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RESEARCH ARTICLE

Robotic-Assisted STEM Worksheets for Renewable Energy: A Multi-Stakeholder Needs Analysis in Junior High School Science

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Abstract

The development of educational technology requires science learning in junior high schools to shift toward more interactive, contextual, and skill-oriented approaches that support 21st-century competencies. However, observations and needs analysis reveal that renewable energy learning is still dominated by lecture-based instruction and limited media use, resulting in students' difficulty visualizing concepts and experiencing hands-on experimentation. This study aims to analyze the needs of teachers and students as the foundation for developing Student Worksheets (LKPD) assisted by block programming–based STEM robotics on renewable energy materials. A qualitative descriptive design was employed involving 52 ninth-grade students and 8 science teachers selected through purposive sampling. Data were collected using questionnaires, interviews, and documentation, then analyzed through data reduction, data display, and conclusion drawing. The findings show that 57.7% of students prefer experiment-centered learning, 44.2% have never conducted renewable energy experiments, 73.1% have never used robotic media, and 88.5% are highly interested in learning through block programming–robotic activities. From the teacher perspective, 100% reported that robotic-based LKPD is not yet available in schools, and all teachers expressed strong interest in adopting such media. Additionally, 75% indicated that school facilities do not sufficiently support coding-robotic activities. Overall, these results emphasize the urgent need for STEM-based LKPD assisted by block programming and robotics to concretely visualize renewable energy processes, enhance conceptual understanding, foster scientific inquiry, and support meaningful technology integration in science learning. Furthermore, the development of such learning materials has the potential to improve the effectiveness of science laboratory activities by providing accessible, interactive, and technology-enhanced experimentation experiences, thereby supporting the broader implementation of innovative science education practices in Indonesian schools.

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INTRODUCTION

The development of 21st-century educational technology requires science learning in junior high schools to shift toward more interactive and contextual models that strengthen higher-order thinking skills, as highlighted in recent studies on technology-enhanced science education (Li et al., 2022). However, current classroom practices still rely heavily on teacher-centered lectures and limited instructional media, a condition that has been widely reported to restrict students' exploration, experimentation, and problem-solving activities in science learning (Movahedazarhouligh et al., 2023). These constraints contribute to low student motivation and persistent difficulties in understanding abstract scientific concepts, particularly those related to renewable energy systems that demand process visualization and hands-on learning (Hodges et al., 2020). Similar findings have been reported in previous studies, which indicate that limited availability of experimental equipment and interactive learning media may contribute to students' misconceptions and insufficient conceptual understanding of scientific concepts (Bahtaji, 2023). In contrast, learning environments that incorporate contextual experiences, interactive activities, and technology-based support have been shown to facilitate students' conceptual development, particularly in energy-related topics that require visualization and dynamic modeling processes (Al-Azawei, 2023). These findings suggest that the integration of innovative technologies into renewable energy instruction is essential for promoting deeper conceptual understanding and providing more meaningful learning experiences for students. These findings are consistent with recent studies published in Jurnal Pembelajaran Fisika, which reported that STEM-oriented learning media and interactive worksheets significantly improve students' conceptual understanding and scientific reasoning by providing opportunities for active exploration and experimentation (Pratama et al., 2023; Nisa et al., 2024). Therefore, integrating STEM-based robotics and block programming into renewable energy learning may provide a more meaningful and contextual learning experience for junior high school students.

Comparable findings have also been documented in science education research. Suhandi (2023) noted that limited access to experimental media can make it difficult for students to develop a sound understanding of scientific concepts, which may lead to misconceptions. Furthermore, Pebriana and Nuryaman (2023) reported that science learning tends to be less engaging and less effective when interactive and inquiry-based media are rarely used in classroom instruction. In addition, (Ainiyatul Azizah, 2025) emphasized that a lack of contextual and technology-supported learning resources hinders students' ability to connect scientific concepts with real-life applications. These findings collectively underline the urgent need for the integration of innovative, technology-enhanced learning tools that can support visualization, experimentation, and active problem-solving in renewable energy education.

