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Preliminary Study: Renewable Bionergy Based On Problem Based Learning as a Recommended Media to Improve Students' Critical Thinking Skills

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ABSTRACT

Penelitian ini bertujuan untuk mengidentifikasi kebutuhan media pembelajaran berbasis Pembelajaran Berbasis Masalah (PBL) pada topik bioenergi terbarukan dan mengevaluasi efektivitasnya dalam meningkatkan kemampuan berpikir kritis siswa. Dengan menggunakan pendekatan kuantitatif deskriptif, penelitian ini menggunakan instrumen tes berdasarkan indikator berpikir kritis Facione yaitu interpretasi, analisis, inferensi, dan evaluasi serta mengumpulkan data melalui pretes dan postes yang diberikan kepada 36 siswa di SMAN 7 Surabaya. Temuan penelitian menunjukkan peningkatan skor rata-rata dari 2,06 menjadi 3,64 setelah intervensi pembelajaran, dengan sebagian besar siswa mencapai kategori kinerja "baik" dan "sangat baik". Media pembelajaran yang terintegrasi dengan baik, termasuk modul pengajaran, lembar kerja siswa (LKPD), simulasi virtual PhET, dan presentasi PowerPoint, terbukti efektif dalam mendukung implementasi PBL yang kontekstual dan berdampak. Hasil ini menggarisbawahi potensi media PBL bertema bioenergi terbarukan sebagai alat inovatif untuk meningkatkan keterampilan berpikir kritis siswa sekaligus menumbuhkan literasi sains dan kesadaran lingkungan.

This study aims to identify the need for Problem-Based Learning (PBL) based instructional media on the topic of renewable bioenergy and evaluate its effectiveness in enhancing students' critical thinking abilities. Using a descriptive quantitative approach, the study employed test instruments based on Facione's critical thinking indicators interpretation, analysis, inference, and evaluation and collected data through pretests and posttests administered to 36 students at SMAN 7 Surabaya. The findings revealed an increase in average scores from 2.06 to 3.64 after the learning intervention, with most students reaching the "good" and "very good" performance categories. Properly integrated learning media, including teaching modules, student worksheets (LKPD), PhET virtual simulations, and PowerPoint presentations, proved effective in supporting contextual and impactful PBL implementation. These results underscore the potential of renewable bioenergy themed PBL media as an innovative tool for promoting students' critical thinking skills while also fostering scientific literacy and environmental awareness.

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INTRODUCTION

Critical thinking represents one of the most essential competencies required in the 21st century, especially within the educational context that aims to prepare students for complex, real world

challenges. In recent years, global educational reform has increasingly emphasized the importance of equipping learners with the ability to analyze information, reflect deeply, evaluate arguments, and make reasoned decisions. Despite this growing emphasis, the implementation of critical thinking in many school environments remains limited and inconsistent, particularly at the secondary education level. Many schools and educators still rely heavily on conventional instructional practices that prioritize content delivery and rote memorization. As a result, students often develop passive learning habits and demonstrate limited engagement in activities that demand deeper cognitive skills (Zakaria & Sunarti, 2025).

Educational institutions that implement teacher centered instruction tend to place the teacher at the core of knowledge transmission, with students playing a relatively passive role in receiving and recalling information. In such classrooms, students are rarely challenged to question, analyze, or interpret learning materials beyond surface level understanding (Gupta et al., 2015). This type of learning environment restricts students' opportunities to practice critical thinking, thereby limiting their development of higher order cognitive skills such as reasoning, argumentation, and problem solving. The dominance of this approach presents a substantial gap between the intended outcomes of 21st century education and the realities of classroom practice (Habibbulloh et al., 2024).

