion

Figure 2 shows several sections of the module that have been validated by experts. Figure 2 is the cover of the teaching module. Figure 2 is a section of the module that explains the mass measuring instrument.

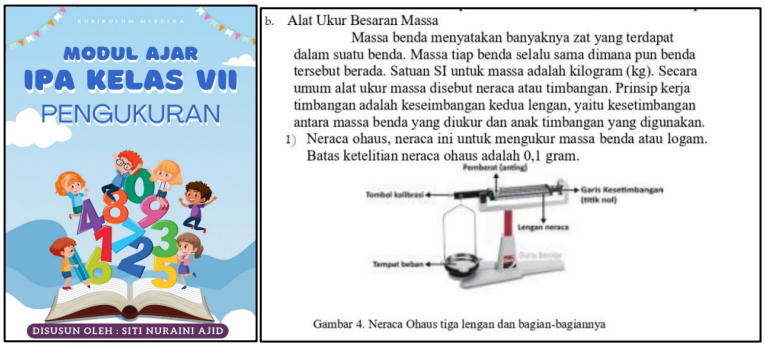

Figure 2. Learning Module Cover

Figure 3 shows a section of the module demonstrating the integration of problem-based learning aimed at enhancing critical thinking skills. These skills are confirmed through cognitive activities related to measuring density using various instruments. This activity is conducted by students within the module (Figure 3).

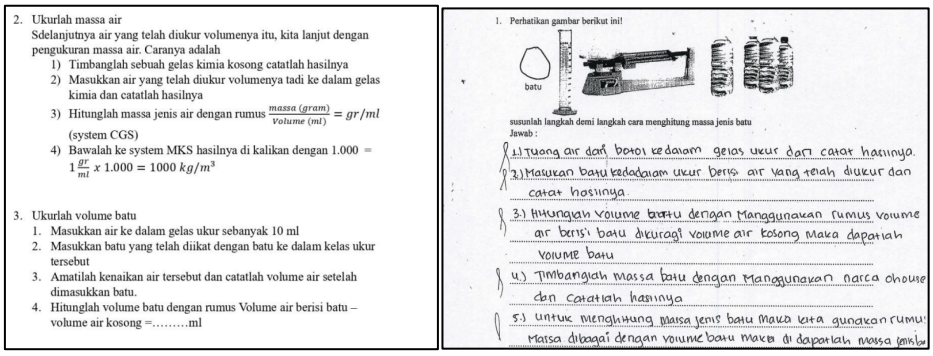

Figure 3. Integration of Problem-Based Learning Modules

The module was validated by subject matter experts (5 experts) and media experts (5 experts). The average validation score from subject matter experts was 97.86, while the average score from media experts was 95.89. The average validation score from learning experts was 97.44. These results indicate that the module is suitable for use.

The validation results for the test items by learning experts (4 experts) showed an average feasibility score of 97.44, indicating that the test instruments are suitable for use. An example of a test item is shown in Figure 4, which assesses students' ability to use a micrometer screw gauge.

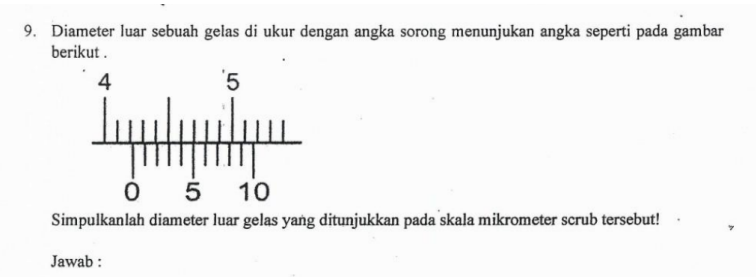

Figure 4. Micrometer Screw Gauge

Figure 5 shows an example of students' work in measuring the density of irregular objects. In this activity, students need to use a volume measuring instrument by immersing the solid object into water as part of the measurement process. This activity promotes critical thinking skills during the measurement process (Figure 5).

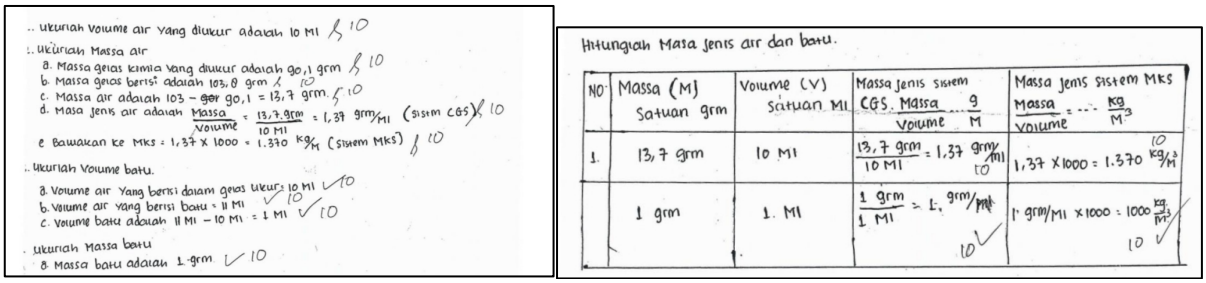

Figure 5. Example of Student Work in Measuring the Density of Irregular Objects

In the diagnostic measurement, it was found that only 7 students understood measurement concepts. The learning conducted

with this module was able to increase the number of students who understood measurement. The test results from various measurements are shown in Figure 6.

