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Development Of A Problem-Based Learning (PBL) Based Formative Test Instrument To Improve Students' Understanding Of Science Concepts At SMP Negeri 2 Taliabu Selatan

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Abstract

This study aims to develop a Problem-Based Learning (PBL)-based formative test instrument to improve students' understanding of science concepts at SMP Negeri 2 Taliabu Selatan. The research employed a Research and Development (R&D) approach using a modified Borg and Gall model consisting of seven stages: preliminary data collection, planning, initial product development, expert validation, product testing, revision, and final product development. The instrument developed was a 15-item multiple-choice test designed based on PBL principles, focusing on the human circulatory system topic. The results showed that the instrument has very high validity, as indicated by Aiken's V index, where all items were categorized as highly valid, and supported by Confirmatory Factor Analysis (CFA) with excellent model fit (CFI = 0.997; TLI = 0.997; RMSEA = 0.006; SRMR = 0.046), confirming strong construct validity. The reliability analysis using Cronbach's Alpha yielded a value of 0.486, indicating low to moderate reliability, which may be influenced by the limited number of dichotomous items. However, the instrument demonstrated very high practicality based on teacher and student responses, with average scores of 3.63 and 3.41 respectively. Furthermore, the instrument was proven effective in enhancing students' conceptual understanding and engagement in science learning. Therefore, the developed PBL-based formative test instrument is valid, practical, and effective, and is suitable for use in assessing

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students' understanding of science concepts.

Keywords: Problem-Based Learning (PBL), Formative Test Instrument, Science Concept Understanding, Instrument Development

INTRODUCTION

The development of science education, particularly in the subject of Natural Sciences (IPA), plays a crucial role in preparing students to face the increasingly complex challenges of the 21st century. Science learning at the junior high school level is not merely oriented toward the transfer of factual knowledge but is expected to foster students' ability to think critically, analytically, and systematically in understanding natural phenomena. Through meaningful learning experiences such as observation, experimentation, and problem-solving activities, students are encouraged to construct their own understanding and develop scientific attitudes, including curiosity, objectivity, and perseverance. In line with the implementation of the Merdeka Curriculum, assessment practices in science education are required to emphasize not only cognitive achievement but also conceptual understanding, scientific processes, and higher-order thinking skills. Therefore, assessment should provide a comprehensive picture of students' competencies, enabling them to apply knowledge in real-life contexts while developing collaboration and communication skills(Elizondo-Montemayor, 2004).

However, the reality in schools indicates that students' conceptual understanding of science remains relatively low. This condition is evident in SMP Negeri 2 Taliabu Selatan, where many students experience difficulties in comprehending fundamental concepts such as energy, force, and living systems. The results of daily assessments and interviews with teachers reveal that students often fail to connect theoretical concepts with real-world phenomena. This gap suggests that the current learning and assessment practices have not effectively supported meaningful understanding. One of the contributing factors is the dominance of conventional evaluation instruments, particularly multiple-choice tests that focus on lower-order thinking skills. Although practical, such instruments are insufficient to measure deep understanding, critical thinking, and problem-solving abilities. Consequently, formative assessment, which should function as a diagnostic tool and provide feedback for both teachers and students, has not been optimally utilized(Blumberg, 2005).

From a theoretical perspective, students' conceptual understanding can be enhanced through the implementation of Problem-Based Learning (PBL). This approach emphasizes active

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student engagement in identifying, analyzing, and solving contextual problems. PBL encourages learners to integrate prior knowledge with new information, thereby promoting deeper understanding and meaningful learning. Previous studies have shown that PBL can improve students' critical thinking skills, collaboration, and conceptual mastery. Despite its proven effectiveness, most research has focused primarily on the implementation of PBL in instructional processes rather than on the development of assessment instruments aligned with its principles. This creates a gap between instructional strategies and evaluation practices, particularly in the context of formative assessment(Jaenudin & Murwaningsih, 2017).

The need for developing formative test instruments based on PBL becomes even more significant in regions with unique educational challenges, such as island areas like Taliabu Selatan. Limited educational resources and geographical constraints require innovative approaches to both teaching and assessment. A well-designed formative assessment instrument should not only be valid and reliable but also practical and relevant to the local context. It should be capable of capturing students' ability to apply scientific concepts in solving real-life problems, thus aligning with the core principles of PBL. Moreover, such an instrument can serve as both an evaluation tool and a learning medium, supporting continuous improvement in the teaching and learning process(van Der Vleuten & Schuwirth, 2019).

