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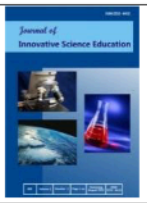

Strategies for Promoting Energy Literacy in Physics Education: Insights from a Systematic Literature Review

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Abstract

In physics education, fostering energy literacy is essential to equip students with the skills needed to navigate resource scarcity and environmental issues. By developing energy literacy, students are better prepared to manage energy consumption in a sustainable and sustainable manner. This research aims to explore effective strategies and approaches to improve students' energy literacy through the Systematic Literature Review (SLR) method. The study analyzed academic papers from reputable sources such as ScienceDirect, Taylor & Francis, Springer Nature, and ERIC, with a focus on publications from 2020 to 2024. Using keywords such as "energy literacy", "high school students", and "education", this analysis uncovers five main themes: student energy literacy, learning processes, social-scientific exhibitions, teaching modules, and learning media. Most research centers on understanding how students understand the concept of energy and what factors influence their understanding. Successful teaching strategies, including the use of social-scientific exhibitions to raise awareness of energy issues, as well as the development of energy-focused and sustainability-based teaching modules, were found to significantly improve student understanding. In addition, the use of technology-based learning tools has proven effective in conveying complex energy concepts. These findings point to new avenues for research, especially in integrating local wisdom into energy education. This study offers a new perspective on how incorporating local knowledge can improve energy literacy and deepen student engagement with sustainability efforts.

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INTRODUCTION

Energy literacy in physics education not only involves understanding key energy concepts but also cultivating attitudes and behaviors that promote responsible energy use (J.E. DeWaters & Powers, 2011). It is usually broken down into three main domains: cognitive, affective, and behavioral (Blasch et al., 2017). The cognitive domain includes knowledge of basic energy concepts, energy conversion, various energy resources, and the environmental and social impacts of energy consumption. The affective domain focuses on individual values, attitudes, and awareness regarding energy conservation and the development of alternative energy sources. Meanwhile, the behavioral aspects of energy literacy are related to the practical application of knowledge and attitudes in daily life, such as adopting energy-saving habits and making decisions that support sustainability.

Dwyer (2011) further highlights that energy literacy fosters a deeper understanding of the economic and social implications of energy use, motivating students to adopt sustainable energy practices. Similarly, J. E. DeWaters & Powers (2011) emphasize that individuals with high energy literacy can not only understand energy concepts and real-world applications but also recognize broader social, economic, and environmental consequences, making efforts to use energy more efficiently and contribute to sustainability. As a key factor in economic development and community welfare, energy literacy is essential to ensure that future generations can use energy in a wise and sustainable way. In addition, it strengthens an individual's ability to understand, implement, and take action on energy resources, their efficient use, and their environmental impact (J. DeWaters & Powers, 2013). It also includes awareness of energy consumption processes and the ability to seek detailed information on energy-related topics (Brounen et al., 2013).

The global and local challenges associated with the depletion of energy resources and the environmental impacts of energy use are pressing issues. Physics education plays an important role in shaping students' understanding of energy concepts and encouraging more responsible energy consumption behaviors (Usman & Huda, 2021; Khuc et al., 2023; Sianturi et al., 2024). However, research has shown that the energy literacy level of students in various countries, including Indonesia, is still relatively low (Alghamdi & El-Hassan, 2020; Kapas et al., 2021; Dangkua et al., 2022; Khuc et al., 2023; Usman & Huda, 2021; Yeh et al., 2017). Research by Dangkua et al. (2022) on 64 high school students in Gorontalo City, Indonesia, revealed that the level of cognitive energy literacy was dominated by very low, with 59.4% of students getting poor scores. Similarly, a study by Usman & Huda (2021) involving 184 students (95 boys and 89 girls) found that energy literacy among Indonesian junior high school students was in the middle category, with very low scores in the cognitive domain. Factors such as the lack of emphasis on energy literacy education and students' low awareness of energy issues have been identified as major contributors to this situation (Martins et al., 2020; Usman & Huda, 2021). Therefore, a more effective teaching strategy is needed to improve students' energy literacy.

The local wisdom-based approach offers a promising alternative to improving students' energy literacy. By integrating the social and cultural context of students' daily lives into the learning process, education can become more relevant and meaningful (Akitsu & Ishihara, 2019). Through incorporating local wisdom into physics education, students can bridge theoretical knowledge with practical sustainability practices rooted in their local communities. This approach is expected to not only improve energy literacy but also encourage sustainable behavior in daily life.

