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Needs Analysis for Developing STEM-PjBL-SSI-Based e-LKPD on Renewable Energy Using Oil Palm Empty Fruit Bunch Waste Context

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Abstract

Renewable energy learning in science education requires contextual teaching materials that connect scientific concepts with local environmental issues and future-oriented skills. However, current classroom practices still face limitations in integrating project-based learning, socio-scientific issues, and entrepreneurial-oriented activities into structured learning resources. This study aimed to analyze the needs for developing a STEM-PjBL-SSI-based electronic student worksheet (e-LKPD) on renewable energy using oil palm empty fruit bunch waste as a local biomass context. A descriptive quantitative approach was employed through a survey involving 29 science teacher respondents. The data were collected using a questionnaire and analyzed descriptively using percentages. The results showed that Problem-Based Learning was the most frequently used learning model, applied by 51.7% of respondents, followed by Project-Based Learning at 37.9%, Discovery Learning at 27.6%, and Inquiry-Based Learning at 10.3%. The most commonly used teaching methods were discussion at 62.1% and experiment at 58.6%, while lectures were still used by 34.5% of respondents. In terms of learning resources, teachers mostly used learning videos at 72.4%, the internet at 65.5%, reference books at 55.2%, modules at 48.3%, and student worksheets at 44.8%. The findings also revealed that 62.1% of teachers were familiar with Socio-Scientific Issues, while misconceptions regarding renewable energy sources were still found among some respondents. Although 75.9% of teachers developed their own student worksheets, the existing worksheets had not systematically integrated STEM, project-based activities, socio-scientific issues, and entrepreneurial skill development. Therefore, the development of STEM-PjBL-SSI-based e-LKPD using oil palm empty fruit bunch waste as a renewable energy context is needed to support more contextual, interactive, and skill-oriented science learning.

Keywords: Needs analysis; e-LKPD; STEM; Project-based learning; Socio-scientific issues; Renewable energy; Oil palm empty fruit bunch waste

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INTRODUCTION

Science education in the 21st century is expected to prepare students not only to understand scientific concepts, but also to apply them in solving real problems related to society, environment, technology, and sustainable development. The increasing complexity of environmental problems, energy demand, and resource management requires science learning that develops critical thinking, problem-solving, creativity, collaboration, and entrepreneurial awareness. Critical thinking is particularly important because students need to analyze information, evaluate evidence, and make decisions based on scientific reasoning when dealing with scientific and environmental issues (Hidayat et al., 2022; Windasari et al., 2021). Therefore, science learning should provide opportunities for students to investigate real phenomena, evaluate scientific information, design solutions, and consider the social and environmental implications of science-based decisions.

One important issue that can be used as a contextual basis for science learning is renewable energy. The transition from fossil fuels to renewable energy has become a global concern because of the increasing impact of carbon emissions, energy insecurity, and environmental degradation. Renewable energy development can reduce dependence on fossil fuels, strengthen energy security, and support sustainable economic growth (Sirota et al., 2020; Granata et al., 2022). However, the implementation of renewable energy still faces technical, infrastructural, and educational challenges that require stronger public understanding and scientific literacy (Pletzer et al., 2015; Dentz et al., 2020). In school science learning, renewable energy topics are highly relevant because they involve concepts from physics, chemistry, biology, environmental science, technology, and engineering.

However, renewable energy learning in schools is often still presented as conceptual knowledge, such as definitions, types of energy sources, and examples of their use. This condition may limit students' opportunities to connect scientific concepts with real environmental problems and local resource potential. As a result, renewable energy learning has not fully encouraged students to analyze problems, design alternative solutions, or understand the economic value of local resources. Previous studies have shown that students' critical thinking skills tend to be less developed when learning activities are not connected to authentic contexts and do not involve students in problem-solving processes (Hidayat et al., 2022; Windasari et al., 2021). Therefore, renewable energy learning needs to be designed in a more contextual and project-oriented manner.

In Indonesia, one local environmental issue that has strong potential to be integrated into renewable energy learning is oil palm empty fruit bunch waste. Oil palm empty fruit bunches are generated in large quantities as by-products of the palm oil industry. If not managed properly, this waste can become an environmental problem. However, from a science and technology perspective, oil palm empty fruit bunch waste has potential as biomass material that can be processed into alternative energy products, such as bio-briquettes or other bioenergy-based products. Previous studies have shown that oil palm empty fruit bunches can be utilized as biomass for renewable energy production and have potential as an environmentally friendly alternative to fossil fuels (Erivianto et al., 2022; Mohd-Faizal et al., 2022). This issue is relevant for science learning because it connects renewable energy concepts with waste management, environmental sustainability, local resources, and economic opportunities.

Contextual renewable energy learning also has the potential to support the development of critical thinking and entrepreneurial skills. Critical thinking is needed when students identify problems, analyze causes, evaluate evidence, compare alternative solutions, and make decisions based on scientific reasoning. Meanwhile, entrepreneurial skills are important for helping students develop initiative, creativity, productivity, and the ability to recognize the economic value of science-based solutions. Project-based learning that involves students in producing tangible products has been reported to support entrepreneurial awareness and entrepreneurial intention because students experience the process of designing, producing, evaluating, and communicating a product (Ilmuyyah et al., 2022; Sakib et al., 2022). In renewable energy learning, these two competencies can be developed through activities that require students to analyze energy problems, design biomass-based products, evaluate product feasibility, and communicate the value of their solutions.

