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Enhancing Students' Scientific Reasoning Skills in Renewable Energy Through Problem-Based Learning and Integrated Worksheets

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Abstract
This study evaluates the pedagogical effectiveness of integrating Problem-Based Learning (PBL) with structured student worksheets to enhance scientific reasoning skills. The primary objective is to address the global demand for sustainability education by focusing on renewable energy topics for junior high school students. The research employs a developmental model to design and evaluate a dual-learning approach through field trials and pre-experimental assessments. Findings indicate that the synergy of PBL and structured worksheets significantly improves students' capacity to analyze scientific data, construct evidence-based arguments, and verify complex assumptions. Students demonstrated a heightened ability to apply scientific knowledge to real-world energy challenges, making the learning process more relevant and engaging. The novelty of this research lies in its dual-approach framework, which systematically scaffolds reasoning processes while aligning with educational goals for sustainable development. This study concludes that while this integration provides a robust practical framework for science education, its success depends heavily on comprehensive teacher preparation in inquiry-based methodologies.

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INTRODUCTION

In the era of the Fourth Industrial Revolution, scientific reasoning has emerged as a critical skill for students to navigate the complex challenges of the 21st century. The ability to engage in structured reasoning and critical thinking is not only fundamental to academic success but also vital in fostering students' capacity to understand and address real-world problems (Tashtoush et al., 2022). Reasoning skills are especially important in scientific fields, where students must not only memorize facts but also synthesize information and apply it to new and unfamiliar contexts (Tambunan, 2019). Studies by Thuneberg et al. (2018)and Ishizuka et al. (2023) emphasize that reasoning ability plays a crucial role in enabling students to critically assess evidence, formulate hypotheses, and draw conclusions—skills that are necessary to thrive in both academic and professional domains.

In Indonesia, scientific reasoning has become increasingly recognized as a core competency within the framework of Education for Sustainable Development (ESD) (Dwita Dana Pradipta et al., 2021). ESD, as defined by UNESCO, is an approach to education that equips students with the knowledge, skills, attitudes, and values necessary to shape a sustainable future (Handtke et al., 2022). As Indonesia works toward achieving the Sustainable Development Goals (SDGs), integrating ESD into the national curriculum has become a priority. Scholars such as Misrom et al. (2020) highlight the importance of fostering scientific literacy, reasoning, and problem-solving skills to empower students to contribute to environmental sustainability, economic development, and social equity. One of the key ways to achieve this is by enhancing students' reasoning abilities, particularly through innovative educational models like Problem-Based Learning (PBL).

Problem-Based Learning (PBL) has been widely adopted in educational systems worldwide as an effective method for enhancing critical thinking and reasoning skills. Research by Schaffar & Wolff (2024) demonstrates that PBL encourages active student engagement, self-directed learning, and collaborative problem-solving, all of which contribute to the development of reasoning abilities. In PBL environments, students are presented with real-world problems that require them to apply interdisciplinary knowledge and think critically to find solutions (Wong et al., 2021). This pedagogical approach aligns well with the goals of ESD, as it empowers students to engage with complex issues, such as renewable energy, climate change, and sustainability, through a reasoning-based, inquiry-driven process.

Renewable energy education is particularly relevant in Indonesia, given the country's commitment to transitioning to sustainable energy sources (Rahmanniar et al., 2024). As Indonesia faces growing environmental challenges, the need to educate students about renewable energy has never been more urgent (Nurika et al., 2024). By integrating PBL with student worksheets (Lembar Kerja Peserta Didik or LKPD), educators can provide structured yet flexible learning experiences that foster scientific reasoning in the context of renewable energy topics. LKPD serves as a valuable tool to guide students through the inquiry process, helping them to organize their thoughts, analyze data, and develop well-reasoned conclusions. Research by Wardah et al. (2022) supports the effectiveness of combining PBL with LKPD in enhancing students' cognitive abilities and reasoning skills, particularly when addressing sustainability issues such as renewable energy.

The primary problem addressed in this research is the weak reasoning ability among junior high school students in Indonesia, a concern that has been highlighted in numerous international assessments (Harris & de Bruin, 2018). Studies conducted by organizations such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) consistently show that Indonesian students underperform in critical areas of reasoning, particularly in science and mathematics (Tashtoush et al., 2022). According to the most recent PISA report, Indonesian students ranked in the lower tier globally in terms of their ability to apply knowledge in real-world scenarios and demonstrate scientific reasoning (Septaria & Dewanti, 2021). This performance gap underscores a broader issue: the existing educational approaches do not adequately develop students' capacity to think critically, solve complex problems, and apply interdisciplinary knowledge.