In addition, the availability of learning media such as renewable energy kits, experimental tools, and science laboratories is still very limited. Teachers use textbooks and presentation slides more often, while learners need media that can connect concepts with real phenomena. The lack of use of this innovative media creates a significant gap between the learning needs of students and the actual instructional practices in the classroom. This gap becomes more urgent when considering that recent studies consistently demonstrate the strong impact of contextual, interactive, and technology-supported learning media in improving students' scientific understanding. For instance, research by (Irvany Nurita Pebriana, 2023) found that interactive digital media integrated with inquiry learning can significantly increase mastery of physics concepts. Similarly, Arafat et al.,(2024) highlighted that STEM–robotics activities provide concrete learning experiences that help eliminate misconceptions and strengthen conceptual understanding. In addition, (Lohakan & Seetao (2024) showed that visual–programming-based experiments enable students to simulate real scientific phenomena more accurately, thereby deepening conceptual comprehension. These consistent findings across different studies and years reinforce the urgency for integrating interactive and technology-enhanced media—such as block-programming-assisted STEM-robotic worksheets—into renewable energy learning to ensure that students engage with concepts in a concrete, meaningful, and scientifically authentic manner.

One of the approaches that has proven effective in overcoming these problems is the STEM (Science, Technology, Engineering, and Mathematics) approach. STEM emphasizes the integration of science concepts with technology, engineering, and mathematics so that learning becomes more applicable and project-oriented. Research (Arafat et al., 2024) found that the implementation of STEM learning combined with robotics was able to improve critical thinking skills, creativity, and motivation to learn science. Through STEM-robotic-based learning, students can visualize renewable energy concepts such as how solar panels or wind turbines work through experiments that resemble real conditions.

The integration of block-based educational robotics is also considered to be very suitable for the characteristics of junior high school students because it is visual, intuitive, and does not require advanced coding skills. (Ouyang & Xu, 2024) emphasized that block programming is able to increase technological literacy and make it easier to understand the working principles of the energy system. This is reinforced by research (Staikova, 2025) which states that block-based robotics learning can significantly improve computational and problem-solving skills.

However, the results of the teacher need analysis show that the integration of STEM-robotic in learning still faces various obstacles, including limited facilities, lack of teacher training, and the unavailability of teaching materials such as LKPD specifically designed to guide STEM-robotic learning. As many as 100% of teachers stated that they need project-based LKPD that facilitates experimental activities, the use of robotics, and problem-solving in the context of renewable energy. This shows the urgency of developing innovative LKPDs that can integrate concept understanding with hands-on learning experiences.

In addition, students showed a high interest in the use of robotic media in learning. As many as 88.5% of students stated that they were interested in learning to use robotics, but 73.1% had never used it in learning. These findings show an inequality between high interest in technology and lack of implementation of technology in learning. Thus, the development of STEM-based renewable energy LKPD can be the right solution to improve concept understanding, scientific thinking skills, and technological literacy skills of junior high school students

Based on this need analysis, the development of STEM-based renewable energy LKPD is very relevant and necessary. This LKPD is expected to be able to help teachers carry out project-based learning, provide an interesting experimental experience for students, and increase an in-depth understanding of renewable energy concepts through the integration of technology and robotics activities. Therefore, this study aims to analyze the needs of students and teachers as the basis for the development of innovative, contextual, and appropriate LKPD developments.

METHOD

Research Design and Procedures

This study employed a qualitative descriptive design to explore teachers' and students' needs regarding the development of a STEM-based student worksheet (LKPD) assisted by block programming on renewable energy topics. A qualitative descriptive approach was selected because it enables researchers to obtain a comprehensive understanding of participants' experiences, perceptions, and instructional needs within their natural educational setting. The study was conducted as part of the Define stage of the 4D development model (Thiagarajan et al., 1974), which focuses on identifying learning problems, learner characteristics, and instructional requirements prior to product development.

The research was carried out at SMP Negeri 3 Sungai Raya, Indonesia. Preliminary observations and interviews with science teachers indicated that renewable energy learning was still predominantly theoretical, learning activities had not integrated robotics or coding, and teachers experienced difficulties in implementing block programming due to limited technological skills and infrastructure. At the same time, students demonstrated strong interest in technology-based learning and renewable energy applications.

Data were collected through classroom observations, semi-structured interviews, questionnaires, and documentation. Classroom observations were conducted to identify existing instructional practices and learning constraints. Semi-structured interviews were carried out with science teachers and students to explore their experiences, expectations, and challenges related to STEM learning, renewable energy instruction, and the integration of block programming. Questionnaires were administered to obtain supporting data regarding students' learning interests, conceptual understanding, experiences with educational technology, and teachers' perceptions of technology integration in science learning. Documentation, including photographs, field notes, and learning artifacts, was used to strengthen the findings.