One approach that can support contextual and skill-oriented science learning is STEM education. STEM integrates science, technology, engineering, and mathematics in solving real-world problems. Through STEM-based learning, students are encouraged to understand scientific concepts, use technology, apply engineering design processes, and make decisions based on data or measurement. Previous studies have indicated that STEM-based project learning can improve students' critical thinking, creativity, and problem-solving skills because students are directly involved in inquiry, design, and solution development (Ke et al., 2021; Stohlmann et al., 2022; Zhang et al., 2021). This approach is suitable for renewable energy learning because energy problems cannot be understood only from one disciplinary perspective. For example, the development of biomass briquettes from oil palm empty fruit bunch waste requires students to understand energy conversion, material characteristics, product design, measurement, efficiency, and environmental impact.

In addition to STEM, Project-Based Learning is also relevant for renewable energy learning because it provides students with opportunities to produce concrete outputs through a structured project process. Project-Based Learning encourages students to investigate problems, plan activities, design products, test results, revise solutions, and present their work. In the context of oil palm empty fruit bunch waste, PjBL can guide students to develop simple renewable energy products or prototypes while applying science concepts in practical activities. This learning process can strengthen students' critical thinking, creativity, collaboration, and entrepreneurial awareness because students are not only asked to understand concepts, but also to produce solutions that have practical and potential economic value (Ke et al., 2021; Stohlmann et al., 2022).

Another approach that can strengthen the relevance of science learning is Socio-Scientific Issues. SSI-based learning connects scientific concepts with social, environmental, ethical, and economic issues that occur in society. Renewable energy and biomass waste utilization are appropriate contexts for SSI because they involve scientific knowledge as well as social considerations, such as environmental sustainability, community needs, industrial waste management, energy access, and economic benefits. SSI-based instruction can improve students' scientific argumentation, reflective judgment, critical thinking, and decision-making because students are guided to examine scientific issues from multiple perspectives and construct arguments based on evidence (Zeidler et al., 2022; Wang et al., 2023; Sadler & Brown, 2024). Therefore, the integration of SSI into renewable energy learning can make science learning more meaningful and closer to real-life decision-making.

Although STEM, PjBL, and SSI have strong potential to support contextual science learning, their implementation requires appropriate teaching materials. One teaching material that can guide students' learning activities systematically is the student worksheet or LKPD. In the digital learning era, LKPD can be developed into electronic student worksheets or e-LKPD. Compared with conventional printed worksheets, e-LKPD can integrate text, images, videos, links, simulations, interactive tasks, and project guidance. Multimedia-based learning resources can help students understand abstract or complex science concepts through visual and verbal representations, especially when the materials are designed according to students' learning needs (Mayer, 2022). Therefore, e-LKPD has the potential to support renewable energy learning by presenting contextual problems, project stages, multimedia resources, and reflective activities in an integrated format.

However, before developing e-LKPD, it is necessary to conduct a needs analysis. Needs analysis is important to identify current learning practices, teaching methods, learning resources, teachers' familiarity with relevant approaches, and the extent to which existing worksheets support the intended learning objectives. Without needs analysis, the development of e-LKPD may not correspond to actual classroom conditions. In the context of this study, needs analysis is needed to examine how teachers currently teach renewable energy, what learning resources they use, how familiar they are with Socio-Scientific Issues, how they understand renewable energy sources, and whether the existing LKPD has supported project-based, contextual, and skill-oriented science learning.

Several previous studies have examined STEM-based learning, Project-Based Learning, SSI-based instruction, and renewable energy learning separately (Ke et al., 2021; Stohlmann et al., 2022; Zeidler et al., 2022; Wang et al., 2023). However, studies that specifically analyze the instructional needs for developing STEM-PjBL-SSI-based e-LKPD using oil palm empty fruit bunch waste as a local renewable energy context are still limited. This gap is important because the development of effective learning materials should be based on empirical information about classroom practices, teacher readiness, learning resource availability, and contextual problems relevant to students' environment. Therefore, a needs analysis is required as the initial foundation for designing e-LKPD that is not only digital, but also pedagogically structured, contextually relevant, and oriented toward critical thinking and entrepreneurial skill development.

Based on these considerations, this study focuses on analyzing the needs for developing STEM-PjBL-SSI-based e-LKPD on renewable energy using oil palm empty fruit bunch waste as a local biomass context. This study does not aim to directly measure the final level of students' critical thinking or entrepreneurial skills, but rather to identify the learning conditions and instructional needs that should be considered in the development of e-LKPD. Specifically, this study analyzes teachers' current learning models and methods, the learning resources used in renewable energy teaching, teachers' understanding of SSI and renewable energy, the characteristics of LKPD currently used in schools, and the implications of these findings for the design of STEM-PjBL-SSI-based e-LKPD. The results are expected to provide an empirical basis for developing contextual electronic worksheets that support renewable energy learning and encourage the integration of scientific understanding, project activities, socio-scientific reasoning, and entrepreneurial-oriented skills.