From Figure 6, it is observed that the average score for the practical test is 88.88, the pre-test score is 86.86, and the post-test score is 91.82. See Table 2 for these statistical results. With these results, the normalized gain score can be calculated as 5.7%, which falls into the moderate category.

Table 2.The Descriptive Statistic Results

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Posttest	91.8214	28	4.00974	.75777
	Pretest	86.8596	28	2.34614	.44338

By using the data in Figure 6 (Pretest and Posttest data), a paired sample T-test analysis can be carried out, the results of which are shown in Table 3.

Table 3. Paired Samples T-Test Results

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Posttest - Pretest	4.96179	3.65548	.69082	3.54434	6.37923	7.182	27	.000

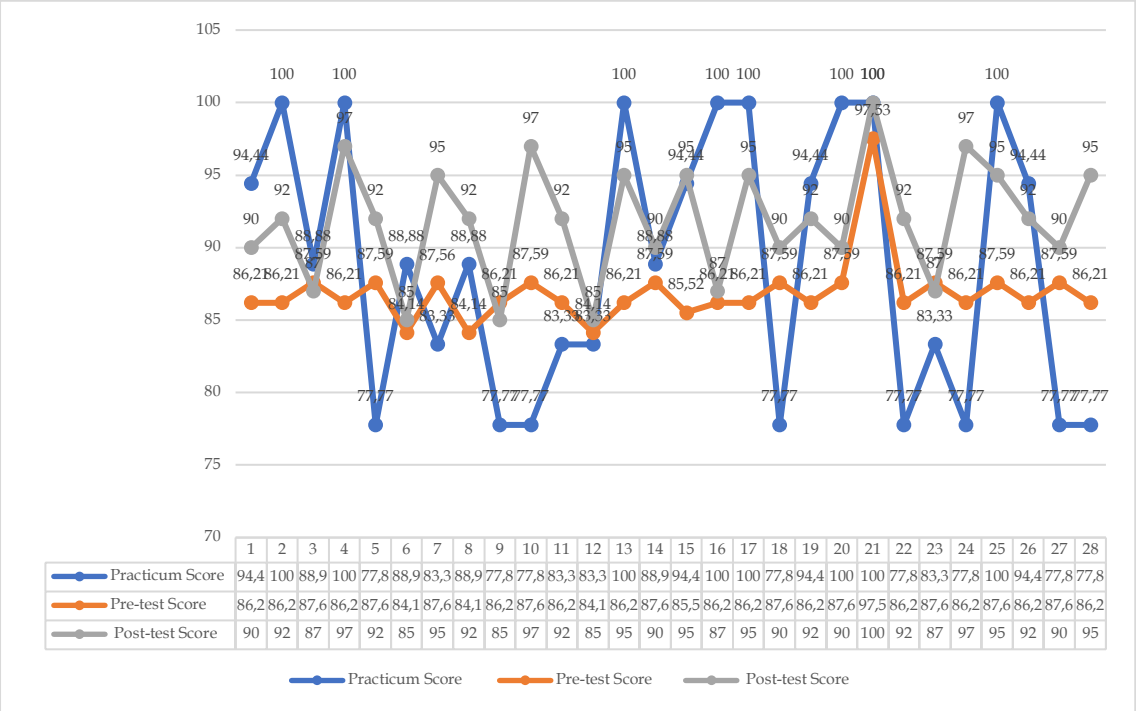

Figure 6. Test Results from Various Measurements

The findings from this study highlight the critical role of problem-based learning in advancing students' critical thinking skills (Alsaleh, 2020; Braun et al., 2020; Cáceres et al., 2020). Problem-based learning is an instructional strategy that places students in the role of problem-solvers, engaging them in real-world issues that require analytical and

creative solutions. This approach encourages deeper understanding and application of knowledge, which is essential for developing critical thinking skills. The significant improvement in students' performance, as evidenced by the post-test scores, reflects the effectiveness of the model in enhancing these skills.

Initially, diagnostic assessments indicated that only seven students demonstrated a clear understanding of measurement concepts. This low baseline underscores the challenge of teaching complex scientific concepts effectively. However, the application of teaching modules led to a marked improvement in students' comprehension. The post-test scores were notably higher compared to pre-test scores, suggesting that the modules facilitated a deeper grasp of the subject matter. The increased average post-test score of 91.82, compared to the pre-test average of 86.86, indicates a substantial gain in students' understanding and skills. Several studies related to the application of problem-based learning with various assistance such as modules encourage the improvement of critical thinking (Braun et al., 2020; Dekker, 2020; Heong et al., 2020). This reinforces that the integration of PBL, e-modules, and formative assessments has the potential to develop thinking skills.