To ensure instrument validity, the questionnaire and interview protocols were evaluated by experts using Aiken's V coefficient. The obtained validity values indicated that all instrument items met the acceptable validity criteria before being administered in the field. Data trustworthiness was established through methodological triangulation involving observations, interviews, questionnaires, and documentation. In addition, qualitative coding was conducted independently by two researchers, and inter-rater agreement was calculated to enhance the credibility and consistency of the thematic findings.

Data analysis followed the interactive model proposed by Miles, Huberman, and Saldaña (2014), consisting of three stages: data reduction, data display, and conclusion drawing/verification. During data reduction, relevant information related to learning needs, technological readiness, and STEM implementation was selected and categorized. The organized data were then displayed in thematic matrices to facilitate interpretation. Finally, conclusions were drawn and continuously verified through comparison across multiple data sources. This process enabled the emergence of major themes, including the limited implementation of robotics and coding in science learning, teachers' difficulties in using block programming, students' positive attitudes toward technology-based learning, and the need for STEM-integrated learning materials on renewable energy.

Population and Sample

The participants of this study consisted of Grade IX students and science teachers at SMP Negeri 3 Sungai Raya. Participants were selected using purposive sampling because they possessed direct experience related to renewable energy learning and technology-based instructional activities. The student participants comprised 52 Grade IX students who had studied renewable energy topics, while the teacher participants consisted of eight science teachers responsible for teaching science subjects.

Purposive sampling was chosen because qualitative research prioritizes information-rich participants who can provide relevant and in-depth insights into the investigated phenomenon rather than statistical representativeness. The selected participants were therefore considered appropriate for identifying instructional needs and challenges associated with the development of a STEM-based LKPD assisted by block programming for renewable energy learning.

Data Collection and Instrument

Data was collected through questionnaires, interviews, and documentation. The questionnaire instrument for the needs of teachers and students was developed based on learning needs indicators which include learning interests, concept understanding, experience using robotic media and block programming. The questionnaire consists of closed-ended and open-ended questions to provide a comprehensive picture of the respondents' needs. The justification for the use of questionnaires is supported by Riduwan's (2016) research which states that questionnaires are effectively used to obtain perception data in a large number of respondents. In addition, semi-structured interviews were conducted with several teachers and students to explore information that could not be captured through questionnaires. Semi-structured interviews are recommended by Sugiyono (2016) because they are flexible and allow for in-depth exploration. Documentation in the form of photos of activities, observation results, and captures of the use of block programming in media prototypes are also used as supporting data. The use of block programming as an object of study is reinforced by the findings Lohakan & Seetao (2024) which states that visual programming-based learning is effective in facilitating the learning process of renewable energy through robotic simulation and sensory control.

Data Analysis

Data analysis was carried out in a qualitative descriptive manner through three stages, namely data reduction, data presentation, and conclusion drawing as stated by Miles, Huberman, & Saldana (2014). The data obtained from the questionnaire was calculated using a frequency percentage to see the trend of teacher and student needs. Furthermore, the data was analyzed to identify patterns of needs, learning barriers, technological readiness, and opportunities for the implementation of block programming in renewable energy learning. Qualitative analysis is used to interpret open-ended answers from questionnaires and interviews, so as to obtain a more comprehensive understanding of learning conditions. This approach is in line with the findings Putra et al., (2023) that qualitative descriptive analysis is effectively used in research on the development of STEM-based teaching materials to map initial needs. The results of this analysis are then used as the basis for compiling an initial design of LKPD assisted by block programming – robotics that is relevant to the needs of teachers and students.

RESULT AND DISCUSSION

Analysis of the needs for the development of Student Worksheets assisted by block programming – STEM-based robotics on renewable energy materials was obtained through I observation. Observations were made on 52 grade IX students who had learned on renewable energy materials, as well as 8 teachers teaching science. The results of the study are obtained in the following table.