METHOD

Research Design

This study employed a descriptive quantitative approach with a needs analysis design. This design was used to obtain an empirical description of current science learning practices, learning resources, teachers' understanding of Socio-Scientific Issues (SSI), renewable energy literacy, and the need for developing STEM-PjBL-SSI-based e-LKPD on renewable energy. Descriptive research is appropriate for systematically describing the characteristics, perceptions, and needs of a particular group based on data collected in the field (Fraenkel et al., 2012). In this study, the needs analysis was conducted as the initial stage for identifying instructional conditions that should be considered in developing electronic student worksheets that are contextual, project-oriented, and relevant to renewable energy learning using oil palm empty fruit bunch waste as a local biomass context.

This study did not aim to directly measure students' final critical thinking skills or entrepreneurial skills. Instead, it focused on identifying instructional conditions and learning needs that can support the development of these skills through future e-LKPD design. Therefore, the data collected in this study were used to describe teachers' current practices and the extent to which existing learning resources and worksheets support contextual, project-based, and socio-scientific issue-oriented science learning.

Participants and Sampling Technique

The participants of this study were 29 science teachers who were involved in science learning and had experience teaching topics related to energy, environmental issues, or renewable energy. The respondents were selected using purposive sampling because they were considered to have relevant knowledge and experience regarding classroom learning practices, teaching materials, and the use of student worksheets in science learning. Purposive sampling allows researchers to select participants based on specific criteria that are relevant to the research objectives (Creswell, 2014).

The selection of teacher respondents was considered appropriate because this study focused on analyzing instructional needs from the perspective of teachers as curriculum implementers and learning material users. Teachers' responses were expected to provide information about the learning models and methods commonly used, the availability of learning resources, the use of LKPD, teachers' understanding of SSI and renewable energy, and the potential need for developing STEM-PjBL-SSI-based e-LKPD in renewable energy learning.

Research Instrument

The instrument used in this study was a needs analysis questionnaire. The questionnaire was developed to collect information about science learning practices and the need for developing e-LKPD on renewable energy. The questionnaire covered several aspects: learning models used by teachers, teaching methods applied in renewable energy learning, learning resources and media used in the classroom, teachers' familiarity with Socio-Scientific Issues, teachers' knowledge of renewable energy sources, the use and development of LKPD, and the need for electronic student worksheets that integrate STEM, Project-Based Learning, and Socio-Scientific Issues.

The questionnaire consisted of closed-ended and multiple-response items. Closed-ended items were used to obtain specific responses related to teachers' understanding and practices. Multiple-response items were used for questions that allowed respondents to select more than one answer, such as learning methods, learning resources, and types of renewable energy known by teachers. The use of this questionnaire enabled the researcher to obtain quantitative data that could be analyzed descriptively in the form of frequencies and percentages.

Table 1. Aspects of the Needs Analysis Questionnaire

Aspect	Focus of Information
1. Learning models	Teachers' use of PBL, PjBL, Discovery Learning, and Inquiry-Based Learning.
2. Teaching methods	Teachers' use of lectures, demonstrations, discussions, and experiments.
3. Learning resources and media	Use of reference books, LKPD, modules, learning videos, and internet sources.
4. Understanding of SSI	Teachers' familiarity with Socio-Scientific Issues in science learning.
5. Renewable energy literacy	Teachers' knowledge of renewable and non-renewable energy sources.
6. LKPD use and development	Teachers' use of self-developed or externally sourced LKPD.
7. e-LKPD development needs	Need for digital, contextual, project-based, and SSI-oriented learning materials.

Data Collection Procedure

Data were collected by distributing the needs analysis questionnaire to science teachers. Before completing the questionnaire, respondents were informed that the purpose of the study was to identify current science learning conditions and the need for developing STEM-PjBL-SSI-based e-LKPD on renewable energy. Respondents were asked to answer each item based on their teaching experience and actual classroom practices.

The questionnaire responses were then compiled and tabulated according to each aspect of the needs analysis. For multiple-response items, the frequency of each option was calculated based on the number of respondents who selected that option. Therefore, the total percentage in several items could exceed 100% because respondents were allowed to choose more than one answer.

Data Analysis

The data were analyzed using descriptive statistics in the form of frequencies and percentages. Frequency analysis was used to determine the number of respondents who selected each response option, while percentage analysis was used to describe the proportion of responses for each aspect of the needs analysis. The percentage of each response was calculated using the following formula:

$$P = \frac{f}{N} \times 100\%$$

where P is the percentage, f is the frequency of respondents selecting a particular option, and N is the total number of respondents.

The results of the analysis were interpreted to identify patterns in current science learning practices and the need for developing STEM-PjBL-SSI-based e-LKPD. The interpretation focused on determining whether existing learning models, methods, learning resources, and

LKPD had sufficiently supported contextual renewable energy learning, project-based activities, socio-scientific reasoning, and entrepreneurial-oriented skill development. The findings from this analysis were then used as the basis for formulating design implications for the development of STEM-PjBL-SSI-based e-LKPD on renewable energy using oil palm empty fruit bunch waste as a local biomass context.