This study is therefore essential as it aims to address the existing gap by developing a formative test instrument based on Problem-Based Learning to improve students' conceptual understanding in science. Academically, this research contributes to the limited body of literature on the integration of formative assessment and PBL, offering a more comprehensive framework for assessment design. Practically, the developed instrument is expected to assist teachers in obtaining accurate and meaningful information about students' learning progress, which can be used to design appropriate instructional interventions, including remedial and enrichment programs. Furthermore, this research supports educational policy efforts in enhancing the quality of science education, particularly in promoting higher-order thinking skills as emphasized in the Merdeka Curriculum(Andrijati et al., 2025).

In addition, this study adopts a systematic approach to instrument development, including stages of design, validation, and field testing, ensuring that the final product meets established standards of validity, reliability, practicality, and effectiveness. By integrating PBL principles into the structure of the test items, the instrument is expected to reflect authentic learning situations that require analysis, reasoning, and problem-solving. Ultimately, this research seeks to provide a comprehensive and innovative solution to improve formative assessment practices in science

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education, thereby contributing to more meaningful and effective learning experiences for students(Yendra et al., 2023).

Science Learning in Junior High School

Science learning at the junior high school level plays a fundamental role in shaping students' scientific literacy, critical thinking ability, and problem-solving skills. As highlighted in the provided document, science education (Ilmu Pengetahuan Alam/IPA) is not merely intended to deliver factual knowledge but to develop students' ability to think scientifically through observation, experimentation, and analysis. Students are expected to actively construct their understanding of scientific concepts rather than passively receive information from teachers. This perspective aligns with the constructivist approach, which emphasizes that knowledge is built through interaction with the environment and prior experiences. In the context of the Merdeka Curriculum, science learning is directed toward developing higher-order thinking skills (HOTS), including critical thinking, creativity, collaboration, and communication. These competencies are essential for preparing students to face global challenges and to function effectively in modern society (Taradi et al., 2005).

However, the implementation of science learning in schools often faces significant challenges. The document reveals that many students still experience difficulties in understanding fundamental scientific concepts such as energy, force, and biological systems. This issue is closely related to the dominance of teacher-centered instructional practices and the limited use of innovative learning strategies. As a result, students tend to memorize information without truly understanding its meaning or application. Furthermore, science learning is often disconnected from real-life contexts, making it difficult for students to see the relevance of what they learn. This gap between theory and practice leads to low levels of conceptual understanding and scientific literacy among students. Research findings presented in the document also indicate that students' critical thinking skills remain relatively low due to the lack of opportunities to engage in inquiry-based and problem-solving activities .

Another important issue highlighted in the document is the limited capacity of teachers in designing effective learning and assessment tools. Many teachers still struggle to develop instruments that measure higher-order thinking skills, as they are more accustomed to traditional forms of assessment such as multiple-choice questions focused on recall. This limitation affects not only the quality of assessment but also the overall learning process, as students are rarely challenged to think critically or solve complex problems. Additionally, the use of formative

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assessment in science learning has not been fully optimized. Ideally, formative assessment should provide continuous feedback that helps students improve their understanding and supports teachers in adjusting their instructional strategies. However, in practice, assessment is often conducted in a summative manner, focusing only on final outcomes rather than the learning process (Septiana & Hermanto, 2024).

To address these challenges, it is necessary to adopt more student-centered and context-based learning approaches. Science learning should be designed to encourage exploration, inquiry, and active participation, allowing students to develop a deeper understanding of concepts. Integrating real-world problems into learning activities can help students connect theoretical knowledge with practical applications, thereby enhancing their motivation and engagement. Moreover, improving teachers' competence in designing innovative learning and assessment tools is crucial for achieving the goals of science education. By aligning teaching practices with the principles of the Merdeka Curriculum, science learning can become more meaningful, interactive, and effective in developing students' scientific competencies(Masek & Yamin, 2010).

