

Scientific Literacy Competency Profile of Junior High School Students on Sustainable Energy

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Abstract. The increasing demand for sustainable energy solutions presents a critical challenge that necessitates the development of scientific literacy among students. In response to this challenge, it is essential to develop students' understanding of sustainable energy. This study aims to analyze the science literacy profile of junior high school students on sustainable energy materials. A descriptive quantitative study was carried out in August 2024 at a State Junior High School in Kediri Regency, East Java, Indonesia with a sample of 130 grade VIII students. The research instrument was validated literacy test categorized as highly valid, with a reliability score of 92.14%, encompassing three PISA science competencies. The results showed that the majority of students from the sample had science literacy at the basic level or it can be said that it is in the low category with an average score of 49.00, where Students can only search for information in the science texts presented. The science literacy profile in the three competencies was also low, with an average score of 45.50% to explain scientific phenomena, 35.40% to design and evaluate research and interpret data, and 40.00% to research, evaluate, and use scientific information in decision-making. In conclusion, the science literacy of junior high school students is relatively low in all aspects tested, indicating the need for improvement in science learning, especially on the topic of sustainable energy.

Keywords: science literacy profile, junior high school students, sustainable energy

Introduction

Science literacy is one of the goals in science learning. Science literacy is interpreted as an understanding of science and how to apply it in personal, local/national, and global contexts (Valladares, 2021). Science literacy can be measured by the results of student tests that can explain scientific phenomena, construct and evaluate designs for scientific investigation as well as interpret scientific data and evidence critically, research, evaluate, and use scientific information for decision-making and action (Rini et al., 2021). With good science literacy, students are expected to be able to make the right decisions in their daily lives related to increasingly complex science and technology issues (Washburn et al., 2023). Students' science literacy needs to be improved in order to be able to use science

concepts in their entirety and be able to take balanced and appropriate actions against problems in the disruptive era of the 21st century (Purnomo et al., 2023).

The Programme for International Student Assessment (PISA) is the most representative study in measuring science literacy which is held every three years by the Organisation for Economic Cooperation and Development (OECD) (Kemendikbudristek, 2023). Indonesia has always participated in PISA studies from 2000 to 2022. Indonesia's participation in the PISA study allows Indonesia to monitor the quality of its education over time, and compare it with other countries (Fadilah, 2024). Science literacy itself has three core science competencies based on the latest PISA framework, namely explaining scientific phenomena, constructing and evaluating designs for scientific investigations and interpreting scientific data and evidence critically, as well as researching, evaluating, and using scientific information for decision-making and action (OECD, 2023).

First, it explains scientific phenomena, which require individuals to apply scientific knowledge by interpreting data, making predictions, and evaluating the impact of scientific discoveries on society. Second, constructing and evaluating the design of scientific investigations. Individuals must be able to design, assess, and draw conclusions from scientific investigations by identifying research questions and proposing appropriate experimental designs. Third, researching and using scientific information for decision-making. This competency involves the ability to distinguish between valid scientific claims and misinformation, as well as understanding that science is a collective effort that supports sustainable development (OECD, 2023). This science literacy framework develops three important science competency indicators as a reference for evaluation (Deta et al., 2024). The framework also emphasizes the importance of understanding the nature of science, including how scientific knowledge develops and how science relates to technology, society, and the environment (Alhusni et al., 2024). Although Indonesia has always participated in PISA consistently, the science literacy of Indonesian students is still below the OECD average (Hafizha & Rakhmania, 2024).

In 2015, Indonesia recorded an average score of 403, far below the average PISA of 500. With a ranking that occupies the 62nd position out of 70 participating countries, this shows the great challenges faced by the Indonesian education system in developing science literacy among students (OECD, 2023). Entering 2018, Indonesia's average score has decreased to 379. However, the number of participating countries increased to 78, and Indonesia's ranking dropped to 71st place. This decrease in scores reflects the need for evaluation and improvement in science teaching and understanding in schools (Salamah, 2024). In 2022, Indonesia again recorded an average score of 383. Although this score shows a slight increase compared to the previous year, the overall PISA average has dropped to 485, which means that Indonesia is still struggling to meet international standards (Kamal et al., 2024). Indonesia's ranking this year is 67th out of 81 participating countries, showing that despite improvements, much needs to be done to improve the quality of science education (Yang et al., 2024). Overall, the results of the PISA study show that despite efforts to improve science literacy in Indonesia, the challenges are still significant. It is important for all stakeholders to work together in improving the quality of science education so that Indonesian students can be more competitive at the global level (Kemendikbudristek, 2023).