The absence of critical thinking development in schools is not solely due to instructional methods, but also stems from the lack of appropriate and engaging learning media. Instructional materials commonly used in schools are often didactic, one directional, and overly procedural, leaving little space for inquiry or student initiated exploration. For example, textbooks are typically structured to provide fixed information and answers, while worksheets may guide students through step by step activities that do not require them to think independently or evaluate different possibilities. Without media that provoke questioning, debate, and reflective analysis, students are unlikely to develop the critical habits of mind that modern education seeks to instill (Hasyim et al., 2024). Another major factor contributing to the limited cultivation of critical thinking in schools is the insufficient integration of contextually meaningful learning strategies. Many teachers are not yet familiar with or do not fully implementcontext based models such as Problem Based Learning. This approach, which places students at the center of authentic and complex problem solving, encourages learners to collaborate, investigate, and construct knowledge through exploration. Problem Based Learning creates an environment in which students engage in meaningful learning experiences that mirror real life challenges, thereby strengthening their ability to apply reasoning skills in practical situations (Zakaria et al., 2023).

In Problem Based Learning, students are presented with open ended problems that do not have a single correct answer. They must work together to identify what they know, what they need to learn, and how to access relevant resources. This process requires students to develop a deeper understanding of content while simultaneously practicing skills such as critical analysis, hypothesis generation, evaluation of evidence, and justification of solutions. However, when media used in the classroom are not aligned with this model, its potential to foster critical thinking is significantly diminished. The effectiveness of Problem Based Learning depends heavily on the use of supportive and relevant media that facilitate inquiry and encourage active engagement (Maharani & Huda, 2022; Susanti & Arifin, 2023).

Inappropriate or poorly designed instructional media can cause several challenges in the learning process. One significant issue is the difficulty students face in responding to complex problems with analytical and reflective thinking. Materials that are not designed to stimulate critical engagement, such as overly simplified tasks or generic learning modules, fail to provide the cognitive challenge necessary for critical thinking development. This leads to difficulties in identifying central issues, constructing multiple perspectives, proposing alternative solutions, and evaluating the consequences of different choices. These are all essential processes in the development of critical thinking and should be central features of the learning experience (Triyono et al., 2020).

The use of irrelevant media also negatively affects students' learning motivation and interest. Media that do not reflect students' real life experiences or that are disconnected from social and environmental issues can make learning feel abstract and meaningless. In contrast, when learning media are contextualized and relatable, students are more likely to engage deeply and take ownership of their learning process. Moreover, media should facilitate collaboration and meaningful interaction among

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students, allowing them to develop social and communicative competencies alongside cognitive skills. In this way, learning becomes both intellectually stimulating and socially relevant (Balulu, 2022).

The urgency of this issue is heightened by the rapid development of science and technology, which requires students to be not only knowledgeable but also capable of thinking independently and responsibly. Developing these competencies requires a fundamental shift in both instructional strategies and the materials used to support them. Teachers must be empowered through professional development, access to resources, and support systems that enable them to implement student centered and problem oriented learning approaches. Meanwhile, schools must invest in the design and application of innovative learning media that align with educational goals and students' developmental needs (Verawati & Hikmawati, 2021).

The topic of renewable bioenergy offers a promising avenue for addressing this challenge. As a subject that intersects science, technology, environment, and society, renewable bioenergy presents real world problems that are both complex and relevant to students' lives. Teaching this topic through Problem Based Learning provides opportunities for students to engage with authentic issues such as sustainability, energy sources, environmental protection, and ethical decision making (Yuanata et al., 2023). These issues are not only scientifically significant but also demand critical thinking, collaboration, and interdisciplinary exploration. Instructional media that center on renewable bioenergy should be designed to challenge students' understanding, encourage open inquiry, and support structured reflection. These media may include interactive modules, simulation tools, guided worksheets, virtual experiments, and collaborative tasks that encourage students to investigate problems, test ideas, and present reasoned arguments. The integration of such media into Problem Based Learning can help bridge the gap between curriculum content and the competencies students need to thrive in the modern world (Maknun, 2020).