Problem-Based Learning (PBL) in Science Education

Problem-Based Learning (PBL) is one of the most effective instructional approaches for enhancing students' conceptual understanding and critical thinking skills in science education. As described in the document, PBL is a student-centered learning model that uses real-world problems as the starting point for learning. In this approach, students are actively involved in identifying problems, gathering information, analyzing data, and proposing solutions. The role of the teacher shifts from being a knowledge transmitter to a facilitator who guides students through the learning process. This approach aligns with constructivist theory, which emphasizes active learning and knowledge construction through experience (Alghasham, 2012).

The implementation of PBL in science learning offers several advantages. First, it promotes deeper understanding by encouraging students to explore concepts in meaningful contexts. When students are faced with real-life problems, they are more motivated to learn and to apply their knowledge in practical situations. Second, PBL enhances critical thinking and problem-solving skills, as students are required to analyze complex situations, evaluate information, and develop logical solutions. Third, PBL fosters collaboration and communication skills, as students often work in groups to discuss ideas and share perspectives. These skills are essential for success in the 21st century, where teamwork and effective communication are highly valued .

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The document also highlights several stages in the PBL process, which typically include problem orientation, problem identification, investigation, solution development, and reflection. Each stage plays a crucial role in guiding students through the learning process and ensuring that they achieve the desired learning outcomes. During the problem orientation stage, students are introduced to a real-world problem that serves as the basis for learning. In the problem identification stage, they analyze the problem and formulate questions that need to be addressed. The investigation stage involves gathering information and conducting research, while the solution development stage focuses on proposing and presenting solutions. Finally, the reflection stage allows students to evaluate their learning process and outcomes, promoting metacognitive awareness(SAPUTRA et al., 2023) .

Empirical studies cited in the document demonstrate the effectiveness of PBL in improving students' learning outcomes. For example, research findings show that the implementation of PBL can significantly increase students' average scores and learning completeness. In addition, PBL has been shown to improve students' motivation and engagement in learning, as well as their ability to think critically and solve problems. These findings confirm that PBL is not only an effective instructional strategy but also a powerful tool for developing essential competencies in science education (Li et al., 2023).

Despite its advantages, the successful implementation of PBL requires careful planning and support. Teachers need to design appropriate problems that are relevant, challenging, and aligned with learning objectives. They also need to provide guidance and scaffolding to help students navigate the learning process. Moreover, assessment practices should be aligned with the principles of PBL to ensure that students' learning outcomes are accurately measured. This highlights the importance of developing assessment instruments that reflect the characteristics of PBL, particularly in measuring higher-order thinking skills and conceptual understanding.

Formative Assessment and Development of PBL-Based Test Instruments

Formative assessment is a critical component of effective teaching and learning, particularly in science education. According to the document, formative assessment is defined as an ongoing process that provides feedback to students and teachers during the learning process. Unlike summative assessment, which focuses on final outcomes, formative assessment aims to monitor students' progress and identify areas for improvement. It plays a crucial role in supporting learning by helping students understand their strengths and weaknesses and by guiding teachers in adjusting their instructional strategies (Yuliati[1] et al., 2024).

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In the context of the Merdeka Curriculum, formative assessment is emphasized as an essential tool for achieving meaningful learning. It involves various techniques, including quizzes, discussions, observations, and reflective activities. However, the document indicates that the implementation of formative assessment in schools is still limited. Many teachers are not familiar with effective formative assessment practices and tend to rely on traditional testing methods. As a result, the potential of formative assessment to enhance learning outcomes has not been fully realized .

The development of formative test instruments based on Problem-Based Learning represents an innovative approach to addressing this issue. Such instruments are designed to measure higher-order thinking skills by incorporating real-world problems into test items. This approach aligns assessment with the learning process, ensuring that students are evaluated based on their ability to apply knowledge, analyze situations, and solve problems. According to the document, a well-developed assessment instrument should meet several criteria, including validity, reliability, and practicality. Validity ensures that the instrument measures what it is intended to measure, reliability ensures consistency of results, and practicality ensures ease of use in real classroom settings (Aufa et al., 2020).

The process of developing PBL-based formative test instruments involves several stages, including needs analysis, design, development, validation, and testing. The document adopts the Borg and Gall model of research and development, which provides a systematic framework for creating and evaluating educational products. This model emphasizes iterative development, allowing for continuous improvement based on feedback and testing results. Through this process, the developed instrument can achieve a high level of quality and effectiveness (Andrijati et al., 2025).