The weak reasoning ability observed in Indonesian students is problematic because it hampers their ability to engage with more advanced topics, such as renewable energy and sustainability, which require strong analytical and problem-solving skills. Research by Xiao & Liu (2023) emphasizes that students who lack reasoning abilities are less likely to succeed in scientific fields or to become active participants in addressing global challenges like climate change and energy transitions. Without adequate reasoning skills, students struggle to make informed decisions based on evidence, interpret data accurately, and engage in higher-order thinking processes (Pérez-Perdomo & Zabalegui, 2024). This deficiency becomes particularly concerning

as Indonesia moves toward implementing Education for Sustainable Development (ESD), where scientific reasoning is essential to fostering sustainable practices and innovation.

To address this issue, one promising solution is the integration of Problem-Based Learning (PBL) and student worksheets into the educational framework (Wan et al., 2022). PBL has been shown to significantly improve students' reasoning skills by immersing them in real-world problems that require critical thinking and collaborative problem-solving (Pinilla, 2024; Powell & Meyers, 2021). When combined with a worksheet, which provides structured guidance and allows students to organize their thoughts systematically, the dual approach enhances cognitive engagement and facilitates deeper learning (Caesaria et al., 2023; Widyastuti & Utami, 2018). This approach not only helps students improve their reasoning skills but also prepares them to tackle complex issues in renewable energy education, which is crucial for the sustainable development of Indonesia.

A preliminary study was conducted at State Junior High School 1 Maduran, located in Lamongan, East Java, to assess the current state of science learning, particularly in relation to students' reasoning abilities and the integration of renewable energy topics. The study involved a series of interviews with science teachers, students, and school administrators, as well as direct classroom observations. The aim was to gather insights into the teaching methods being used, the challenges faced in developing students' reasoning skills, and the extent to which renewable energy education had been incorporated into the curriculum. The preliminary findings highlighted significant gaps in both the teaching approach and the students' ability to engage in higher-order reasoning.

The interviews conducted with the science teachers revealed that while the curriculum emphasizes critical thinking and problem-solving, there is a lack of practical tools and methods to effectively develop these skills. Teachers expressed difficulties in fostering reasoning among students, citing the heavy reliance on traditional lecture-based methods and rote memorization. The majority of teachers noted that students struggled with understanding complex scientific concepts, such as renewable energy, due to limited exposure to hands-on, inquiry-based learning experiences. Additionally, teachers acknowledged the need for more engaging teaching strategies, such as PBL, but noted that they lacked sufficient training or resources to implement these approaches effectively.

Observations of classroom activities confirmed that students had minimal opportunities to practice reasoning and critical thinking skills. Most lessons were focused on the delivery of factual content, with few interactive or problem-solving activities that would encourage students to apply their knowledge in real-world contexts. Students were often passive recipients of information, which limited their ability to develop essential reasoning skills. Furthermore, while renewable energy was included in the curriculum, it was treated as a supplementary topic and was not integrated into core problem-solving exercises. This lack of integration, combined with the absence of active learning methodologies like PBL, meant that students were not able to fully engage with the material in a meaningful way.

The results of this preliminary study clearly demonstrate the need for more effective teaching methods that can bridge the gap between content delivery and the development of reasoning skills. The findings highlight the importance of adopting a dual approach that combines PBL with student worksheets to create a more interactive and inquiry-driven learning environment. Such an approach would not only enhance students' reasoning abilities but also better prepare them to tackle real-world issues, such as renewable energy, in line with the goals of Education for Sustainable Development (ESD). Given the current limitations observed in both teaching methods and student engagement, it is evident that further research is needed to explore the effectiveness of this dual approach in fostering reasoning skills among junior high school students in Indonesia.

Several studies have explored the relationship between PBL and the development of reasoning skills in science education, yet gaps remain, particularly in the context of integrating renewable energy topics in Indonesian junior high schools. For example, Indriani et al. (2021)found that PBL is effective in enhancing critical thinking and reasoning skills among students; however, the study focused on general scientific concepts without addressing the specific challenges of renewable energy education. Similarly, research by Anggereini* et al. (2023) emphasized the benefits of PBL in fostering problem-solving abilities, but their work lacked a focus on the use of structured student worksheets as a support tool, which is essential for guiding inquiry-based learning in less developed educational systems like Indonesia's. Another relevant study by Rahmanniar et al. (2024) examined the role of worksheets in improving cognitive engagement but did not assess their combined effect with PBL in reasoning development, creating a gap that this research seeks to fill.

Moreover, a study by Hiğde (2022) highlighted the need for incorporating renewable energy topics into science education, showing that students have limited exposure to sustainability-related content. However, the research did not investigate the methods that could effectively enhance reasoning skills in such contexts. Furthermore, Ishizuka et al. (2023) conducted a study on PBL's impact on reasoning in Indonesian students, but their research was limited to general science subjects and did not explore the integration of renewable energy topics, which are increasingly critical for Indonesia's sustainable development agenda. These studies indicate that while there is substantial evidence supporting the benefits of PBL and worksheets in enhancing reasoning skills, there remains an urgent need to explore their combined impact in the context of renewable energy education. This research aims to address these gaps and offer insights into more effective educational practices for developing reasoning skills among junior high school students.