The practical activities integrated into the modules were crucial in achieving these results. Activities such as measuring density using various tools provided students with hands-on experience that bridged the gap between theoretical knowledge and practical application. These experiments not only reinforced students' understanding but also enhanced their ability to apply concepts in real-world scenarios. The practical approach of the modules ensured that students engaged actively with the content, which is vital for reinforcing learning and developing problem-solving skills (Chua & Islam, 2021; Houghton, 2023; Tseng, 2020).

The design and validation of the teaching modules and student worksheets were essential in guiding the learning process. The modules were developed based on instructional design principles that align with the problem-based approach, incorporating problem-solving tasks and real-world applications. The high validation scores from experts in media and content confirm the quality and effectiveness of these materials. Experts evaluated various aspects, including the completeness of components, relevance of content, and alignment with learning goals. The modules received an average validation score of 97.44, indicating their suitability for educational use. These results are in line with several studies that digital modules have the potential to improve critical thinking skills (Rini et al., 2020; Yunita et al., 2021).

Furthermore, the inclusion of formative assessments in the modules played a significant role in measuring and enhancing students' critical thinking skills (Braun et al., 2020; Peat et al., 2005; Rahmat et al., 2020). These assessments were designed to evaluate students' problem-solving abilities and application of knowledge, providing valuable feedback to both students and instructors. The high validation scores for the assessment instruments reflect their effectiveness in gauging students' progress and supporting their development. Formative assessments, such as quizzes, peer reviews, and reflective journals, provide ongoing feedback to students (Chevalier et al., 2022; Rakoczy et al., 2019). This feedback helps students understand their current level of understanding and areas needing improvement. Regular feedback encourages them to think critically about their learning process and adjust their strategies accordingly (Habibaturrohmah et

al., 2022; Adhantoro et al., 2025). By engaging students in formative assessments, they are encouraged to actively participate in their learning. Activities that require them to analyze, evaluate, and apply knowledge help develop their critical thinking skills (Saputra et al., 2019; So et al., 2020). Formative assessments can be designed to encourage students to ask questions, explore different solutions, and consider alternative viewpoints (Abdurrahman & Setyaningsih, 2019; Changwong et al., 2018; Fuad et al., 2017). This promotes a mindset of inquiry and curiosity, which is essential for critical thinking.

The integration of problem-based into the teaching modules has proven to be highly effective in improving students' critical thinking skills and learning outcomes. The substantial increase in post-test scores and the positive impact of practical activities highlight the benefits of this approach. The high validation scores for the modules and assessments further validate their effectiveness. Integrating problem-based learning into teaching modules can significantly enhance the learning experience by focusing on real-world problems and encouraging active problem-solving. It involves presenting students with real-world problems or scenarios that are relevant to their field of study (Lah et al., 2024; Liu & Pásztor, 2022b). This relevance makes learning more engaging and helps students understand the practical application of their knowledge. Instead of passively receiving information, students actively engage with the problem (Alsaleh, 2020; Cáceres et al., 2020; Dekker, 2020; Heong et al., 2020). They work in groups or individually to research, analyze, and develop solutions. This active involvement fosters deeper learning and helps develop critical thinking skills. It encourages students to integrate knowledge from various subjects or disciplines to address the problem at hand (Changwong et al., 2018; Fuad et al., 2017). This interdisciplinary approach helps students see connections between different areas of study and apply their knowledge in a comprehensive manner (Changwong et al., 2018; Houghton, 2023; Jin & Bridges, 2014). This study supports the continued use and development of problem-based instructional materials to foster an engaging and effective learning environment. Future research could explore further refinements to these materials and assess their impact across different educational contexts.

4. Conclusion

The implementation of problem-based learning through specially designed teaching modules and formative assessments has significantly enhanced students' critical thinking skills and learning outcomes. The study revealed a marked improvement in students' understanding of measurement concepts, as evidenced by the increase in average post-test scores from 86.86 to 91.82. The practical activities embedded within the modules effectively bridged theoretical knowledge with real-world application, reinforcing students' skills. The high validation scores from experts confirm the modules' quality and effectiveness. This study underscores the value of problem-based learning in creating an engaging, effective learning environment that fosters critical thinking and practical problem-solving skills. Future research should continue to explore and refine problem-based learning approaches to further enhance educational practices across various contexts.

5. Acknowledgments

This study was supported by Hibah Penelitian Tesis Mahasiswa (Thesis Writing Grants) from the Directorate of Research,

technology, and Community Services, the Ministry of Education and Culture of the Indonesian Republic under contract number 0459/E5/PG.02.00/02024, 107/E5/PG.02.00.PL/2024, 0609.12/LL5-INT/AL.04/2024.

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