This study responds to the need for more effective instructional strategies and materials by exploring the development and use of media that support critical thinking within the framework of Problem Based Learning (Abror & Nabillah, 2025). The focus is specifically on the topic of renewable bioenergy, chosen for its contextual relevance and potential to foster both scientific literacy and environmental awareness. The research aims to identify the characteristics of effective media for supporting critical thinking, analyze how students respond to such media in the learning process, and evaluate the extent to which these materials contribute to meaningful and systematic improvement in students' critical thinking abilities. By addressing these dimensions, the study contributes to ongoing efforts to transform education into a more engaging, reflective, and future oriented practice. Developing students' critical thinking is not merely an academic goal but a social imperative in preparing young people to become responsible, informed, and capable citizens. The integration of context rich topics like renewable bioenergy with student centered learning approaches offers a powerful strategy for achieving this vision. The findings of this study are expected to inform educators, curriculum developers, and policymakers on how to effectively design and implement learning experiences that truly empower students to think critically and act responsibly in the face of global challenges.

METHODS

The School Field Introduction Program (Pengenalan Lapangan Persekolahan or PLP) was carried out from February 12, 2025, to June 11, 2025, at SMAN 7 Surabaya. This program, which can be converted into academic credits, is designed to provide students with authentic, hands-on teaching experience. Through participation in PLP, students are expected to familiarize themselves with the school environment, develop a strong work ethic, gain deeper insights into high professional standards, and cultivate a culture of excellence within the teaching profession (Hayati & Nuriyah, 2023). In line with this context, the present study adopts a quantitative descriptive research design. Quantitative research is grounded in the philosophy of positivism and is recognized as a scientific method due to its adherence to empirical, objective, measurable, rational, and systematic principles. The approach focuses on the analysis of numerical data, which is then processed using appropriate statistical techniques to draw meaningful insights (Muharom & Zaini, 2021). Specifically, descriptive quantitative analysis serves to present, illustrate, and summarize data in a structured and informative way. This method uses statistical tools to help identify patterns and tendencies within a given data set. However, because quantitative data often presents absolute figures without explaining the underlying causes or

motivations, inferential analysis is sometimes required to gain a more comprehensive understanding. By utilizing descriptive statistics, researchers are better equipped to examine the basic characteristics of the data and make more accurate conclusions about the phenomena being observed (Suwarno, 2024).

Figure 1. Research Flow

The technique used in data collection is adapted to the type of research being conducted. Data analysis is carried out based on the results gathered from the instruments applied during the research process. In this study, two types of research instruments are employed to support the collection of accurate and relevant data. These instruments are selected to ensure that the data obtained aligns with the research objectives and enables a comprehensive analysis of the variables under investigation.

Table 1. Research Instrument

No	Instrument Type	Measurement Indicators	Analysis Techniques
1	Test Instrument	Critical Thinking Skills	Descriptive Statistics and Indicator Analysis
2	Questionnaire Instrument	Responses and Recommendations for Learning Media	Likert Scale Analysis and Indicator Analysis

The critical thinking assessment in this study is based on a framework that emphasizes four main indicators, namely interpretation, analysis, inference, and evaluation. These indicators were selected to align with a validated model that focuses on essential components of critical thinking skills relevant to the research context. Each of these indicators plays a specific role in measuring students' ability to understand information, break down concepts, draw logical conclusions, and assess the validity of arguments (Facione, 2013). The instrument and assessment tools used in this study were developed specifically to capture students' performance in these four domains, providing a comprehensive profile of their critical thinking abilities. The following section outlines the specific aspects evaluated under each indicator,

Table 2. Critical Thinking Skills Indicators

Indicators	Critical Thinking Sub Skills
Interpretation	1. Classifying data or opinions 2. Restating data in different expressions accompanied by real examples
Analysis	1. Identifying problems 2. Providing opinions and supporting reasons
Evaluation	1. Determine the truth of a statement based on what is known. 2. Assess the relevance of arguments to the situation at hand.
Inference	1. Assess information to determine the logic of an opinion. 2. Draw conclusions to confirm or reject a hypothesis based on relevant data

RESULTS AND DISCUSSION

The results and discussion in this study were obtained based on the results of Critical Thinking skills tests and student responses. Based on the test instrument provided with 4 indicators of critical thinking skills against 5 questions, the results of the student problem-solving skills profile were as follows,