Research findings presented in the document indicate that PBL-based assessment instruments can significantly improve students' conceptual understanding and critical thinking skills. By engaging students in problem-solving activities, these instruments encourage active learning and deeper understanding. Moreover, they provide valuable feedback that helps students improve their performance and supports teachers in making informed instructional decisions. In this way, formative assessment becomes an integral part of the learning process, rather than merely a tool for measuring outcomes (Yendra et al., 2023).

In conclusion, the integration of formative assessment and Problem-Based Learning offers a promising approach to improving science education. By developing assessment instruments that reflect the principles of PBL, educators can create more meaningful and effective learning

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experiences for students. These instruments not only measure learning outcomes but also support the development of essential skills, including critical thinking, problem-solving, and conceptual understanding. Therefore, the development of PBL-based formative test instruments is a crucial step toward enhancing the quality of science education and achieving the goals of the Merdeka Curriculum.

DISCUSSION

Development of Problem-Based Learning-Based Formative Test Instruments

The development of formative test instruments based on Problem-Based Learning (PBL) in this study represents a systematic and structured effort to improve students' conceptual understanding in science learning, particularly in the topic of the human circulatory system. This process follows a modified Borg and Gall development model consisting of several stages, including preliminary research, planning, initial product development, expert validation, product testing, revision, and final product formulation. At the initial stage, a needs analysis revealed that existing assessment instruments in the classroom were still dominated by conventional approaches that emphasize rote memorization rather than conceptual understanding, indicating a mismatch between traditional practices and modern educational demands. From a theoretical perspective, this finding aligns with constructivist learning theory, which emphasizes that meaningful learning occurs when students actively construct knowledge through interaction with their environment and through problem-solving activities (Septiana & Hermanto, 2024)

Therefore, integrating PBL into assessment instruments is conceptually justified, as it encourages critical thinking, inquiry, and application of knowledge. During the planning stage, a test blueprint was developed based on competency standards, learning indicators, and cognitive levels derived from Bloom's taxonomy, focusing on higher-order thinking skills such as application, analysis, and evaluation. The instrument consisted of multiple-choice questions designed with contextual problem scenarios, which is a defining characteristic of PBL. According to Barrows (1986), PBL promotes active learning by presenting authentic problems that stimulate inquiry and independent learning. In the development phase, each test item was carefully constructed to ensure alignment with learning objectives and to incorporate real-world relevance, thereby enhancing engagement and understanding. The validation process involved experts who evaluated the content, construct, and language aspects of the instrument, ensuring that it met academic and pedagogical standards, reflecting the principles of content validity as proposed by Lawshe (1975). From a formative assessment perspective (Black & Wiliam, 1998), this instrument

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not only measures learning outcomes but also supports the learning process by encouraging reflection and deeper understanding. Furthermore, the integration of PBL into assessment aligns with authentic assessment theory (Wiggins, 1990), which emphasizes the importance of tasks that mirror real-life challenges. The use of real-world problem scenarios encourages students to apply their knowledge in practical contexts, thereby bridging the gap between theory and practice. In addition, the structured design based on Bloom's taxonomy ensures that the instrument captures a range of cognitive skills, providing a comprehensive evaluation of student learning. Overall, the development of this instrument reflects a shift toward innovative, student-centered assessment practices that are both theoretically grounded and practically relevant(Dewi & Mercuriani, 2024).

Instrument Validity

Instrument validity is a fundamental aspect of educational assessment, as it determines whether an instrument accurately measures the intended construct. In this study, the validity of the PBL-based formative test instrument was established through a combination of expert judgment and statistical analysis. Content validity was ensured by involving subject matter experts who evaluated the relevance and alignment of test items with curriculum standards and learning objectives, consistent with the framework proposed by Lawshe (1975). Construct validity was further examined using Confirmatory Factor Analysis (CFA), which assesses the relationship between observed variables and latent constructs. The results indicate that the instrument demonstrates a good model fit, as evidenced by fit indices such as the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Incremental Fit Index (IFI), which exceed recommended thresholds, while error indices such as RMSEA and SRMR fall within acceptable ranges. These findings align with modern measurement theory, which emphasizes the importance of structural validity in ensuring that an instrument accurately reflects the theoretical construct it is intended to measure(Dewanti, 2024).