RESULTS AND DISCUSSION

This section presents the results of the needs analysis for developing STEM-PjBL-SSI-based e-LKPD on renewable energy using oil palm empty fruit bunch waste as a local biomass context. The analysis focused on teachers' current learning models, teaching methods, learning resources, familiarity with Socio-Scientific Issues (SSI), knowledge of renewable energy, and the use of LKPD in science learning.

Learning Models Used in Science Learning

The first aspect analyzed was the learning models commonly used by teachers in science learning. The results are presented in Figure 1.

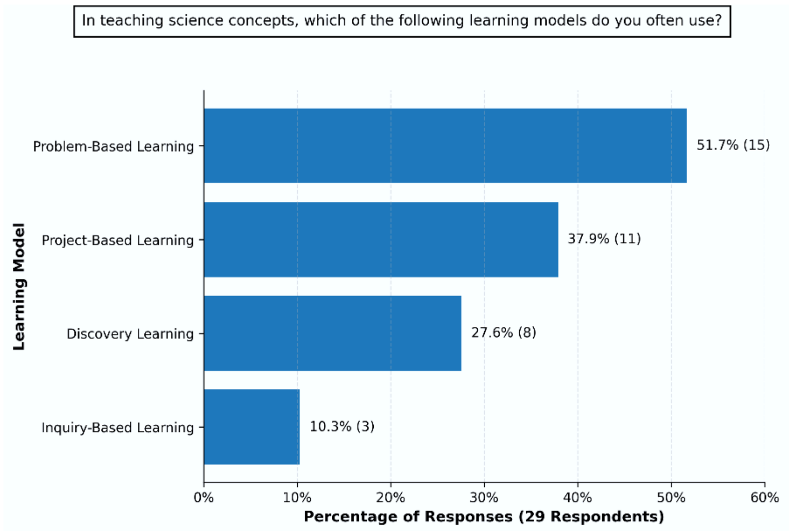

Figure 1. Learning models used by teachers in science learning (N = 29)

The survey results showed that Problem-Based Learning (PBL) was the most frequently used learning model, selected by 15 out of 29 respondents or 51.7%. Project-Based Learning (PjBL) was selected by 11 respondents or 37.9%, followed by Discovery Learning with 8 respondents or 27.6%. Meanwhile, Inquiry-Based Learning was selected by only 3 respondents or 10.3%.

These findings indicate that teachers have begun to implement active learning models in science classrooms. The dominance of PBL suggests that teachers are relatively familiar with learning that begins with contextual problems. This is relevant to science learning because students need opportunities to analyze phenomena, identify problems, explore information, and construct understanding through investigation and discussion. PBL is widely recognized as a learning model that can support problem-solving and critical thinking because students are placed in situations that require them to investigate and propose solutions based on evidence (Arends, 2012; Windasari et al., 2021).

However, the percentage of teachers using PjBL was still lower than those using PBL. This finding is important because renewable energy learning, especially in the context of oil palm empty fruit bunch waste, requires not only problem analysis but also product design, testing, evaluation, and communication. PjBL provides a more suitable structure for guiding students to produce concrete outputs, such as biomass-based energy products or simple briquette prototypes. Therefore, the development of STEM-PjBL-SSI-based e-LKPD should help teachers move from problem discussion toward structured project implementation.

The limited use of Inquiry-Based Learning also indicates that scientific investigation may not yet be fully implemented in classroom practice. In renewable energy learning, inquiry activities are important because students need to observe phenomena, formulate questions, collect data, test products, and draw conclusions. Thus, the e-LKPD should integrate inquiry elements within the PjBL structure, so that students are not only asked to complete a project but also to understand the scientific reasoning behind the project.

Teaching Methods Applied in Renewable Energy Learning

The second aspect analyzed was the teaching methods used by teachers when teaching renewable energy topics. The results are shown in Figure 2.

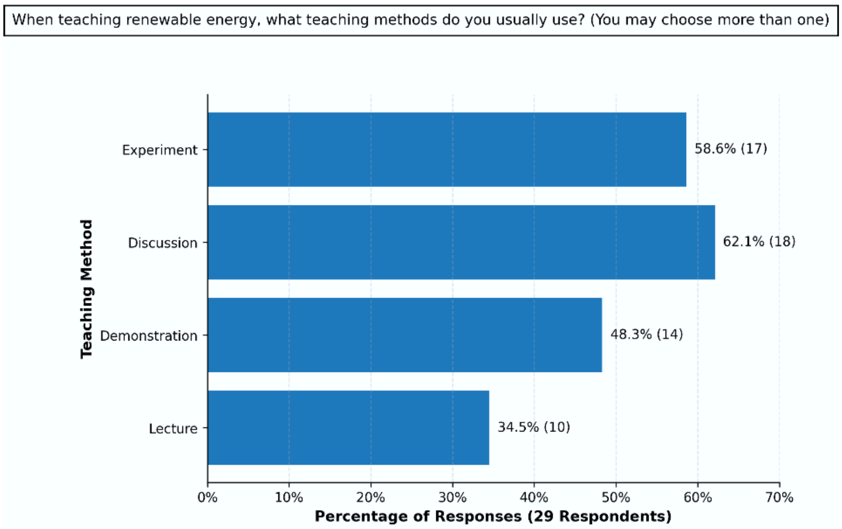

Figure 2. Teaching methods applied in renewable energy learning (N = 29)

Figure 2 shows that discussion was the most frequently used teaching method, selected by 18 respondents or 62.1%. Experimentation was selected by 17 respondents or 58.6%, demonstration by 14 respondents or 48.3%, and lecture by 10 respondents or 34.5%.