The novelty of this research lies in its dual approach, combining Problem-Based Learning (PBL) with student worksheets to specifically foster reasoning skills in renewable energy education—a topic of growing importance for sustainable development in Indonesia. While previous studies have explored PBL as a method to enhance critical thinking (Sukaisih et al., 2020; Wan et al., 2022; Wong et al., 2021), and others have investigated the role of worksheets in improving cognitive engagement (Apriani et al., 2021; Nurzaman et al., 2021), there has been no comprehensive research that examines the combined effects of PBL and worksheets on reasoning skills in the context of renewable energy. The integration of renewable energy content in this study adds a unique dimension that addresses both the cognitive and content-specific gaps left by earlier research, thus providing a new avenue for education in science and sustainability.

In addition, this research addresses specific gaps identified in studies such as those by Wan et al. (2022), which focused on the limited exposure students have to renewable energy topics, and Ishizuka et al. (2023), which explored PBL's impact on reasoning without considering the integration of specialized worksheets. The novelty of this study stems from its attempt to bridge these gaps by not only introducing renewable energy into the reasoning skill-building process but also by enhancing students' structured learning through the guided use of a worksheet. This dual-method approach is tailored to meet the needs of Indonesian junior high school students, who may struggle with unstructured problem-solving tasks without the proper scaffolding that the worksheet provides.

Furthermore, the scope of this research is broader than previous studies as it focuses on addressing reasoning skills development, specific to renewable energy education, within the context of Indonesia's secondary education system. By investigating how PBL combined with worksheets can foster reasoning, this study contributes to both the theoretical understanding of how structured learning can enhance critical thinking and to the practical need for more effective educational tools in the field of renewable energy. It fills a critical research gap by aligning the

educational focus on both cognitive development and sustainable content, which is currently lacking in the literature.

This research offers several important benefits, particularly for future students and science education as a whole. For students, the dual approach of PBL and worksheets not only strengthens reasoning skills but also equips them with the ability to engage more deeply with real-world problems, particularly in the field of renewable energy. As the global demand for sustainable practices increases, students who have been trained to think critically and reason through complex issues will be better prepared to contribute to future advancements in science, technology, and environmental stewardship (Schaffar & Wolff, 2024; Solarz et al., 2022). By developing reasoning skills specifically within the context of renewable energy, this research ensures that students are gaining relevant knowledge that will help them navigate the sustainability challenges of the future.

For stakeholders such as educators, policymakers, and curriculum developers, this research provides a valuable model for improving science education in Indonesia. It offers evidence-based insights into how PBL and worksheets can be effectively integrated into existing educational frameworks to promote deeper cognitive engagement and problem-solving abilities. The findings of this study can inform future curriculum revisions, teacher training programs, and educational policies aimed at enhancing both critical thinking and content-specific knowledge, particularly in the areas of science and sustainability.

METHODS

This study employs a Design and Development Research (DDR) framework, utilizing a Research and Development (R&D) approach to integrate both quantitative and qualitative data. This methodological choice aims to obtain a comprehensive understanding of how the synergy between Problem-Based Learning (PBL) and structured student worksheets impacts scientific reasoning skills in renewable energy education. The primary purpose of this research is twofold: to conduct a formative evaluation of the developed pedagogical tools and to perform intervention testing to assess their effectiveness in a real-world classroom setting. By adopting this design, the study ensures that the developed materials are not only theoretically sound but also practically viable for enhancing higher-order thinking skills.

The systematic development process follows the Borg & Gall model (Sari & Apriyantika, 2020; Sukmawati, 2022), which traditionally consists of ten rigorous stages: (1) research and information collecting; (2) planning; (3) development of the preliminary form of the product; (4) preliminary field testing; (5) main product revision; (6) main field testing; (7) operational product revision; (8) operational field testing; (9) final product revision; and (10) dissemination and implementation. In accordance with the scope of this educational intervention, this study intentionally concludes at the ninth stage (final product revision) and omits the tenth stage of mass production and commercial dissemination.

The rationale for this omission is deeply rooted in the research objectives, which prioritize pedagogical optimization over commercial viability. The study focuses on refining the teaching approach and materials within a specific educational context to ensure they meet the complex needs of junior high school students. By concluding at the ninth stage, the researcher emphasizes the iterative cycles of testing and revision required to produce a high-quality instructional tool that is scientifically validated. This focus allows for a more intensive evaluation of the intervention's impact on reasoning skills, ensuring that the final product is a refined pedagogical model ready for localized school adoption rather than a market-ready commercial product. This methodological boundaries ensure that the research remains concentrated on the effectiveness of the learning process and the achievement of specific cognitive outcomes.

