Renewable Energy Science Literacy for Elementary School Students for Ecological and Social Awareness

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Abstract

The global energy crisis, driven by fossil resource depletion, heavy dependence on non-renewable energy, and the impacts of climate change, highlights the urgent need for a transition toward renewable energy. Primary education holds a strategic role in shaping students' character, critical thinking, and ecological awareness from an early age. Science literacy, which includes the ability to understand, evaluate, and apply scientific concepts, serves as a crucial foundation to address the complexity of energy and environmental issues. However, Indonesia's elementary curriculum has not yet fully optimized the integration of renewable energy materials and remains dominated by lecture-based approaches, leaving students with theoretical knowledge without developing deeper ecological awareness. This study adopts a qualitative descriptive method to analyze the urgency of enhancing renewable energy science literacy in primary schools. Findings reveal that contextual, interactive, and problem-based learning can significantly improve science literacy while fostering students' social responsibility in energy use. Thus, renewable energy education emerges as a strategic means to cultivate environmentally responsible global citizens.

1. Introduction

The global energy crisis has emerged as one of the most critical challenges in the 21st century. The depletion of fossil resources such as oil, gas, and coal, coupled with excessive reliance on non-renewable energy, has intensified the impacts of climate change. Fossil fuel combustion releases greenhouse gases that significantly contribute to global warming. The consequences extend beyond rising global temperatures, triggering extreme weather, sea level rise, and ecosystem disruptions that ultimately threaten human survival. This reality demands an urgent transition to renewable energy sources that are cleaner, more sustainable, and environmentally friendly. Renewable resources such as solar, wind, hydro, and biomass are regarded as strategic solutions to reduce fossil fuel dependence while tackling climate change. In Indonesia, renewable energy holds vital relevance considering the nation's vast natural potential. Despite this abundance, utilization remains suboptimal (Langer et al., 2021).

One key barrier is the low level of public energy literacy. Limited awareness about efficient energy use and the need for transition to clean energy hampers progress. The situation is further reflected in Indonesia's lagging performance in the Programme for International Student Assessment (PISA), which indicates that Indonesian students' science literacy is still below the OECD average. This underscores the urgent necessity to enhance science literacy, particularly in renewable energy, starting from the basic education level. Primary schools serve as the foundation for shaping character, cultivating critical thinking, and fostering ecological awareness. At this stage of cognitive development, children learn best

through concrete experiences and hands-on exploration. Instilling renewable energy science literacy in primary education is therefore not limited to knowledge acquisition but also involves shaping environmentally responsible attitudes and behaviors. In the long run, this becomes an investment in nurturing a generation that is environmentally conscious and capable of facing future global challenges (Emina, 2021).

Science literacy within the context of renewable energy encompasses the ability to understand relevant scientific concepts, evaluate information critically, and make informed decisions based on evidence (Rico et al., 2021). This includes the capacity to explain scientific phenomena such as the conversion of solar energy into electricity through photovoltaic panels assess the credibility of scientific information, and apply knowledge to daily life situations. Equipping students with these skills encourages ecological awareness, strengthens critical thinking, and builds sustainable energy practices from an early age. Nevertheless, the current Indonesian primary school curriculum has not yet fully integrated renewable energy concepts and science literacy in a comprehensive manner. Many schools continue to adopt conventional lecture-centered methods that fail to engage students actively. As a result, students often grasp concepts only at a theoretical level without understanding their real-world applications. In contrast, contextual and experiential learning approaches are essential to demonstrate the relevance of renewable energy to daily life. Simple activities, such as building a mini wind turbine or observing solar panel applications, provide direct experience that not only makes learning enjoyable but also trains students' scientific inquiry skills.