The high use of discussion indicates that teachers provide opportunities for students to exchange ideas and respond to questions during science learning. This method is relevant to renewable energy topics because energy issues are closely related to environmental, technological, economic, and social dimensions. Through discussion, students can compare different energy sources, analyze the advantages and limitations of renewable energy, and evaluate the environmental impact of fossil fuel use. When guided by evidence-based questions, discussion can support critical thinking and scientific argumentation (Hidayat et al., 2022; Wang et al., 2023).

The frequent use of experimentation is also a positive finding. Experimental activities allow students to observe scientific phenomena directly and connect theoretical concepts with empirical evidence. In the context of renewable energy, experiments can be used to investigate biomass characteristics, combustion processes, heat production, or simple testing of biomass-based products. However, experimentation alone is not sufficient if it is only used to verify concepts. To support STEM-PjBL-SSI learning, experiments need to be connected to problem identification, engineering design, product development, data analysis, and evaluation.

The use of demonstration and lecture remains useful in certain learning situations, especially when teachers need to introduce basic concepts or show processes that are difficult to conduct directly in the classroom. However, renewable energy learning should not rely heavily on teacher explanation because the topic requires contextual exploration and active problem-solving. Therefore, the e-LKPD should organize these methods into a coherent learning sequence, beginning with SSI-based problem orientation, followed by discussion, investigation, product design, experimentation, reflection, and presentation.

Learning Resources and Media Used by Teachers

The third aspect analyzed was the learning resources and media used by teachers in renewable energy learning. The results are presented in Figure 3.

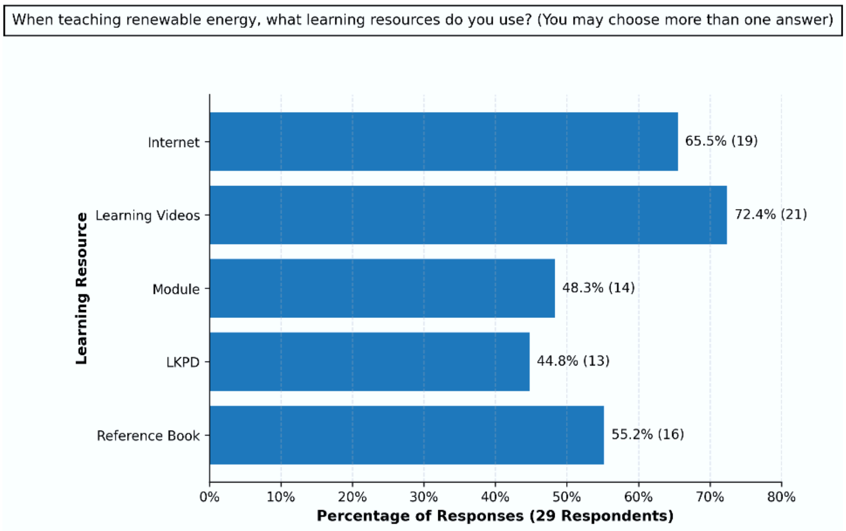

Figure 3. Learning resources and media used by teachers in renewable energy learning (N = 29)

The survey results showed that learning videos were the most frequently used resource, selected by 21 respondents or 72.4%. Internet sources were used by 19 respondents or 65.5%, followed by reference books with 16 respondents or 55.2%, modules with 14 respondents or 48.3%, and LKPD with 13 respondents or 44.8%.

The high use of learning videos and internet sources indicates that teachers have started to integrate digital resources into science learning. This condition is important for the development of e-LKPD because it suggests that teachers are already familiar with digital learning support. Videos can help explain abstract science concepts and processes that are difficult to observe directly, while internet sources can provide examples, visualizations, and updated information related to renewable energy. Multimedia learning can support students' understanding when visual and verbal information is presented in a meaningful and structured way (Mayer, 2022).

However, the use of digital resources does not automatically make learning systematic or project-oriented. Videos and internet materials may only function as supplementary resources if they are not connected to guiding questions, inquiry tasks, project procedures, and reflection activities. Therefore, the e-LKPD should not merely present digital content, but should integrate multimedia resources into structured learning tasks. For example, students may be asked to watch a video about biomass energy, identify the problem of oil palm waste, analyze the potential of biomass conversion, and design a simple renewable energy product.

The relatively lower use of LKPD compared with videos and internet sources shows that worksheets have not become the main guide in renewable energy learning. This is a key issue because LKPD should ideally help students follow systematic learning stages. If worksheets are not optimally used or are not designed for project-based learning, students may not receive sufficient guidance in connecting scientific concepts, environmental problems, and product development. Therefore, the proposed e-LKPD needs to function as a structured guide that integrates digital resources, STEM concepts, PjBL stages, SSI contexts, and entrepreneurial-oriented activities.