To achieve the research objectives, this study implemented a rigorous iterative process of design, evaluation, and refinement to develop a high-quality PBL-based intervention and

integrated worksheet. This iterative cycle began with a comprehensive needs analysis at State Junior High School 1, Maduran, which specifically identified pedagogical gaps in fostering scientific reasoning within renewable energy topics. Following the data collection from teachers and students through structured interviews and curriculum reviews, the research team developed a preliminary version of the worksheet anchored in PBL principles. This initial product underwent an expert appraisal phase, where subject matter specialists provided qualitative feedback regarding content validity, linguistic clarity, and pedagogical alignment. The research team then utilized these feedback loops to execute systematic revisions before proceeding to the empirical testing phases.

The testing process was conducted through two distinct stages: a preliminary pilot trial and a main field trial, designed to facilitate continuous product improvement. In the small-group pilot trial, the researchers focused on identifying technical usability issues and initial student responses to the PBL syntax. Data from this stage, collected through observations and brief evaluative questionnaires, served as a formative basis for further refinement of the intervention materials. Subsequently, the revised product was implemented in a large-scale field trial to ascertain its pedagogical efficacy in improving students' reasoning abilities. This dual-layer testing ensured that every version of the instructional tool was empirically validated and progressively optimized based on actual classroom performance data.

The sampling strategy utilized in this study was purposeful sampling, a deliberate choice made to select participants who could provide the most significant data regarding the targeted intervention. Unlike random sampling, which seeks generalizability across a broad population, purposeful sampling allowed the researchers to focus on a specific cohort, the 7th-grade students at State Junior High School 1, Maduran, who were currently engaging with the foundational science curriculum relevant to renewable energy. This method was chosen to ensure that the intervention's effectiveness was tested on a group with the necessary prior knowledge and developmental readiness to engage in higher-order scientific reasoning.

Participants were selected based on three specific criteria: academic performance, diversity, gender representation, and consistency in school attendance. To ensure the robustness of the findings, the researchers categorized students into high, medium, and low academic achievement levels, ensuring that the PBL-worksheet approach was effective across varying cognitive baselines. Exclusion criteria were strictly applied to students with a history of high absenteeism or those who had not completed the preceding basic science modules, as their inclusion might have skewed the evaluation of the intervention's impact. The total sample was divided into two groups: a limited trial group consisting of 10 students for initial feasibility testing, and a main trial group of 24 students from class 7A for the evaluation of the final pedagogical model. The detailed distribution of the population and the specific sample utilized in this study are delineated in Table 1 below:

Table 1. Population and sample

Group	Total Population	Sample Size	Gender Distribution	Age Range	Social Background
7th Grade (All Students)	120	-	Mixed (Male/Female)	12-13 years	Varied (Urban/Rural)
Small Group Trial	120	10	5 Male, 5 Female	12-13 years	Varied
Large Group Trial (7A)	24	24	12 Male, 12 Female	12-13 years	Varied

The diversity of the research sample was meticulously managed through a stratified selection process to ensure a balanced representation of gender and varied socio-economic backgrounds. This balance was achieved by coordinating with school administrators to review student profiles, ensuring that no single demographic dominated the trial groups. The specific age range of 12–13 years (7th-grade students) is fundamentally relevant to the research objectives, as this period marks a critical cognitive transition from concrete to formal operational thinking.

At this developmental stage, students begin to cultivate the capacity for abstract reasoning and systematic problem-solving, making it the optimal phase for implementing inquiry-based interventions like PBL and worksheets to foster scientific reasoning.

Data collection followed the iterative Borg & Gall framework, emphasizing continuous feedback to refine the instructional tools. The primary instruments, consisting of interview protocols, observation checklists, and reasoning tests, underwent a rigorous expert validation process before implementation. Three senior experts in science education and pedagogical evaluation reviewed the instruments to ensure content and construct validity. Furthermore, a pilot test was conducted with a non-sample group to assess the reliability and readability of the items. The pre- and post-tests were specifically designed to measure four core indicators of scientific reasoning: (1) the ability to analyze scientific evidence, (2) the capacity to construct evidence-based arguments, (3) the skill to verify scientific assumptions, and (4) the ability to draw logical, data-driven conclusions within the context of renewable energy.

The pre- and post-tests utilized a series of open-ended essay questions to capture the depth of students' thought processes rather than simple factual recall. This quantitative measurement allowed the researchers to evaluate the magnitude of cognitive shift triggered by the PBL worksheet intervention. In addition to student performance data, qualitative feedback was systematically gathered from both teachers and students regarding the usability, clarity, and engagement level of the worksheet materials. This triangulation of data sources—combining objective test scores with subjective experiential feedback—provided a holistic view of the intervention's pedagogical effectiveness and practical utility in a real-world classroom setting.