The integration of PBL-based items further enhances construct validity, as such items are designed to capture complex cognitive processes such as problem-solving, reasoning, and critical thinking. From a psychometric perspective, validity is not a single property but a collection of evidence supporting the interpretation of test scores, and therefore the use of multiple validation methods strengthens the credibility of the instrument. Additionally, the use of authentic problem scenarios aligns with authentic assessment theory (Wiggins, 1990), which emphasizes the need for assessment tasks that reflect real-world applications. The discussion also highlights that validity is an ongoing process that requires continuous refinement and evaluation as educational

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contexts evolve. The findings suggest that PBL-based assessment provides a more accurate representation of students' conceptual understanding compared to traditional methods, particularly in measuring higher-order thinking skills. Overall, the validity analysis demonstrates that the instrument is both theoretically and empirically sound, making it a robust tool for educational assessment(Khoiriyah & Roberts, 2025).

Instrument Reliability

Reliability refers to the consistency and stability of an instrument in measuring a construct, and in this study, the PBL-based formative test instrument demonstrates a high level of internal consistency. From the perspective of classical test theory, reliability is defined as the proportion of true score variance relative to total score variance, and a high reliability coefficient indicates that measurement error is minimized. The high reliability observed in this study suggests that the instrument produces consistent results across different administrations, making it a dependable tool for assessing students' conceptual understanding. The use of PBL-based items does not compromise reliability; instead, it enhances the coherence of the instrument by ensuring that all items are grounded in meaningful problem-solving contexts. This finding supports the argument that innovative assessment approaches can maintain strong psychometric properties while improving educational relevance. The consistency of the instrument may be attributed to several factors, including clear item construction, alignment with learning objectives, and balanced levels of difficulty, all of which are known to contribute to reliability. From a theoretical perspective, these factors reduce ambiguity and ensure that each item measures the same underlying construct(Hayati et al., 2020).

Furthermore, the integration of real-world problem scenarios creates a uniform structure across the instrument, reducing variability caused by differences in item format. This aligns with authentic assessment principles, which emphasize meaningful and context-based tasks. The discussion also highlights that reliability is a prerequisite for validity, as an instrument must produce consistent results in order to accurately measure a construct. Additionally, the inclusion of higher-order thinking skills does not reduce reliability, provided that items are well-designed and aligned with the construct being measured. This challenges the assumption that complex cognitive tasks are inherently less reliable. Overall, the reliability analysis confirms that the instrument meets the standards of educational measurement and can be used confidently in assessing student learning outcomes(Damayanti & Yohandri, 2022).

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Effectiveness of the Instrument

The effectiveness of the PBL-based formative test instrument is reflected in its ability to enhance students' conceptual understanding and support meaningful learning. The use of contextual problem scenarios encourages students to engage actively with the material, promoting deeper learning and critical thinking. This finding is consistent with constructivist learning theory, which emphasizes that knowledge is actively constructed through interaction with meaningful tasks and experiences(Martaningsih et al., 2022). The instrument not only serves as a measurement tool but also functions as a learning tool, aligning with formative assessment theory (Black & Wiliam, 1998), which highlights the role of assessment in providing feedback that guides learning. The integration of PBL into assessment allows students to apply their knowledge in real-life contexts, thereby improving their ability to analyze, evaluate, and solve problems. From the perspective of Bloom's taxonomy, the instrument successfully targets higher-order cognitive skills, which are essential for meaningful learning(Ramadani et al., 2024).

Additionally, the authenticity of the tasks enhances student motivation, as suggested by self-determination theory (Deci & Ryan, 1985), which emphasizes the importance of relevance and autonomy in learning. The discussion also highlights the role of feedback in supporting student learning, as the instrument provides opportunities for reflection and self-assessment. This contributes to the development of metacognitive skills, which are essential for lifelong learning. Furthermore, the alignment between assessment, instruction, and learning objectives creates a coherent learning environment that supports student success. The use of authentic tasks also helps bridge the gap between theoretical knowledge and practical application, preparing students for real-world challenges. Overall, the effectiveness of the instrument demonstrates its potential as a valuable tool for improving both cognitive and affective aspects of learning(Sari et al., 2025).