In line with modern pedagogical trends, education requires an active, contextual, and problem-based approach that involves students directly in the learning process. Models like Problem Based Learning (PBL) and Project Based Learning (PjBL) have shown effectiveness in enhancing science literacy. For example, PBL encourages students to investigate real-world problems through inquiry, collaboration, and reflection (Chen, 2021). When renewable energy materials are connected to everyday contexts, students not only achieve a deeper understanding of scientific concepts but also develop ecological awareness and social responsibility. Based on these considerations, this study emphasizes the urgency of improving renewable energy science literacy among primary school students. The research seeks to explore renewable energy as a contextual and meaningful learning resource, while examining the potential of active learning models to strengthen students' scientific literacy skills. By integrating renewable energy education effectively, primary schools can prepare future generations with the knowledge, awareness, and responsibility

2. Literature Review

2.1. Science Literacy and Renewable Energy in Basic Education

literacy is an individual's ability to understand, evaluate, and apply scientific concepts in daily life. This definition is not limited to theoretical knowledge, but also includes critical thinking skills, problem-solving, and science-based decision-making. According to Ke et al. (2021), science literacy plays an important role in equipping students with the ability to explain scientific phenomena, design investigations, and

interpret data and scientific evidence. In the context of basic education, science literacy is very crucial because it forms the foundation of knowledge while instilling a scientific attitude and ecological awareness from an early age.

Renewable energy is a very relevant topic in the development of primary school students' science literacy. This is because renewable energy has a direct connection to daily life, such as the use of solar panels, wind turbines, or biogas from household waste. Through the introduction of these concepts, students can directly observe how energy can be generated from environmentally friendly natural resources. This learning is applicative and contextual, so renewable energy can function as a "living laboratory" for students. For example, simple activities such as making a mini waterwheel or observing the process of heating water with sunlight can be a means to hone students' scientific skills. Thus, renewable energy material has great potential to develop science literacy while building the ecological awareness of primary school students.

2.2. Active Learning Models for Improving Science Literacy

Various previous studies show that active learning models can significantly improve students' science literacy. The Problem Based Learning (PBL) model is one of the most widely used approaches. Lin and Tsai (2021) found that the application of PBL can increase student activity and learning outcomes, as well as strengthen science literacy skills. Similar findings were revealed by Pradana et al. (2020) who stated that PBL provides a significant increase in the aspect of science process skills. Banda and Nzabahimana (2021) added that the integration of PBL with digital simulations such as PhET can be more effective in training the ability to interpret

scientific data. Besides PBL, the Project Based Learning (PjBL) model also has great potential in improving science literacy.

Through projects that emphasize real problem-solving, students are actively involved in the planning, implementation, and evaluation of learning. Rachman (2020) confirmed that PBL can increase students' environmental awareness, while Kahar et al. (2018) showed that problem-based learning assisted by Student Worksheets (LKPD) is also able to improve science literacy despite facing a number of challenges. Lestari and Rahmawati (2020) added that both the direct use of PBL and its integration with other methods show positive potential in improving students' science literacy. Based on the results of these studies, it can be concluded that science literacy, especially in the context of renewable energy, requires an active, contextual, and applicative learning approach. Learning models such as PBL and PjBL allow students to not only understand concepts, but also build critical thinking skills and ecological awareness. Therefore, renewable energy science literacy in primary school students should be integrated through innovative and student-centered learning strategies, not just mastery of theoretical material.

3. Methods

This study uses a qualitative descriptive approach because it aims to describe in depth the phenomenon of improving renewable energy science literacy in primary school students. This approach was chosen so that researchers can explore the experiences, perceptions, and learning practices that occur in the classroom naturalistically, without manipulating variables. With the qualitative method, the data

obtained is more narrative and reflective, so that it can reveal the meaning of each learning event in its actual social context. In addition to students, class teachers are also key informants because they have a central role in designing, implementing, and evaluating learning. Thus, data is obtained from two main sources, namely students as learners and teachers as learning facilitators.

Data collection was carried out through several techniques. First, direct observation was carried out in the classroom to observe the science learning process, especially on renewable energy material. Observations focused on student involvement in learning activities, the use of learning methods, and the interaction between teachers and students. Second, semi-structured interviews were conducted with teachers to explore in depth their perceptions about the importance of science literacy, their experience teaching renewable energy, the challenges they faced, and the strategies they used. Third, documentation in the form of learning notes, lesson plans (RPP), and student work results were collected to enrich the research data.