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Table 3. Descriptive quantitative

N	Average	Median	Max Value	Min Value	Std. Error	Std. Dev
40	45.52	28	50	10	2.08	16.23
Average Score of Critical Thinking Skills			**Interpretation**	**Evaluate**	**Analysis**	**Inference**
			10.5	11.5	15.5	9.5

The results show that students' critical thinking skills are in an average score of 45.52, which is categorized as moderate. This result aligns with the standard deviation value of 16.23 presented in Table 3, indicating a moderate spread of data from the mean. The standard error of 2.08 also suggests that the sample mean is a reliable estimate of the population mean. Meanwhile, the median score is 28, with the highest score recorded at 50 and the lowest at 10, reflecting a wide range of student performance (Mutakinati et al., 2018; Puspita et al., 2024).

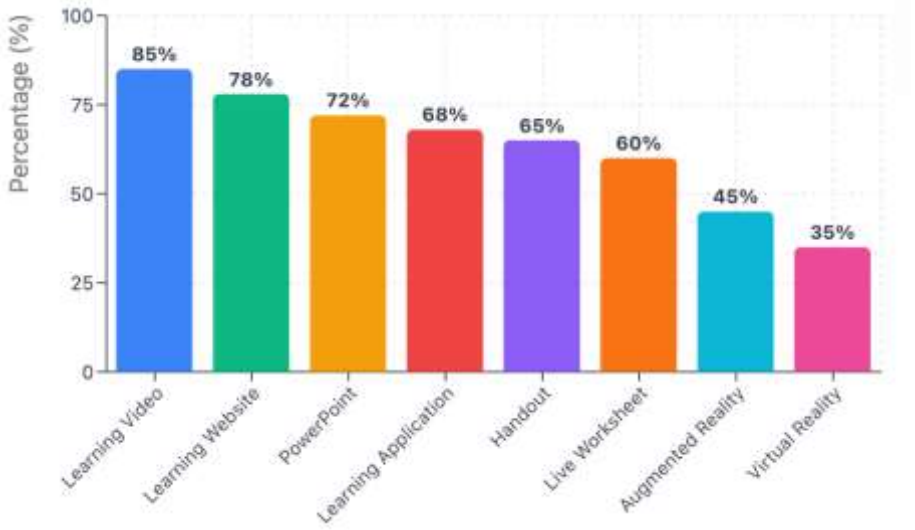

Figure 2. Student Learning Method Preferences

Learning media play a pivotal role in the implementation of Problem-Based Learning (PBL), particularly in developing students' critical thinking skills such as interpretation, evaluation, analysis, and inference. Learning videos, websites, and PowerPoint presentations are among the most recommended media because they align well with the stages of PBL and are highly preferred by students. Learning videos enable students to interpret problems through rich visual contexts and effectively trigger initial group discussions (Putri et al., 2024). Learning websites provide access to diverse information sources, enhancing students' ability to evaluate data and draw logical inferences. PowerPoint presentations support the systematic delivery of content, facilitating the interpretation and analysis of complex concepts during problem exploration. Learning applications and live worksheets offer interactive platforms that support student engagement through exercises and formative assessments, particularly in the evaluation and analysis stages. Handouts serve as supplementary materials that aid in interpretation and inference, though they are relatively static compared to digital media. Augmented reality (AR) and virtual reality (VR) provide immersive, simulation-based experiences that can significantly enrich analytical and inferential thinking. However, their current use is limited due to infrastructure and technical expertise requirements (Saprudin et al., 2025). Educators should therefore align the selection of learning media with instructional objectives, technological readiness, and student characteristics to maximize the impact of PBL in cultivating critical thinking skills comprehensively.