Table 1. Results of Student Needs Analysis

No.	Analysis Questions
1	57.7% of students prefer physics learning done with real experiments
2	71.2% of students prefer assignments in the form of experiments rather than working on problems
3	57.7% of renewable energy learning processes on books and whiteboards
4	44.2% of students have never conducted renewable energy experiments
5	73.1% of students have never used robotic media in lessons
6	Only % of students have a sufficient understanding of renewable energy
7	44.2% of students have difficulty learning because there is no real experiment; 15.4% consider learning too abstract and noteworthy; 15.4% consider learning media to be less attractive; and 25% think learning is not as closely linked to real life
8	78.8% of students find it difficult to understand the concept of renewable energy, because the teaching aids cannot visualize the renewable energy process (19.2%), and learning is not interesting (2%)
9	25% of students are confused that learning renewable energy is associated with daily problems
10	88.5% of learners are interested in coding-robotics-based learning
11	69.2% of students have computer skills
12	61.5% of students think that if learning is done with robotic media, it will be more exciting and interesting; 19.2% will easily understand the concept and 15.4% can see the real application of the renewable energy process
13	88.5% of participants are interested in coding-robotics-based renewable energy learning with STEM-based LKPD

Table 2. Results of Teacher Needs Analysis on Learning Strategy Aspects

Question	Answer Options	Percentage of Answers
How do you teach physics, especially renewable energy materials?	Lectures and discussions	0%
	Practicum in the Laboratory	0%
	Technology-based learning media	100%
What learning media do you often use in renewable energy learning?	Package book and workbook	25%
	Learning videos	37,5%
	Medium medium	12,5%
	Simple experiments	12,5%
	Computer simulation	12,5%
Does the learning media used effectively visualize renewable energy processes?	Yes, the media can visualize the process of renewable energy	75%
	Not	25%

Based on the results of the questionnaire on teacher needs in terms of learning strategy, all respondents (100%) have used technology-based learning media in teaching renewable energy materials. These findings show that teachers have readiness to integrate digital technology into learning. However, the types of technology used are still diverse and tend to be simple. The dominance of learning videos shows that technology practices are still at the level of information presentation, not yet reaching the stage of interactive exploration or digital experimentation.

As many as 75% of teachers stated that the media used could visualize the renewable energy process, but another 25% revealed that the visualization had not fully provided students with a comprehensive understanding of the concept. This condition indicates that existing media do not provide a hands-on, interactive, and problem-solving learning experience, as emphasized in STEM-based learning.

Scientific justification shows that interactive media such as robotic and block programming have been shown to improve students' concept understanding, learning motivation, and high-level thinking skills (Arafat et al., 2024). In addition, technology-integrated STEM learning is considered effective in helping students represent abstract phenomena such as renewable energy systems through digital or physical models (Ainiyatul Azizah, 2025). Therefore, teachers urgently need LKPD that is able to combine technology, visualization, experimentation, and simple programming to deliver a more meaningful learning experience.

This finding is supported by previous studies in Jurnal Pembelajaran Fisika, which demonstrated that STEM-integrated worksheets can facilitate students' conceptual construction and increase engagement in inquiry-based activities. Interactive learning resources that combine experimentation and technology have been shown to strengthen students' ability to relate physics concepts to real-world phenomena and improve learning effectiveness in science classrooms (Pratama et al., 2023; Nisa et al., 2024).

The findings indicate that although teachers have utilized various technology-based learning media, most instructional practices still rely on videos, textbooks, and presentation materials. These media provide information but offer limited opportunities for students to directly explore renewable energy systems through experimentation. Consequently, students often encounter difficulties in understanding abstract processes such as energy conversion, electricity generation, and system interactions within renewable energy technologies. Therefore, there is a need for more interactive learning resources that integrate experimentation, visualization, and problem-solving activities. STEM-based robotics assisted by block programming can address this challenge by enabling students to construct, observe, and control renewable energy models directly, thereby promoting deeper conceptual understanding and authentic scientific inquiry.

Table 3. Results of Teacher Needs Analysis on Media & Learning Resources Aspects

Question	Answer Options	Percentage of Answers
Are robotic-assisted LKPDs available in schools?	Available, rarely used	0%
	Available and frequently used	0%
	Not available	100%
If available, are you interested in using robotic-assisted STEM-based LKPDs for renewable energy?	Very interested	100%
	Not interested	0%

The results of the questionnaire showed that 100% of teachers stated that robotic-assisted LKPD was not yet available in schools, so the renewable energy learning process still relied on conventional learning resources such as books and regular exercise sheets. This condition emphasizes the low availability of technology-based learning media in schools, especially media that allows the exploration of concepts through hands-on practice. The absence of robotic LKPD results in theoretical learning and has not been able to present inquiry-based and experiment-based learning experiences that meet the demands of 21st century learning.