This research aims to explore strategies and approaches to improve students' energy literacy in physics education through a local wisdom-based approach and assess its impact on students' attitudes towards energy-related issues. By integrating the concept of energy with local knowledge, the research seeks to create contextual learning strategies that engage students with real-life experiences, promote conceptual understanding, and develop critical thinking and problem-solving skills. In addition, this approach is expected to increase student motivation and engagement.

The results of this research are expected to contribute to the development of more effective and meaningful learning methods that are in harmony with the local cultural context. In addition, this

research aims to increase students' awareness and sense of responsibility regarding energy sustainability while providing valuable insights to educators to design teaching strategies that foster sustainable behaviors in the future.

METHODS

In this study, the researchers used the Systematic Literature Review (SLR) method to collect and analyze various articles focusing on improving energy literacy. The SLR approach is specifically designed to thoroughly review a wide variety of research on a particular subject. To ensure credible and high-quality articles, the process begins with a comprehensive search through a trusted and accessible database (Prasetya, 2021). Once an article is found, inclusion and exclusion criteria are established to ensure only the most relevant and reliable sources are selected for further analysis.

The selected articles are then compiled in a narrative format to offer a detailed overview of various strategies and approaches to improve energy literacy. This method allows researchers to clearly identify key insights across various studies, helping to uncover trends and connections. By recognizing these patterns, they can show how different studies support each other. Descriptive analysis is then used to explain the findings clearly, providing a deeper understanding of how these strategies have evolved over time.

Establishing inclusion and exclusion criteria is an important first step in the SLR process. These criteria help researchers narrow the literature to the most relevant sources, ensuring that the analysis remains focused on high-quality and credible material (Kulenović et al., 2021; Akbar & Arifin, 2023). Inclusion criteria are carefully selected to ensure the research meets specific requirements, such as being directly related to the topic, using good methodologies, and published within a specified time frame. On the other hand, the exclusion criteria are applied to remove sources that are irrelevant or do not meet the required standards. This step is crucial for handling large amounts of data and ensuring that research findings are accurate and credible. By carefully defining these criteria, researchers ensure research remains focused and high-quality from the start.

Table 1. Inclusion and Exclusion Criteria

Category	Inclusion	Exclusion
Publication and Time	Articles published in the last 5 years, namely from 2020 to 2024	Articles published before 2020, except for highly relevant studies
Type of Study	Empirical, qualitative, quantitative or mixed research	Opinion, editorial, or essay articles that have no empirical data.
Language	Articles written in English.	Articles are written in languages other than English.
Subject Relevance	Articles that discuss strategies or approaches to improve students' energy literacy, especially in the context of physics learning.	Articles not focusing on physics education or energy literacy.
Strategy Impact	Articles that measure the contribution of strategies or approaches to changing students' attitudes towards energy issues.	The study did not address the relationship between learning strategies and student attitude changes.
Accessibility	Articles with full access through trusted databases	Articles that are not available in full text or are abstracts only.
Journal Source	Articles from international journals indexed by Scopus or Sinta (ranked 1-3).	Articles from non-indexed journals or those in Sinta below rank 3.
Scope of Education	Articles that discuss high school education.	Articles that are not relevant to high school education.

The literature search for this study used several major databases, including ScienceDirect, Taylor & Francis, Springer Nature, and ERIC. This systematic approach is designed to ensure that only the most relevant and high-quality articles are selected for analysis. To further improve the search process, the researchers also used Publish or Perish software, which helps streamline access to various sources.

Keywords used in searches include "energy literacy," "high school students," and "education." Boolean operators are employed to refine the results, ensuring that the selected literature is well suited to the research objectives. These keywords were carefully chosen to reflect the primary focus of energy literacy studies in the context of secondary school education. By following this search strategy, this study was able to gather a collection of relevant literature to support its research objectives.