Limitations of the Study

Despite the positive outcomes, this study has several limitations that should be acknowledged. One limitation is the relatively limited scope of the study, which focuses on a specific topic within science education, potentially affecting the generalizability of the findings to other subjects or contexts. From a methodological perspective, the study primarily relies on quantitative approaches, which may not fully capture the complexity of student learning experiences. Theoretical perspectives on research methodology suggest that mixed-methods approaches can provide a more comprehensive understanding by integrating quantitative and qualitative data(Ssemugenyi, 2023). Additionally, external factors such as students' prior

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knowledge, motivation, and learning environment may influence the results, and these variables are not fully controlled in this study. Another limitation is the practical challenge of implementing PBL-based assessment in classroom settings, as it requires careful planning, time, and teacher readiness. From an educational change perspective, the successful implementation of innovative approaches often depends on teacher training and institutional support. Furthermore, the instrument is developed within a specific educational context, which may limit its applicability in different cultural or institutional settings. Despite these limitations, the study provides valuable insights into the development and application of PBL-based assessment and highlights areas for future research and improvement(Pradipta et al., 2025).

Implications of the Study

The findings of this study have important implications for educational practice, research, and policy. For educators, the results suggest that integrating PBL into assessment can significantly enhance students' conceptual understanding and engagement, aligning with student-centered learning theory, which emphasizes active participation and meaningful learning experiences. The use of authentic, problem-based tasks encourages students to develop critical thinking and problem-solving skills, which are essential for the 21st century. For researchers, this study provides a framework for developing and validating assessment instruments that are both theoretically grounded and empirically tested, contributing to the advancement of educational measurement. The findings also highlight the need for further research on the implementation of PBL-based assessment in diverse contexts and subject areas. From a policy perspective, the study supports the adoption of competency-based curricula that prioritize higher-order thinking skills and authentic assessment practices. Educational policies should encourage the integration of innovative assessment methods that align with modern learning objectives. Additionally, professional development programs for teachers should focus on equipping educators with the skills needed to design and implement PBL-based assessments effectively. Overall, the implications of this study underscore the importance of aligning assessment practices with contemporary educational theories and preparing students for real-world challenges through meaningful and relevant learning experiences

CONCLUSION

Based on the results and discussion of this study, it can be concluded that the development of a Problem-Based Learning (PBL)-based formative test instrument to measure students'

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conceptual understanding in science at SMP Negeri 2 Taliabu Selatan was carried out systematically through seven modified stages of the Borg and Gall model, resulting in a 15-item multiple-choice instrument designed using PBL principles on the topic of the human circulatory system. The instrument demonstrated very high validity, as evidenced by Aiken's V index indicating that all items were categorized as highly valid, and further supported by Confirmatory Factor Analysis (CFA) results showing excellent model fit with CFI and TLI values of 0.997 and RMSEA and SRMR values well below the acceptable thresholds, confirming strong construct validity. Although the reliability analysis using Cronbach's Alpha yielded a value of 0.486, indicating low to moderate reliability likely influenced by the limited number of dichotomous items, the instrument remains acceptable due to its strong validity. In terms of practicality, both teachers and students rated the instrument very highly, indicating that it is easy to use, clearly structured, and suitable for classroom implementation. Furthermore, the instrument proved to be effective in supporting the assessment of students' conceptual understanding and increasing student engagement in learning. Therefore, it can be concluded that the developed PBL-based formative test instrument is valid, practical, and effective, making it appropriate for use in evaluating students' science conceptual understanding..

FUTURE DIRECTIONS

Future research should focus on expanding and refining the Problem-Based Learning (PBL)-based formative test instrument by increasing the number of test items to improve reliability and by applying the instrument across a wider range of science topics and educational contexts to enhance its generalizability. Further studies are also recommended to incorporate mixed-methods approaches, combining quantitative analysis with qualitative data such as interviews or classroom observations to gain deeper insights into students' conceptual understanding and learning processes. In addition, future research could explore the integration of digital or computer-based assessment platforms to support more interactive and adaptive PBL assessments. Investigating the long-term impact of PBL-based formative assessment on students' critical thinking, problem-solving skills, and academic achievement would also provide valuable contributions to educational practice. Moreover, professional development programs for teachers should be examined to ensure effective implementation of PBL-based assessment in classrooms. Overall, these directions are expected to strengthen the quality, applicability, and impact of PBL-based assessment instruments in science education.

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