Nevertheless, all respondents (100%) stated that they were very interested in the availability of robotic-assisted STEM-based LKPD for renewable energy materials. The high enthusiasm of these teachers shows that there is an urgent need for innovative learning media, especially those that are able to visualize the concept of renewable energy in a concrete and iterative manner through robotic technology and block programming. Very high interest is also in line with increasing students' interest, understanding of concepts, and problem-solving skills (Rapti et al., 2025).

In addition, global trends show that the integration of robotics and block programming in science learning supports technology literacy, computational thinking, and 21st century skills (Ouyang & Xu, 2024). This reinforces the argument that the development of robotic-assisted LKPDs is not relevant, but also important to improve the quality of renewable energy learning at the junior high school level.

Table 4. Results of Teacher Needs Analysis on Facilities / Infrastructure Aspects

Question	Answer Options	Percentage of Answers
Are there computers in schools that support ICT learning?	Available, and frequently used	75%
	Available, rarely used	12,5%
	Not available	12,5%
Do school facilities support robotic coding learning?	Yes	25%
	Not	75%

Table 5. Results of Teacher Needs Analysis on Aspects of Technology & STEM Integration

Question	Answer Options	Percentage of Answers
In your opinion, to what extent is ICT integrated into science learning, particularly renewable energy topics?	ICT has not been implemented in physics learning	37,5%
	ICT has been implemented but not coding-based learning – robotic	62,5%
Have you ever taken a robotic learning coding training?	Yes	50%
	Not	50%
Have you ever used Block Programming while learning?	Often applied in learning	0%
	I've tried but haven't been able to get it right	0%
	I don't know about the prigram discussion	100%
Have you ever used robotic media in learning?	Yes	0%
	No	100%

The results of the questionnaire show that the availability of technology devices in schools is still not optimal to support ICT-based learning and coding – robotic (Table 4). Most schools have computers and use them regularly (75%), but only 25% of teachers consider that these facilities actually support coding-robotic learning. This condition reflects the gap between the availability of devices and the readiness of supporting infrastructure such as software, network, and user competencies. The lack of robotic supporting facilities has the potential to hinder the implementation of innovative STEM-based learning, which requires computational, sensory, and robotic media devices as a means of concept exploration (Ouyang & Xu, 2024).

The findings also reinforce the results of previous research that confirmed that the success of STEM-robotic learning is greatly influenced by the readiness of facilities and infrastructure, including adequate computer equipment, ICT laboratory space, and access to advanced technology (Arafat et al., 2024). The tendency of facilities causes teachers to tend to use simple lecture methods or media, rather than implementing project-based learning that demands the use of technology (Allita Marsya, Anwar Syafi'i, 2022). In addition, the low support of robotic facilities is in line with reports that schools in Indonesia are still in the early stages of integrating smart technology in learning practices (Riskawat et al., 2025), so that the implementation of STEM – robotics requires more adequate support of facilities. Thus, the results of this questionnaire indicate the need to strengthen school infrastructure to promote block programming-robotic-based renewable energy learning, because the availability and readiness of facilities are the determining factors for improving the quality of technology-based science learning.

The results of the teacher needs questionnaire show that the implementation of ICT and robotics in renewable energy learning is still very low (Table 5). As many as 37.5% of teachers stated that ICT has not been implemented, while 62.5% stated that ICT has been used but not based on coding – robotics. This shows that the use of technology is still limited to the use of simple media or learning videos, not yet to the stage of integration of computational thinking or block programming recommended in science learning 21.

In addition, 50% of teachers have never participated in robotic coding training, and 100% of teachers are not familiar with block programming, so teachers' skills are an inhibiting factor in the implementation of technology-based learning media. This lack of experience or training is in line with the finding that 100% have never used robotic media in renewable energy learning. This condition reinforces that schools do not yet have a robotic and block programming-based learning ecosystem.