The entire literature search and screening process is visually summarized in the following diagram:

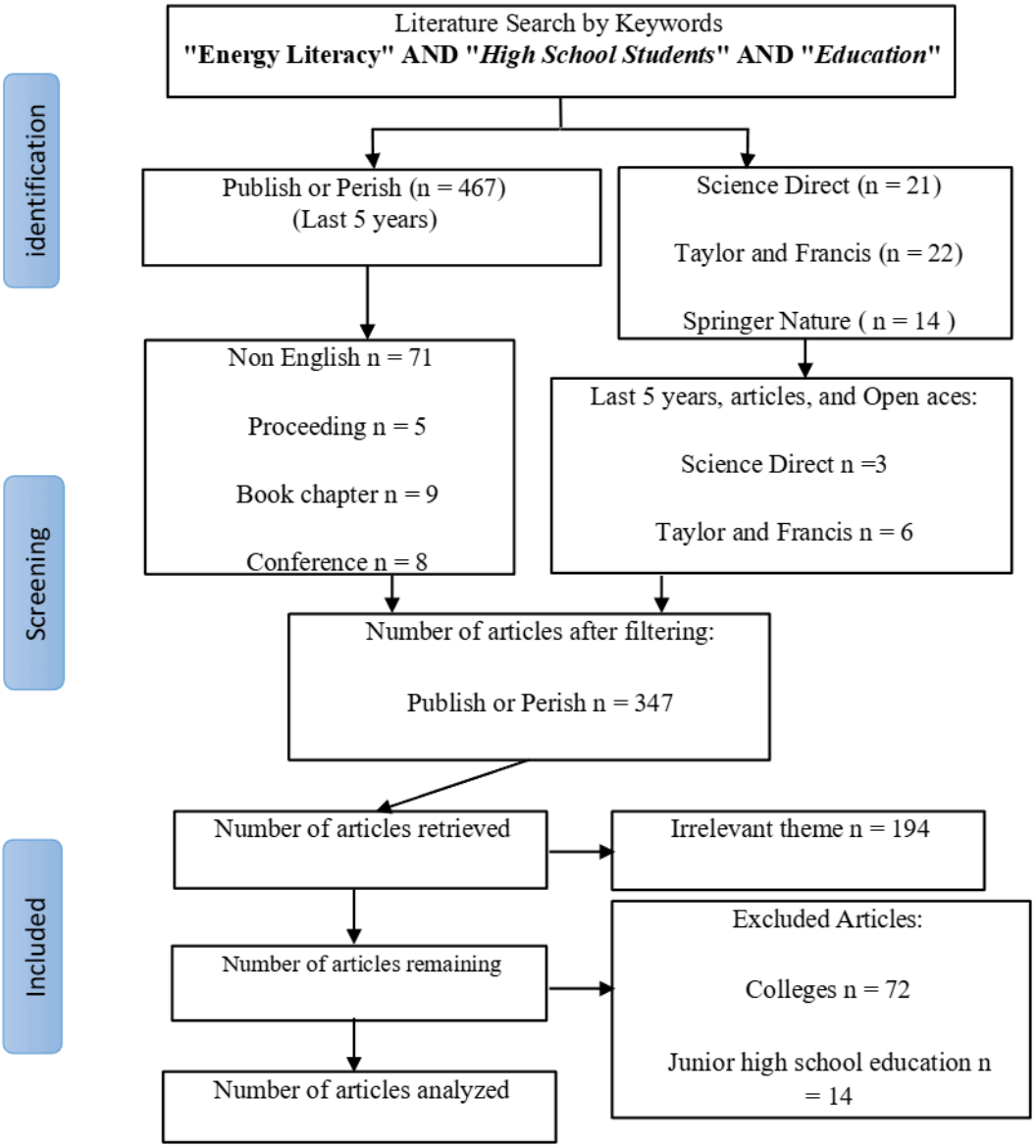

Figure 1. Literature Search and Screening Process Diagram

RESULTS AND DISCUSSION

As a result of the search process and the application of inclusion and exclusion criteria, as illustrated in the PRISMA diagram, 467 articles were retrieved from Publish or Perish and 59 articles from ScienceDirect, Taylor & Francis, Springer Nature, and ERIC. After the screening process, 357 articles remained, and following the eligibility assessment, 125 articles were selected. Articles focusing on high school education were included, while those related to elementary and junior high education, universities, teachers, and school principals were excluded. Ultimately, 12 of the most relevant articles were analyzed in depth to answer the research questions regarding strategies and approaches to improving high school students' energy literacy.