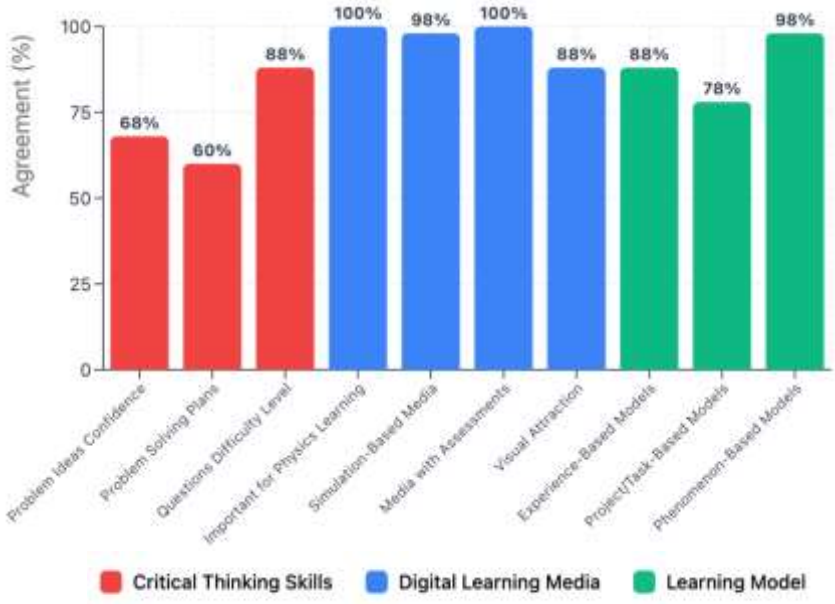

Figure 3. Learning Aspects Analysis

The analysis indicates strong student support for digital learning media, with consistently high agreement levels reflecting its perceived importance in modern physics instruction. Phenomenon-based learning emerges as the most preferred model, suggesting that students are more engaged when learning is rooted in real-world contexts. However, students' confidence in their critical thinking abilities varies, highlighting the need for scaffolding and targeted strategies within the learning process. The findings also underscore students' awareness of the role of digital integration in enhancing learning experiences, particularly when supported by embedded assessments, which are considered essential for measuring progress and understanding (Fitriani & Kurniawan, 2021).

The integration of digital learning media within the framework of Problem-Based Learning (PBL) has been widely acknowledged as relevant in contemporary science education. Various studies emphasize that digital tools, such as videos, simulations, and interactive applications, contribute significantly to the development of critical thinking skills. These media allow students to engage more deeply with real-world problems, enabling them to interpret information, evaluate evidence, analyze complex scenarios, and draw informed conclusions—core competencies in the 21st-century learning paradigm. In terms of state of the art, current research highlights the emergence of immersive technologies like Augmented Reality (AR) and Virtual Reality (VR) in educational contexts (Rahmawati & Prasetyo, 2022). These technologies are being explored for their potential to simulate authentic environments and experiences that traditional media cannot offer. Although promising, their implementation is still at a developmental stage, requiring substantial infrastructure and pedagogical adjustments (Susilawati & Nuraini, 2023). Simultaneously, blended or multi-modal approaches that combine traditional and digital formats are increasingly recognized for their effectiveness in addressing diverse student needs and learning styles. The novelty of this study lies in its specific linkage between students' preferences for digital media and the structured development of critical thinking indicators within a PBL setting. Unlike prior research that often treats media effectiveness in isolation, this work offers a pedagogically grounded rationale for selecting and sequencing media types according to the stages of critical thinking. Such alignment not only enriches the PBL process but also provides a practical model for instructional design that responds directly to student engagement patterns and learning objectives (Bagci et al., 2025).

CONCLUSION

This study reveals that students' critical thinking skills are at a moderate level, with analysis being the most dominant indicator, followed by evaluation, interpretation, and inference. Digital learning media such as videos, websites, and PowerPoint are highly effective in supporting different stages of

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critical thinking within the Problem Based Learning model. Students show a strong preference for phenomenon-based learning and emphasize the importance of media that include integrated assessments. While immersive technologies like Augmented Reality and Virtual Reality have potential to enhance learning, their implementation is still limited. The alignment between media preferences and critical thinking development offers a strategic direction for designing engaging and effective science learning environments.

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