These findings are consistent with previous research that states that teacher readiness is a key factor in the successful implementation of STEM – robotics (Arafat et al., 2024). The duration of the training also has an impact on the low adoption of new technologies in learning (Riskawat et al., 2025). The implementation of STEM-based LKPD assisted by block programming and robotics in schools remains challenging due to a combination of infrastructural and pedagogical constraints. Although this approach has considerable potential to enhance students' conceptual understanding, problem-solving abilities, and digital literacy, its adoption is often hindered by limited technological resources, including inadequate robotics equipment, insufficient computer facilities, and unreliable internet access required to support programming and robotics activities (Riskawat et al., 2025). In addition, teacher readiness continues to be a significant concern, as opportunities for professional development related to robotics, coding, and STEM integration remain limited, resulting in a lack of confidence and competence in implementing technology-rich learning environments (Arafat et al., 2024). The persistence of conventional instructional practices, which are largely dependent on textbooks and teacher-centered explanations, further restricts students' opportunities to engage in inquiry, exploration, and project-based learning activities. As reported by Addido et al. (2023), the limited integration of interactive and technology-supported learning media may reduce student engagement and constrain the effectiveness of science instruction. Therefore, while the development of a block programming–assisted STEM robotics LKPD is pedagogically relevant and responsive to contemporary educational needs, its successful implementation requires adequate technological infrastructure, continuous teacher professional development, and institutional support that encourages the integration of innovative STEM-oriented learning practices in science classrooms.

The findings also have broader implications for science laboratory effectiveness in Indonesian schools. The limited availability of laboratory equipment often restricts students' opportunities to conduct meaningful investigations of renewable energy phenomena. Robotics integrated with block programming can function as an alternative laboratory medium that enables students to design experiments, collect data, test engineering solutions, and observe energy transformation processes in a more accessible manner. Consequently, the proposed STEM-based LKPD may not only enhance conceptual understanding and technological literacy but also strengthen the effectiveness of laboratory-oriented science learning by providing interactive and inquiry-driven learning experiences even in schools with limited conventional laboratory facilities.

CONCLUSION

The findings of this study reveal a substantial need among both teachers and students for the development of a STEM-based LKPD assisted by block programming and robotics in renewable energy learning. Teachers consistently reported that robotic-based LKPDs have not yet been available in their schools and that the integration of information and communication technology (ICT) into classroom instruction remains limited. At the same time, students expressed considerable interest in coding and robotics activities and emphasized the need for learning media capable of illustrating renewable energy concepts in a more concrete and understandable manner. These findings suggest that learning practices that rely primarily on textbooks and instructional videos are insufficient to provide the interactive, investigative, and project-based experiences required to support twenty-first-century learning.

From a theoretical perspective, the results support the relevance of STEM education, Constructionism theory proposed by Papert, and Computational Thinking theory introduced by Wing as foundations for designing meaningful learning experiences. The strong demand for robotics-based activities indicates that students learn more effectively when they actively construct knowledge through exploration, programming, and hands-on experimentation. Furthermore, the use of block programming offers an accessible entry point to computational thinking by minimizing the complexity of coding syntax while encouraging problem-solving and logical reasoning. Therefore, the development of a STEM-oriented LKPD assisted by block programming is theoretically well grounded, as it integrates scientific inquiry, engineering practices, and digital literacy within a single learning framework.

The findings also reveal several practical challenges that may hinder the implementation of robotics-based learning, particularly limited technological facilities and inadequate teacher preparation. These conditions should be carefully considered during the development process. Consequently, the proposed LKPD should incorporate several essential features, including guided block-programming activities, interactive simulations that can be utilized in schools with limited access to robotics equipment, conceptual diagnostic tasks to identify and address misconceptions, and teacher-support components such as programming tutorials, implementation guidelines, and troubleshooting instructions. Such features are expected to increase the usability and adaptability of the LKPD across schools with different levels of technological readiness.

Despite these contributions, the present study was limited to the needs analysis stage within the Define phase of the 4D development model. As a result, the effectiveness of the proposed LKPD has not yet been examined in actual classroom settings. Future studies should focus on developing and validating a complete LKPD prototype, followed by iterative implementation in various school contexts. Further investigation is also needed to evaluate its impact on students' conceptual understanding of renewable energy, STEM-related competencies, computational thinking skills, and problem-solving abilities. In addition, longitudinal research may provide valuable insights into the extent to which sustained engagement with robotics-based learning influences students' interest in and aspirations toward science and technology careers.

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