Table 2. List of Articles Analyzed

No.	Journal Name	Author and Year	Result
1	Journal of Environmental Education	Derek Gladwin, Carrie Karsgaard & Lynette Shultz (2022)	Cross-cultural collaborative learning facilitates interactions with diverse local experiences, helping students understand the global impacts of climate justice and energy and identify the drivers of energy-related injustice.
2	Environmental Education Research	Yi-Fang Lee, Huang Bao Ngoc Nguyen Hsiu-Te Sung (2022)	Students' energy knowledge remains relatively low, whereas their values, attitudes, intentions, and behaviors related to energy conservation tend to be high.
3	Sustainability 2023	Hyunjung Ji, Alexandria B. Coronado, Mark A. Mueller, Laurel J. Esposito, Daniel Tait and HyunJin Kim (2023)	Energy education programs enhance students' information-seeking behavior regarding energy-related topics, with virtual resources and family engagement playing a crucial role in energy literacy development.
4	Frontiers in Education	Sarah Kellberg, Jeffrey Nordine, Melanie Keller, Doris Lewalter (2023)	Environmental exhibitions that encourage exploration of identity and energy transitions can significantly increase students' willingness to adopt pro-environmental behaviors.
5	European Journal of Educational Research	Oziah Othman, Zanaton H. Iksan, Ruhizan Mohammad Yasin (2022)	CT-STEM modules have proven effective in creating engaging learning experiences while enhancing students' STEM skills and sustainability awareness.
6	Journal of Education and Learning Progress (JELA)	Kris Maiden L. Joyosa, Ericka Danielle S. Dimaala, & Albert Andry E. Panergayo (2024)	Environmental awareness contributes positively to energy literacy, with academic level and learning strategies being key influencing factors, rather than demographic variables.
7	Journal of Science Education Research (JPPIPA)	Ujang Sudrajat, Didit Ardianto, Anna Permanasari (2023)	The implementation of Engineering Design Process (EDP)-based learning can improve students' creative thinking skills, which are essential for globalization and 21st-century competencies, particularly in the context of alternative energy topics.

No.	Journal Name	Author and Year	Result
8	Journal of Science Education Research	Yanti Yuliarti, Leni Marlina, Sardianto Markos Siahaan, Apit Fathurohman, Sudirman (2023)	Students' critical thinking skills remain low due to limited literacy on renewable energy, lack of exposure to higher-order thinking problems, and traditional physics instruction with minimal experimentation.
9	Journal of Science Education Research	Fitri Azizah, Siti Nurul Khotimah (2024)	The PLTS (Solar Power Plant) prototype has been shown to be an effective learning tool, improving students' understanding of renewable energy concepts.
10	Journal of Science Education Research (JPPS)	Sri Astutik, Lu'luul Maknuniyah (2022)	The collaboration-based Cosheet strategy is effective in enhancing energy literacy and improving students' physics learning outcomes.
11	Journal of Science Education Research (JPPS)	Muhammad Satriawan, Rosmiati (2022)	The Simple Floating Ocean Wave Energy Converter is a viable learning medium for energy-related education.
12	Lifesci Newspaper	Talha Dangkua, Yulandi Mudutob, Apris Tilomek (2022)	Students' energy literacy is alarmingly low (59.4%), significantly influenced by parental educational background, as most parents are high school graduates.

Based on Table 2, the results of the author's identification regarding energy literacy revealed five main research categories: student energy literacy, learning process, socio-scientific exhibitions, teaching modules, and learning media. Student energy literacy emerged as a primary focus in many studies, addressing students' level of understanding of energy concepts as well as the factors influencing their energy literacy (Dangkua et al., 2022; Ji et al., 2023; Joyosa, K. M., Dimaala, E. D., & Panergayo, 2024; Lee et al., 2022; Yuliarti et al., 2023). In addition, research also highlighted the role of the learning process in enhancing students' comprehension of energy, particularly through effective teaching methods and strategies (Astutik & Maknuniyah, 2022; Gladwin et al., 2022; Sudrajat et al., 2023).

This aligns with studies on the effectiveness of socio-scientific exhibitions, which found that social science-based exhibitions can increase students' awareness of energy issues (Kellberg et al., 2023). Studies on the development of teaching modules have shown that materials focused on energy and sustainability can significantly improve students' understanding of energy literacy (Othman et al., 2022). In addition, research on educational tools has examined how different learning media effectively convey the concept of energy to students (Azizah & Khotimah, 2024; Satriawan & Rosmiati, 2022).