Teachers' Familiarity with Socio-Scientific Issues

The fourth aspect analyzed was teachers' familiarity with the term Socio-Scientific Issues. The results are shown in Figure 4.

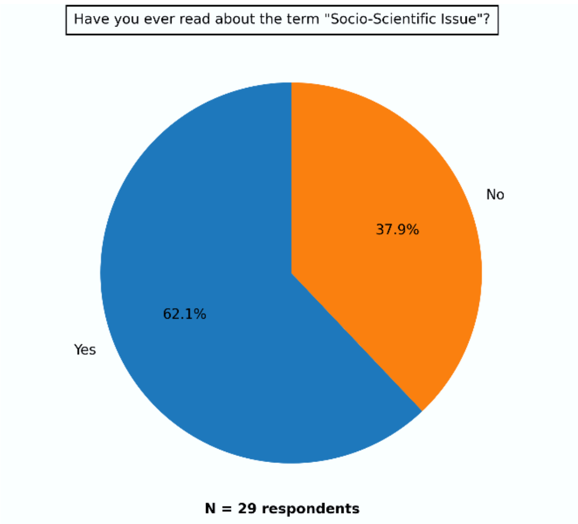

Figure 4. Teachers' familiarity with Socio-Scientific Issues (SSI) (N = 29)

Figure 4 shows that 18 respondents or 62.1% stated that they had read or were familiar with the term Socio-Scientific Issues, while 11 respondents or 37.9% stated that they were not familiar with it.

This finding indicates that most teachers have initial awareness of SSI, but a considerable proportion still lacks familiarity with this approach. This is relevant because renewable energy is not only a scientific topic but also a socio-scientific issue. The use of biomass from oil palm empty fruit bunch waste involves scientific, environmental, economic, and social considerations. Students need to understand not only the concept of biomass energy, but also the environmental problems caused by waste, the potential value of local resources, and the social implications of renewable energy development.

SSI-based learning can help students analyze scientific issues from multiple perspectives and construct arguments based on evidence. Previous studies have shown that SSI instruction can support students' scientific reasoning, reflective judgment, argumentation, and decision-making skills (Zeidler et al., 2022; Wang et al., 2023; Sadler & Brown, 2024). Therefore, the finding that some teachers are not yet familiar with SSI has direct implications for e-LKPD development. The e-LKPD should make the SSI component explicit through contextual problem narratives, guiding questions, data interpretation, argumentation tasks, and reflection activities.

In the context of this study, an SSI-based task may begin with the issue of oil palm empty fruit bunch waste accumulation. Students can be guided to discuss why the waste becomes an environmental problem, how it can be used as biomass material, what benefits and limitations may arise from its use as renewable energy, and how such products may have economic value. In this way, SSI becomes the entry point for scientific inquiry and project development.

Teachers' Knowledge of Renewable Energy and Bioenergy

The fifth aspect analyzed was teachers' knowledge of renewable energy sources. The results are presented in Figure 5. The results showed that bioenergy was the most recognized renewable energy source, selected by 18 respondents or 62.1%. Solar energy was selected by 17 respondents or 58.6%, while wind energy and hydro energy were each selected by 13 respondents or 44.8%. Ocean wave energy was selected by 11 respondents or 37.9%.

This finding is important because bioenergy is directly related to the context of this study. Oil palm empty fruit bunch waste is a biomass material that can be introduced as a potential source of renewable energy. Previous studies have shown that oil palm empty fruit bunches can be processed into biomass-based energy products, including briquettes or other bioenergy products (Erivianto et al., 2022; Mohd-Faizal et al., 2022). Therefore, teachers' familiarity with bioenergy provides a useful starting point for developing renewable energy learning based on local waste utilization.

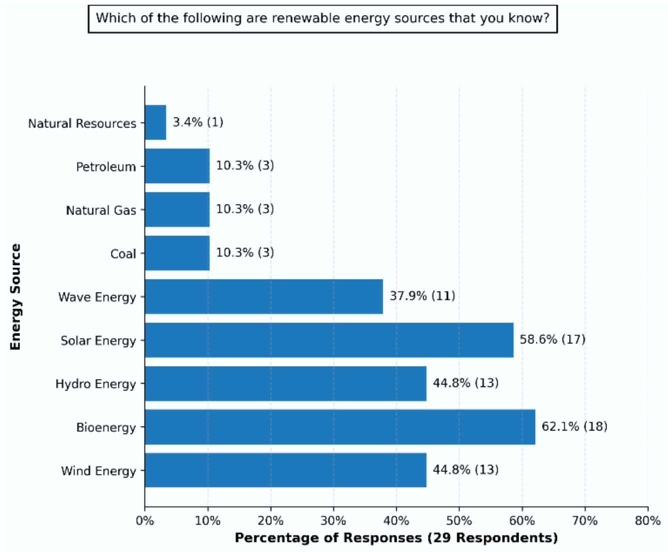

Figure 5. Renewable energy sources recognized by teachers (N = 29)

However, Figure 5 also shows that some respondents still had misconceptions about renewable energy. Coal, natural gas, and petroleum were each selected by 3 respondents or 10.3% as renewable energy sources. In addition, one respondent or 3.4% selected "natural resources," which is too general and does not specifically refer to a renewable energy source. These findings indicate that some teachers still need stronger conceptual understanding of the distinction between renewable and non-renewable energy sources.