The data obtained was then analyzed using the interactive qualitative analysis technique of the Miles and Huberman model. This analysis consists of three stages, namely data reduction, data presentation, and conclusion drawing/verification. In the data reduction stage, researchers select and focus data that is relevant to the research focus. The data presentation stage is carried out in the form of a narrative description that describes the learning phenomenon as a whole. The final stage is drawing conclusions by interpreting the meaning of the analyzed data, so as to produce valid and reliable findings. To ensure the credibility of the data, researchers

used source and method triangulation techniques. Source triangulation was carried out by comparing information from students, teachers, and observation results.

Meanwhile, method triangulation was carried out by combining observation, interviews, and documentation. Thus, the research results are expected to have strong validity and provide a comprehensive picture of the urgency of improving renewable energy science literacy in primary schools. This qualitative descriptive approach allows the research to not only assess the extent to which science literacy has been integrated into renewable energy learning, but also to understand the inhibiting and supporting factors in its implementation. The results of this study are expected to provide significant input for the development of curricula and learning strategies in primary schools to be more responsive to the needs of the 21st century, especially in preparing a generation that is science-literate, ecologically aware, and responsible for energy use.

4. Results and Discussion

The results of this study indicate that the condition of primary school students' science literacy, especially in the context of renewable energy, still faces significant challenges. Based on observations in the classroom, students did show enthusiasm when introduced to the concept of renewable energy through concrete examples such as solar panels, mini wind turbines, and simple biogas. However, this enthusiasm has not been fully facilitated with appropriate learning methods. Teachers tend to use lecture methods that focus on conveying information, so students only understand the concept superficially without having enough

opportunity to carry out exploration and scientific investigation. This condition is in line with the initial findings from interviews with teachers, who stated that limited facilities, time, and pedagogical training are obstacles in implementing active problem-based learning.

The curriculum in place in schools also has not integrated renewable energy literacy optimally. Energy material is still treated as a small part of science lessons, without special emphasis on broader science literacy (Kinslow et al., 2019). As a result, students mostly memorize the definitions of energy, energy sources, and the advantages and disadvantages of renewable energy without understanding the connection of these concepts to real life. For example, when students are asked about how solar panels generate electricity, most only answer that "solar panels convert sunlight into electricity" without being able to explain the energy conversion process that occurs. This shows a gap between factual knowledge and a deeper conceptual understanding.

In terms of student participation in learning, the observation results show that students are more interested when the teacher provides practical activities that involve direct experience (Sormunen et al., 2020). For example, when the teacher brought a mini solar panel to light a small LED lamp, students showed high curiosity by asking various questions. They were also interested in trying for themselves how light affects the lamp's light. This proves that renewable energy can be a contextual learning material as well as stimulating students' curiosity, as long as it is presented with the right approach.

Interviews with teachers show an awareness that conventional learning methods are no longer adequate to develop comprehensive science literacy. Teachers realize the importance of active learning models such as Problem Based Learning (PBL) or Project Based Learning (PjBL), but they still face limitations in terms of knowledge and skills to implement these models. Teachers also mentioned limited facilities as a major obstacle, for example, the lack of renewable energy props that can be used in simple practical activities. As a result, teachers prefer lecture and question-and-answer methods, which are considered more practical even though they are less effective in developing students' scientific skills.

Documentary data in the form of student work results also shows that their ability to explain scientific phenomena is still limited. Most students are only able to write short answers without in-depth explanations. For example, when asked to explain how a windmill generates energy, many students only answer "because the wind turns it" without being able to connect it to the principle of kinetic energy being converted into mechanical energy and finally electrical energy. This shows that students are not used to connecting scientific concepts with more complex causal explanations.

These findings are consistent with previous research which states that the application of the PBL model can significantly improve students' science literacy skills. Anwar and Jurotun (2019) and Shofiyah and Wulandari (2018) emphasized that PBL is effective in increasing learning activities as well as students' critical thinking skills. Pradana et al. (2020) also found that the aspect of science process skills is the aspect that experiences the highest increase when students are taught

with the PBL model. Banda and Nzabahimana (2021) further showed that the use of digital simulations such as PhET can strengthen the ability to interpret data and scientific evidence, which is one of the important indicators of science literacy. These findings strengthen the argument that the integration of renewable energy with active learning models can be a strategic solution to improve the quality of primary school students' science literacy.