Quantitative data analysis was performed using IBM SPSS Statistics software to ensure high precision in the results. Before the main analysis, a normality test (Shapiro-Wilk) was conducted to verify that the data followed a normal distribution. Subsequently, a Paired Sample t-test was employed to determine whether there was a statistically significant difference between the pre-test and post-test scores, thereby measuring the intervention's impact. To further quantify the effectiveness of the dual approach, the researchers calculated the Normalized Gain (N-gain) score, which provided a clear indicator of the improvement level in students' reasoning skills. This statistical rigor, supported by the methodological framework of Sudirman et al. (2020), ensures that the conclusions regarding cognitive development are empirically sound.

For the qualitative data, a systematic thematic analysis was conducted manually to maintain a deep contextual connection with the participants' responses. The analysis followed a multi-stage coding process: (1) familiarization with the interview transcripts and field notes, (2) generation of initial codes, (3) searching for overarching themes related to pedagogical challenges and successes, and (4) reviewing and defining the final themes. This manual coding allowed for a more nuanced interpretation of the classroom dynamics and the subtle ways in which students engaged with the PBL activities. By integrating these qualitative findings with the statistical results, the research offers a comprehensive evaluation of how the PBL-worksheet dual approach functions as a catalyst for reasoning development in the Indonesian secondary education context.

RESULTS AND DISCUSSION

Result

Product Development and Expert Validation

The development of the student worksheets was initiated to address the specific deficit in reasoning skills regarding renewable energy topics identified during the preliminary analysis. To ensure the instructional materials were scientifically robust and pedagogically appropriate, the initial design underwent a rigorous validation process involving three distinct experts: a material physicist, an instructional media specialist, and a linguist.

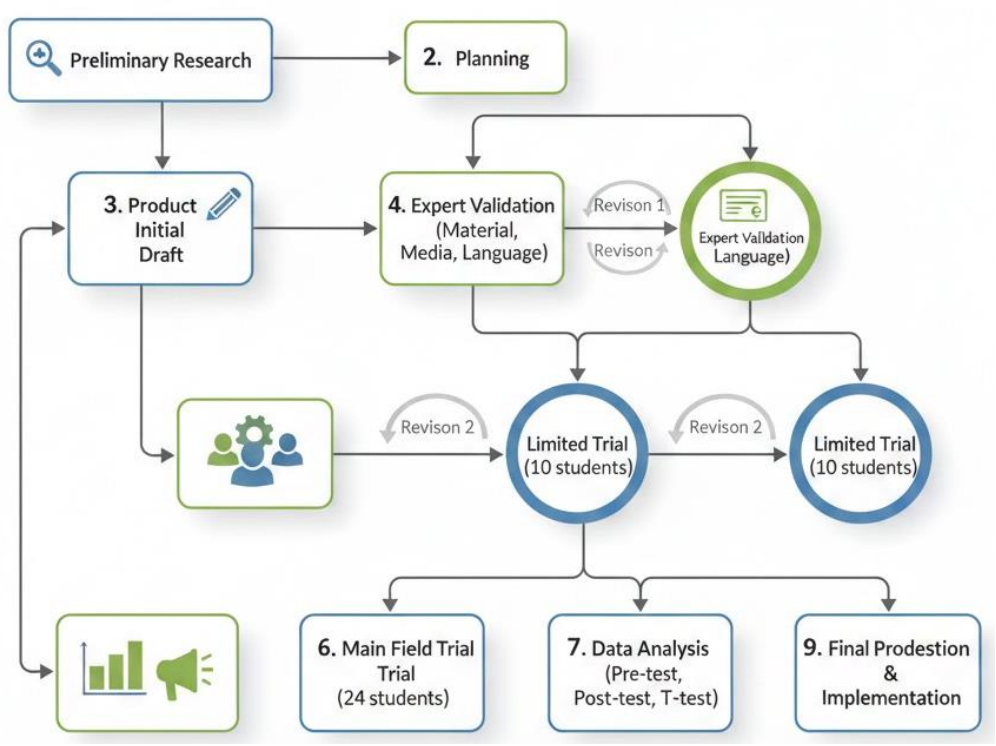


Figure 1. Development steps of the PBL-based worksheet (adapted from Borg & Gall)

This multi-faceted validation is crucial to ensure that the scaffolding provided by the worksheets effectively supports the inquiry-based nature of PBL (Indriani et al., 2021; Rahmanniar et al., 2024). The validation results, quantified in Table 2, demonstrate that the developed worksheet meets the criteria for high validity across all assessed domains.