By categorizing these findings, this study was able to build a solid foundation to answer key research questions about strategies to improve students' energy literacy and its influence on students' attitudes towards energy-related issues. The following discussion will delve deeper into the purpose of the research, especially focusing on student energy literacy.

Strategies or Approaches to Improve Students' Energy Literacy

Findings from the research article on energy literacy and the different approaches used reveal some gaps, which offer an opportunity to explore alternative strategies to improve students' understanding of energy literacy. While much research has concentrated on STEM-based interactive learning methods, technologies, and tools, there has been little research that incorporates local wisdom into the energy literacy education framework.

Local wisdom, along with the cultural values and traditions associated with sustainable energy management, is an important aspect that requires more in-depth investigation in energy education (Sari et al., 2023; Verawati & Wahyudi, 2024). Traditional knowledge of green energy practices, such as the use of renewable energy sources by indigenous peoples, can serve as innovative models to improve students' understanding of energy sustainability.

By integrating local wisdom into energy literacy education, students are provided with a more contextual approach that resonates with their everyday experiences. This method not only strengthens their scientific understanding but also bridges theoretical concepts with practical applications in their daily lives (Sari et al., 2023; Verawati & Wahyudi, 2024). Although many studies emphasize the importance of STEM-based teaching methods and modern technological tools, there are still significant gaps in research that weave local cultural contexts and traditional knowledge into energy literacy learning. Learning models rooted in local wisdom can not only enhance students' knowledge but also inspire sustainable practices (Hidayati et al., 2020; Verawati & Wahyudi, 2024).

Local wisdom, embedded in time-honored cultural values and traditions, can be effectively integrated into energy literacy education. Doing so enriches students' understanding and fosters awareness of responsible energy resource management. Ongoing research in this area is expected to lay the foundation for creating a curriculum based on local culture (Chodkowska-Miszczuk et al., 2021; Sari et al., 2023; Verawati & Wahyudi, 2024).

The Impact of Changing Student Attitudes on Energy Issues

Analysis of the article shows that sustainability and environmental education can have a strong impact on students' attitudes and views on energy-related issues. The results show that hands-on approaches, such as energy-focused projects and student engagement in community-based activities, help foster positive attitudes towards sustainable energy management (Bakkaloğlu & Şimşek, 2021). Additionally, energy education programs that encourage students to seek information and engage in discussions significantly improve their environmental knowledge, better preparing them to take pro-environmental action (Ji et al., 2023). Additionally, social science-based exhibits have been found to be effective in improving students' perspectives on energy and sustainability (Kellberg et al., 2023).

The findings from the SLR point to gaps in research on how local wisdom can shape students' views on energy issues. Previous studies have highlighted that integrating local cultural values into energy education can help students develop a more meaningful and culturally relevant understanding of energy sustainability. Traditional practices, such as utilizing renewable energy sources and managing natural resources sustainably, provide students with a richer and more contextual understanding of energy challenges (Dangkua et al., 2022; Thanyajaroen & Phoochinda, 2023). As a result, incorporating local wisdom into energy education is seen as a way to increase students' awareness of energy issues, engage them in familiar and meaningful activities, and deepen their commitment to sustainability (LaCroix, 2022).

CONCLUSION

From the analysis and discussion, this study concludes that including environmental education and energy sustainability has a significant influence on students' attitudes towards energy-related issues. Hands-on approaches, such as project-based learning in a community setting, are highly effective in raising students' awareness and shaping their views on sustainable energy management. In addition, educational programs that encourage discussion and information-seeking activities help strengthen students' environmental awareness and motivate them to engage in pro-environmental action. The shift in attitudes is also supported by collaboration within the school community, which encourages students' active participation in discussions and initiatives around energy and sustainability.

The findings from the Systematic Literature Review (SLR) also show that there is a gap in research on the integration of local wisdom in energy education. By incorporating local cultural

values into energy education, students can gain a more relevant and contextual understanding of energy sustainability, which will resonate with their cultural backgrounds. Learning about traditional energy practices, such as sustainable resource management and the use of renewable energy in local communities, can help students develop a more responsible and proactive attitude towards energy consumption.

Therefore, future research focusing on integrating local wisdom into energy education is expected to encourage innovative, culturally inclusive, and sustainable educational approaches. This approach will not only enrich students' learning experiences but also equip them with practical knowledge to address energy challenges in a sustainable way.

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