In addition, research by Rachman (2020) shows that PBL not only improves science literacy, but also fosters students' environmental awareness. This finding is relevant to the urgent need to form a generation that has ecological awareness from an early age. Kahar et al. (2018) added that even though the application of PBL assisted by LKPD faces several obstacles, this model still provides a significant increase in students' science literacy. Lestari and Rahmawati (2020) confirmed that both PBL integrated with technology and without integration still provide positive results on science literacy skills. Thus, the results of this study are in line with previous findings that emphasize the effectiveness of active learning models in improving science literacy.

The results of this study also indicate a close link between science literacy and students' ability to make fact-based decisions regarding energy and environmental issues (Murphy et al., 2021). When students are invited to discuss the best energy source choices for the future, most students tend to choose renewable energy such as solar and wind power because it is considered environmentally friendly. However, when asked to provide reasons, they still find it difficult to elaborate on the scientific evidence that supports their opinion. This shows that students' science literacy is still

at a basic level, where they are able to identify issues but are not yet able to evaluate information critically. Discussions on the role of the curriculum in supporting renewable energy science literacy also revealed that the current curriculum is not yet responsive enough to the needs of the 21st century. The curriculum tends to emphasize the achievement of cognitive basic competencies, while aspects of critical thinking skills, problem-solving, and ecological awareness receive less attention. Teachers argue that the integration of renewable energy material in the curriculum is still general and has not emphasized the development of comprehensive science literacy. Therefore, curriculum improvements are needed that not only add renewable energy material, but also encourage the use of innovative learning methods.

The results of this study show that the urgency of improving renewable energy science literacy in primary school students is very real. Science literacy is not just about understanding scientific concepts, but also about shaping a responsible attitude towards the environment. Renewable energy can be used as a relevant learning context to train students to connect science with real life. Problem-based and project-based learning have been proven effective in improving students' scientific skills while fostering ecological awareness. However, its implementation requires an adaptive curriculum, continuous teacher training, and the provision of adequate facilities.

The discussion of these findings also confirms that the success of renewable energy science literacy education in primary schools is highly dependent on the collaboration between teachers, schools, and educational policymakers. Teachers

need to be supported with appropriate pedagogical training so that they can implement active learning effectively. Schools need to be equipped with simple teaching aids and experimental facilities that allow students to learn contextually. Meanwhile, the national curriculum needs to be redesigned to emphasize the comprehensive integration of renewable energy literacy. Thus, education at the basic level can truly equip students with 21st-century skills that include critical thinking, ecological awareness, and social responsibility.

The results of this study ultimately underline that improving renewable energy science literacy is not just a matter of education, but also a long-term investment for the sustainability of the nation. A generation equipped with strong science literacy from an early age will be able to make wise decisions in energy use, actively participate in environmental conservation efforts, and contribute to the achievement of sustainable development. Therefore, the urgency of improving renewable energy science literacy in primary schools cannot be delayed, but must be implemented immediately through the synergy of various parties in the education system.

5. Conclusion

This study confirms that improving renewable energy science literacy at the primary school level is an urgent need to face the global energy crisis and environmental challenges. Science literacy not only functions as a cognitive ability to understand scientific concepts, but also as a means of shaping critical thinking, ecological awareness, and students' social responsibility from an early age. The research results show that students have high enthusiasm when introduced to

renewable energy through direct experience, but learning is still hampered by the dominance of lecture methods, minimal facilities, and the suboptimal integration of renewable energy material in the curriculum. Problem-based learning (PBL) and project-based learning (PjBL) have been shown to have a significant impact on improving students' science literacy, especially in the skills of explaining scientific phenomena, designing investigations, and interpreting data.

Renewable energy as a teaching material has great potential to become a contextual, relevant, and meaningful learning context for primary school students. Therefore, an adaptive curriculum design, the provision of simple experimental facilities, and continuous training for teachers are needed to be able to implement active learning effectively. In conclusion, renewable energy science literacy in primary schools is not just an effort to increase knowledge, but a long-term investment to form a generation that cares about the environment, is wise in decision-making, and is ready to face the challenges of the 21st century. The synergy between teachers, schools, and educational policymakers is very much needed so that renewable energy literacy can be integrated comprehensively and sustainably in basic education in Indonesia.

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