Table 2. Validation results and suggestions from the worksheet validator

Validator	Aspect Assessed	Validation Score	Suggestions
Media Validator	Layout and Usability	85%	Improve visual clarity and provide more space for answers
Material Validator	Accuracy of Content	90%	Add more real-world examples related to renewable energy
Language Validator	Clarity and Simplicity	80%	Simplify complex terms and phrases for better comprehension

The material expert awarded the highest validity score (90%), confirming that the content accurately reflects current renewable energy challenges and aligns with the curriculum. However, qualitative feedback emphasized the need to bridge the gap between abstract theory and local context. In response, the material was revised to include specific case studies, such as the implementation of solar energy in rural Indonesian areas, thereby enhancing the relevance of the learning material. Simultaneously, the media validator (85%) and language validator (80%) provided constructive feedback focused on usability and accessibility. Following the language validator's suggestion to simplify technical jargon for the 7th-grade cognitive level, complex terms were adjusted; for instance, the instruction to "formulate hypotheses" was rephrased to "make a prediction" to ensure students could engage with the scientific process without linguistic barriers. Furthermore, layout adjustments were made to provide ample space for student responses, facilitating the structured cognitive engagement recommended by Sudirman et al. (2020). These revisions ensured the final product was not only valid but also user-friendly prior to classroom implementation.

Feasibility and Student Feedback

Following the expert validation and subsequent revisions, a limited field trial was conducted to assess the feasibility and practicality of the worksheet in a real classroom setting. This phase involved 10 students with varying academic abilities to ensure the tool was inclusive. The primary objective was to evaluate student engagement and the clarity of the problem-based tasks. The summary of student feedback is presented in Table 3.

Table 3. Results of suggestions and input from students at the trial stage 1

Student Feedback	Suggestion
Worksheets were easy to understand	Include more challenging problems
Tasks were interesting, but could be clearer	Add more examples in the instructions
Liked the real-world applications of energy	Provide more time to discuss with peers

The results indicate that while the students found the worksheets accessible, there was a demand for higher cognitive challenges. As detailed in Table 3, students appreciated the real-world application of energy topics but suggested the inclusion of more challenging problems and clearer instructions for complex tasks. This feedback aligns with the findings of Anggereini et al. (2023), who noted that students in PBL environments thrive when presented with challenging, authentic problems. Based on this input, significant refinements were made to the intervention. The results indicate that students specifically requested more time for collaboration. Consequently, the worksheet was restructured to include dedicated sections for peer discussion and reflection. This modification was intended to foster collaborative reasoning, allowing students to verbally articulate their arguments before committing them to paper. Additionally, the complexity of the problem scenarios was increased to stimulate higher-order thinking, moving beyond basic problem-solving to more intricate scenarios involving renewable energy implementation. These iterative improvements ensured that the final version of the worksheet was not only feasible but also sufficiently challenging to provoke the desired reasoning skills in the subsequent large-group trial.

Effectiveness on Reasoning Skills

The field trial phase represents the summative evaluation to determine the empirical impact of the PBL-integrated worksheet on students' reasoning capabilities. This stage involved a larger cohort of 24 students to ensure that the data collected could reflect a broader pedagogical trend within the classroom setting. By implementing a pre-test and post-test design, the researcher could systematically track the cognitive shifts that occurred after the intervention. The following sections detail the quantitative improvements and the statistical rigor applied to validate these findings. The assessment of reasoning skills was categorized into four primary indicators: identifying relationships, constructing arguments, verifying assumptions, and drawing conclusions.

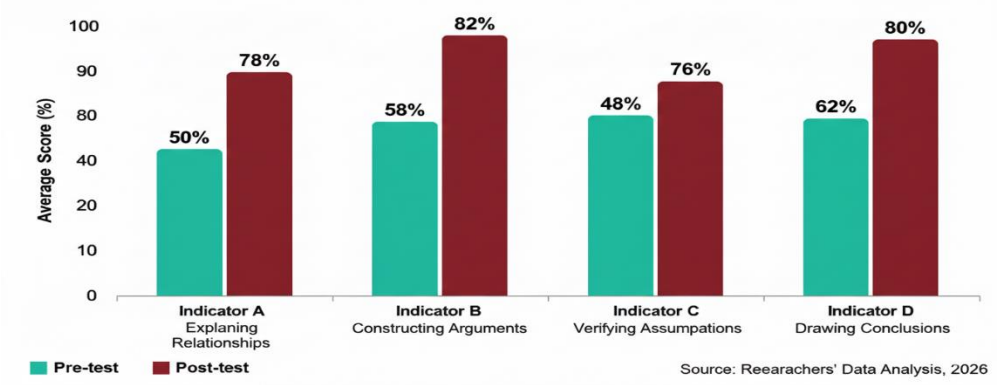


Figure 2. Comparison of students' reasoning skill scores across four indicators.