This misconception is not a minor issue. If teachers are not fully clear about energy classification, classroom explanations and student learning activities may also become conceptually weak. Therefore, the e-LKPD should include clear conceptual reinforcement about renewable and non-renewable energy, characteristics of biomass, energy conversion, sustainability, and environmental impact. The STEM approach can support this reinforcement by guiding students to examine energy sources based on scientific characteristics, technological applications, engineering processes, and quantitative data.

Use and Development of LKPD

The sixth aspect analyzed was teachers' use and development of LKPD. The results are shown in Figure 6.

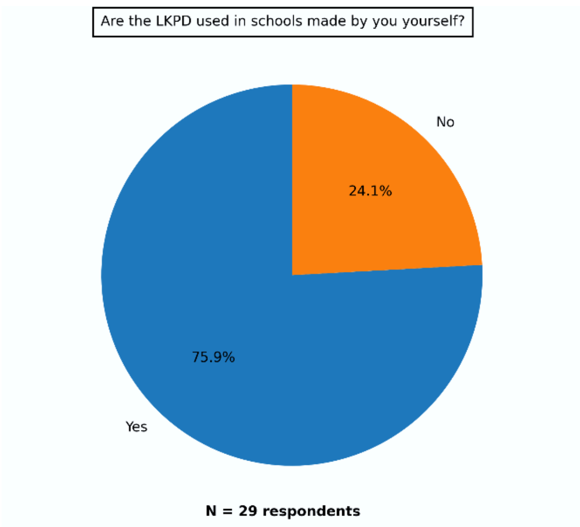

Figure 6. Teachers' responses regarding the development of LKPD used in schools (N = 29)

Figure 6 shows that 22 respondents or 75.9% stated that the LKPD used in learning was developed by themselves, while 7 respondents or 24.1% stated that they used LKPD from other sources, such as publishers, internet sources, or teacher forums.

This finding indicates that most teachers have experience and independence in preparing learning worksheets. This is a positive condition because teacher-developed LKPD can be adapted to classroom conditions, student characteristics, and local contexts. In the development of contextual science learning, teacher independence is important because local issues, such as oil palm empty fruit bunch waste, need to be translated into learning activities that fit the school environment.

However, teacher independence in preparing LKPD does not necessarily mean that the existing LKPD has systematically integrated STEM, PjBL, SSI, and entrepreneurial-oriented activities. Based on the needs analysis, the worksheets currently used by teachers tend to support concept reinforcement or general learning activities, but they have not fully guided students through structured project-based learning. They also have not explicitly integrated socio-scientific issue analysis, engineering design, product testing, and feasibility or value analysis.

This finding provides a strong basis for developing STEM-PjBL-SSI-based e-LKPD. Since many teachers are already accustomed to using or developing LKPD, the proposed e-LKPD can be designed as an improved version of the worksheets they already know. The digital format can support the integration of videos, visual illustrations, links, interactive instructions, documentation tasks, and project reports. Meanwhile, the STEM-PjBL-SSI structure can help teachers implement more contextual and systematic renewable energy learning.

Instructional Needs to Support Critical Thinking and Entrepreneurial-Oriented Skills

The results of the needs analysis also indicate that the development of critical thinking and entrepreneurial-oriented skills requires more structured learning support. The data do not directly measure students' critical thinking or entrepreneurial skills. However, the findings show that current learning practices and existing worksheets have not fully provided systematic activities for training these skills.

Critical thinking can be supported when students are guided to identify problems, analyze causes, evaluate evidence, compare alternative solutions, and justify decisions. In the context of renewable energy, these processes can be developed through activities such as analyzing the environmental impact of oil palm empty fruit bunch waste, comparing biomass energy with fossil fuels, evaluating the feasibility of biomass briquettes, and making decisions based on scientific evidence.

Entrepreneurial-oriented skills can be supported through product-based learning activities. Students can be guided to design biomass-based products, identify their benefits, estimate production feasibility, consider user needs, and communicate product value. Project-based learning has been reported to support entrepreneurial intention and product-oriented learning because students experience the process of designing, producing, evaluating, and presenting a product (Ilmuyyah et al., 2022; Sakib et al., 2022).

Therefore, the e-LKPD should include activities that explicitly connect scientific inquiry with product development and value communication. In this study, oil palm empty fruit bunch waste is not only treated as an environmental problem but also as a learning context for developing renewable energy solutions with potential economic value.

Design Implications for STEM-PjBL-SSI-Based e-LKPD

Based on the findings, the development of STEM-PjBL-SSI-based e-LKPD is necessary to address several instructional needs. Teachers have begun to use active learning models, discussions, experiments, digital resources, and self-developed LKPD. However, project-based learning is not yet dominant, SSI understanding is not evenly distributed, misconceptions about renewable energy still exist, and existing LKPD has not systematically supported STEM-based project activities or entrepreneurial-oriented learning. The design implications are summarized in Table 2.