As illustrated in Table 5, there was a consistent upward trend in the mean scores across all evaluated dimensions of reasoning. This quantitative gain suggests that the structured scaffolding within the worksheet provided a mental framework that guided students through complex cognitive processes. The most significant progress was observed in the ability to draw scientific conclusions, which transitioned from a "low" to a "high" category.

Table 5. Results of average data on pretest and posttest of students' reasoning skills

Student Code	Pre	Post	Student Code	Pre	Post	Student Code	Pre	Post
S1	45	70	S9	65	75	S17	55	95
S2	70	90	S10	60	80	S18	70	95
S3	35	90	S11	60	95	S19	50	95
S4	60	85	S12	70	95	S20	60	100
S5	40	85	S13	45	70	S21	70	85
S6	75	90	S14	70	90	S22	75	95
S7	60	90	S15	60	85	S23	70	85
S8	60	90	S16	35	55	S24	45	80

The visual representation of these gains, as shown in the comparative analysis of pre-test and post-test results, highlights that the "Verifying Assumptions" indicator also experienced a substantial increase. This improvement indicates that students became more critical of the information presented to them regarding renewable energy challenges. According to Syer et al. (2013), fostering such analytical skepticism is a hallmark of effective science education in the 21st century. The integration of real-world energy problems into the PBL model likely played a pivotal role in motivating students to engage more deeply with these logical constructs.

Table 6. Results of the student data normality test

	Statistic	df	Sig.
Pretest	0.9056333899497986	23	0.0283880624920129
Posttest	0.87108230590820	23	0.0055242432281374

To ensure the scientific integrity of the results, the data underwent a series of prerequisite statistical tests before the hypothesis was concluded. As presented in Table 6, the normality test using the Shapiro-Wilk method revealed that the data distribution required careful consideration, although the sample size remained robust for parametric assumptions. Furthermore, the homogeneity test in Table 7 confirmed that the variance between the pre-test and post-test groups was uniform, with a significance value exceeding the 0.05 threshold. These results provide a solid statistical foundation, ensuring that the subsequent analysis was not biased by extreme outliers or inconsistent data spreads.

Table 7. Results of the student data homogeneity test

Levene Statistic	df1	df2	Sig.
1.0131052056789227	1	46	0.3194255521451413

The final determination of effectiveness was established through a Paired Sample T-Test, the results of which are summarized in Table 8. The statistical analysis yielded a significance value (p) of 0.000, which is considerably lower than the alpha level of 0.05, thereby leading to the rejection of the null hypothesis. This outcome confirms that the implementation of the PBL-based worksheet had a statistically significant effect on enhancing the reasoning skills of junior high school students. These findings are consistent with the research by Wardah et al. (2022), which posits that project-based and problem-based interventions significantly outperform traditional lecture-based methods in developing scientific literacy and critical thinking.

Table 8. Results of paired sample t-test of student data

t	df	Sig. (2-tailed)
12.090909090909092	23	1.9008565995942298e-11

Discussion

The integration of PBL with student worksheets creates a synergistic effect that significantly elevates students' reasoning capabilities. This research demonstrates that the intervention successfully transitions students from passive recipients of information to active problem solvers in the context of renewable energy. Unlike traditional lecture-based methods, the dual approach compels students to systematically analyze complex environmental issues through structured inquiry. The success of this model lies in its ability to operationalize abstract scientific concepts into tangible problem-solving steps. Consequently, the significant statistical improvement observed in this study validates the hypothesis that structure and context are equally vital for cognitive development.

The fundamental success of this intervention stems from the strategic combination of open-ended inquiry and structured scaffolding. While PBL provides the necessary context for exploration, the Student Worksheets serve as a cognitive guide that directs students' intellectual focus. Misrom et al. (2020) previously noted that PBL could be ineffective if students lack a mechanism to organize their unstructured thoughts. This study resolves that limitation by utilizing a worksheet to provide the missing structural framework for novice learners. Furthermore, these findings corroborate the work of Muliyati et al. (2021), who emphasized that structured worksheets significantly enhance cognitive engagement during complex tasks. Consequently, the worksheet acts as a critical bridge that allows students to navigate the complexities of PBL without becoming overwhelmed.

The substantial improvement in specific reasoning indicators can be attributed to the iterative nature of the inquiry process embedded in the worksheets. Students demonstrated a marked increase in their ability to explain relationships and draw conclusions because the intervention forced them to verify their assumptions first. This step-by-step validation process aligns with the observations of Schaffar and Wolff (2024), who argue that deep reasoning requires active and sustained engagement with the subject matter. However, this research advances current understanding by applying these cognitive demands specifically to the often-neglected domain of renewable energy. By addressing the gaps identified by Riess et al. (2022), this study confirms that reasoning skills are best cultivated when students are challenged to validate their hypotheses against real-world data. Thus, the structured format ensures that students do not merely guess answers but construct logical arguments based on evidence.

The distinct novelty of this research lies in its contextualization of reasoning skills within the urgent framework of renewable energy education. Reasoning abilities are not developed in a vacuum; rather, they are sharpened when applied to relevant societal issues such as LPG scarcity and solar energy implementation. This approach directly addresses the critical "content gap" highlighted by Xiao and Liu (2023), who argued that students often lack exposure to sustainability-related problem-solving scenarios. By integrating these specific topics, the study fulfills the objectives of Education for Sustainable Development (ESD) by equipping students with the tools to analyze environmental challenges critically. Consequently, the intervention transforms renewable energy from a theoretical textbook topic into a dynamic platform for intellectual development. This proves that high-level reasoning and essential sustainability literacy can be developed simultaneously in the classroom.

Despite the significant improvements in student reasoning, this study possesses several inherent limitations that warrant careful consideration. The relatively small sample size of twenty-four students from a single school may restrict the broader generalizability of the findings to different educational contexts. External variables such as the students' prior interest in

environmental issues or their varying levels of digital literacy might have influenced the outcomes. These constraints align with the perspectives of Creswell and Guetterman (2019), who emphasize that small-scale developmental trials often prioritize depth over statistical breadth. Therefore, future research should involve a more diverse and larger demographic to validate the consistency of this dual approach across various regions. Acknowledging these limitations ensures a transparent interpretation of the data while providing a clear roadmap for subsequent large-scale investigations.

Research Implication

The findings of this study extend beyond the immediate improvements in student performance to offer significant insights for educational stakeholders. By demonstrating the efficacy of combining PBL with structured student worksheets, this research provides a practical framework for addressing the systemic weakness in reasoning skills identified in Indonesian students. The following implications address the specific needs of policymakers, educators, and the broader research community.

The results of this study offer critical empirical support for the ongoing implementation of Indonesia's Independent Curriculum (Kurikulum Merdeka). While this curriculum emphasizes student-centered flexibility, the findings suggest that autonomous inquiry requires structured scaffolding to be effective in complex sustainability education. Policy developers should prioritize the integration of standardized worksheets alongside Problem-Based Learning (PBL) models to ensure consistent reasoning development across different school settings. This structured approach is essential for achieving the national objectives of Education for Sustainable Development (ESD) within the secondary education framework. By institutionalizing this dual method, the curriculum can better equip students with the cognitive skills necessary for the country's transition to sustainable energy sources.

For classroom practitioners, this research highlights that implementing PBL alone is often insufficient for students with developing reasoning abilities. Teachers must utilize valid supporting tools, such as the worksheet developed in this study, to provide the necessary guidance for complex problem-solving scenarios. This scaffolding is particularly crucial for students who are accustomed to passive learning methods and struggle with unstructured critical thinking tasks. The worksheet serves as a navigational aid that helps students systematically organize their arguments and verify assumptions during the inquiry process. Consequently, educators should view these worksheets not as supplementary administrative tasks but as vital pedagogical instruments for facilitating deep cognitive engagement.

The successful application of this model provides a replicable blueprint for future research in other STEM disciplines requiring higher-order thinking skills. Scholars can adapt the dual approach of PBL and worksheet to address other abstract scientific concepts beyond renewable energy, such as climate change adaptation or biotechnology. This study also establishes a clear methodology for measuring specific reasoning indicators, such as explaining relationships and drawing conclusions, which can be utilized in broader educational assessments. Future investigations should explore how this structured framework can be translated into digital formats to further enhance interactivity and accessibility in the classroom. Ultimately, this research paves the way for longitudinal studies to determine the long-term impact of scaffolded inquiry on scientific literacy and environmental stewardship.

CONCLUSION

This research confirms that the integration of Problem-Based Learning (PBL) with structured worksheets significantly improves students' reasoning skills regarding renewable energy topics. The findings demonstrate that providing cognitive scaffolding through worksheets allows students to navigate the complexities of inquiry-based learning effectively, particularly in

analyzing relationships and drawing evidence-based conclusions. In a practical sense, these worksheets provide a concrete pathway for teachers to bridge abstract energy concepts with real-world problem-solving while supporting the "Merdeka Curriculum" goals of student autonomy. The primary contribution of this study lies in its unique synthesis of reasoning development and renewable energy literacy, which addresses a critical gap in sustainable science education. Although this study involves a limited sample size, the positive outcomes establish a robust foundation for broader applications; therefore, future research should develop specific training modules for PBL and worksheet integration through lesson study frameworks to ensure sustainable implementation across diverse educational levels.

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