Table 2. Needs Analysis Findings and Design Implications for e-LKPD

Needs Analysis Findings	Design Implications for e-LKPD
1. PBL is used more frequently than PjBL	e-LKPD should provide clear PjBL stages, including problem identification, project planning, product design, testing, revision, and presentation.
2. Discussion and experimentation are commonly used	e-LKPD should integrate discussion prompts, experimental procedures, data analysis, and reflective questions.
3. Learning videos and internet sources are widely used	e-LKPD should include curated multimedia resources linked to structured inquiry and project tasks.
4. Some teachers are not familiar with SSI	e-LKPD should provide explicit SSI contexts, issue analysis, argumentation tasks, and decision-making activities.
5. Misconceptions about renewable energy still appear	e-LKPD should reinforce the distinction between renewable and non-renewable energy sources.
6. Most teachers develop their own LKPD	e-LKPD should be adaptable so teachers can adjust it to classroom conditions and local contexts.
7. Existing LKPD has not fully supported project-based and entrepreneurial-oriented learning	e-LKPD should include product design, feasibility analysis, benefit identification, and communication of product value.

The proposed e-LKPD should therefore be designed with several key characteristics. First, it should begin with a socio-scientific issue related to oil palm empty fruit bunch waste, renewable energy, and environmental sustainability. Second, it should integrate STEM components by guiding students to understand scientific concepts, use technology-based information, apply engineering design, and conduct simple measurement or calculation. Third, it should follow PjBL stages so that students can move from problem identification to product development and presentation. Fourth, it should include critical thinking prompts that guide students to analyze causes, compare alternatives, evaluate evidence, and justify conclusions. Fifth, it should include entrepreneurial-oriented activities, such as identifying product benefits, estimating feasibility, considering user needs, and communicating product value.

These findings suggest that the development of STEM-PjBL-SSI-based e-LKPD is relevant to actual classroom needs. The e-LKPD is expected to function not only as a digital worksheet but also as a structured learning guide that connects renewable energy concepts with local environmental issues and project-based activities. By using oil palm empty fruit bunch waste as the learning context, the e-LKPD can help students learn renewable energy through scientific investigation, socio-scientific reasoning, engineering design, and product-oriented activities.

Since this study is limited to teacher responses, the findings should be interpreted as a foundation for instructional material development rather than as evidence of the effectiveness of the e-LKPD. Further research is needed to develop, validate, and test the practicality and effectiveness of the STEM-PjBL-SSI-based e-LKPD in classroom implementation.

CONCLUSIONS

This study analyzed the needs for developing STEM-PjBL-SSI-based e-LKPD on renewable energy using oil palm empty fruit bunch waste as a local biomass context. The findings from 29 science teachers indicate that science learning has begun to adopt active learning models and methods, particularly Problem-Based Learning, discussion, and experimentation. However, Project-Based Learning has not yet become the dominant learning model, even though renewable energy learning requires students to engage in product design, experimentation, testing, evaluation, and presentation. This condition shows that teachers need structured teaching materials that can guide project-based learning more systematically, especially in connecting renewable energy concepts with local environmental problems.

The results also show that teachers have started to use various learning resources, particularly learning videos and internet sources, which indicates readiness to integrate digital materials into science learning. Nevertheless, LKPD has not yet become the main learning guide, and the existing worksheets have not fully integrated STEM, PjBL, SSI, critical thinking activities, and entrepreneurial-oriented tasks. Teachers' familiarity with Socio-Scientific Issues also remains uneven, although SSI is highly relevant to renewable energy learning because the use of oil palm empty fruit bunch waste involves scientific, environmental, economic, and social dimensions. In addition, some misconceptions regarding renewable and non-renewable energy sources were still found, indicating the need for conceptual reinforcement in learning materials.

Based on these findings, the development of STEM-PjBL-SSI-based e-LKPD is necessary to support renewable energy learning that is more contextual, structured, interactive, and relevant to local potential. The proposed e-LKPD should include socio-scientific issue orientation, STEM-based concept exploration, project-based learning stages, experimental activities, data analysis, critical thinking prompts, and entrepreneurial-oriented activities such as product feasibility analysis and communication of product value. Since this study is limited to a needs analysis based on teacher responses, the findings should be interpreted as an empirical foundation for instructional material development, not as evidence of the effectiveness of the e-LKPD. Further development, validation, practicality testing, and effectiveness testing are needed in classroom implementation.

RECOMMENDATION

Based on the results of this needs analysis, it is recommended that future research continue to the development stage by producing a complete prototype of STEM-PjBL-SSI-based e-LKPD on renewable energy using oil palm empty fruit bunch waste as the learning context. The e-LKPD should be designed in an adaptable digital format so that teachers can modify it according to school conditions, student characteristics, available facilities, and local environmental contexts. The prototype should be validated by experts in science education, learning media, STEM learning, and renewable energy content, followed by practicality testing with teachers and students. Effectiveness testing is also needed to examine whether the e-LKPD can improve students' understanding of renewable energy concepts, critical thinking, socio-scientific reasoning, project performance, and entrepreneurial-oriented skills.

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CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

INFORMED CONSENT
We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL
The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee.

DATA AVAILABILITY
The data that support the findings of this study are available on request from the corresponding author.

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