To measure students' science literacy skills, an assessment in the form of a comprehensive test is needed. This test not only measures mastery of science content, but also critical thinking skills, information analysis, and decision-making based on scientific evidence (OECD, 2023). The characteristics of the test include the use of authentic contexts, performance-based assessments, and the integration of various disciplines (Ding, 2022). The test questions are designed to test not only factual knowledge, but also science process skills and higher-order thinking abilities (Sumanik et al., 2024). This science

literacy test also considers aspects of scientific attitudes such as curiosity, objectivity, and a willingness to consider new evidence (Deta et al., 2024).

In its implementation, science literacy tests can use a variety of assessment formats, including multiple-choice questions, essays, research projects, and computer-based simulations (Nazhifah et al., 2022). The ultimate goal is to prepare students for the challenges of the 21st century, where understanding and applying science is becoming increasingly important in personal and social decision-making (Oliver & Adkins, 2020). Thus, the evaluation of science literacy not only measures academic achievement, but also helps to develop citizens who are literate in science and able to contribute to a knowledge-based society (Tucel et al., 2023).

Increasing science literacy in junior high school students is very important as a foundation for further education and daily life. One of the crucial topics in this context is sustainable energy, which has high relevance to current and future global challenges (Wulandari et al., 2024). Understanding the concept of sustainable energy is not only important to meet curriculum needs, but also to develop students' awareness and skills in dealing with environmental and energy issues (Afikah et al., 2024). Although science learning in junior high school has included sustainable energy materials, there is still a gap between what is taught and the level of understanding and application of concepts by students (Alomari et al., 2023). This can be seen from the low ability of students to analyze, evaluate, and apply knowledge about sustainable energy in a real context (Novitasari et al., 2022). This gap shows the need for evaluation and improvement in teaching methods as well as the development of more effective science literacy, especially in the topic of sustainable energy, to prepare students to face future challenges (Purnomo et al., 2023).

The low science literacy ability of students is strengthened by several previous studies that have analyzed the science literacy of junior high school students in various fields of science. These studies, such as those conducted by Dinata (2024) on the topic of heat transfer, Rizky (2024) on the topic of environmental pollution, and Bungawati (2024) on the topic of ecosystems, consistently show that the science literacy profile of junior high school students is still relatively low. Although these studies are limited to specific materials, the results indicate the need for further research on other science materials, including sustainable energy. Therefore, this study aims to describe the science literacy profile of junior high school students on sustainable energy materials, using three main science competency indicators used by PISA.

Methods

This study is a quantitative research with descriptive analysis. This research was carried out in August 2024 at a State Junior High School in Kediri Regency, East Java, Indonesia. From a population of 340 students, a random sample was selected using random sampling techniques, namely 5 classes VIII E, VIII F, VIII G, VIII H, VIII I totaling 130 students. The science literacy test instrument used adapts the PISA test to sustainable energy materials which contains the topic of energy concepts, sources and types of energy, energy changes, and sustainable energy itself (Dieni et al., 2022). This test instrument consists of 10 questions in the form of multiple choice containing three science competencies. The classification of the test is presented in Table 1.

Table 1. Classification of scientific literacy tests

Science Competency	Question Number
Explaining scientific phenomena	1, 5, 8, 10
Constructing and evaluating designs for scientific investigation and critically interpreting scientific data and evidence	2, 9
Research, evaluate, and use scientific information for decision-making	3, 4, 6, 7

Before the student science literacy test instrument is tested on students, the instrument is tested for validity and reliability. The validity assessment was obtained from three validators which were then analyzed in a quantitative descriptive manner by calculating the value of the mode of each aspect of the validity assessment by the validator. The assessment scale used is a likert scale of 1-4. The Likert scale criteria used are shown in Table 2.

Table 2. Criteria for assessing the validity of science literacy tests instruments

Modus	Category	Description
4	Very Valid	Can be used without revision
3	Valid	Can be used with minor revisions
2	Quite Valid	Can be used with multiple revisions
1	Invalid	Can not be used

The instrument is said to be valid if it has a mode score of 3 (Nuryadi et al., 2017). Furthermore, reliability is analyzed to determine the quality or stability of the assessment results. The equation used is the percentage of agreement equation as follows

$$\text{Reliability (\%)} = \left(1 - \frac{A - B}{A + B}\right) \times 100 \quad (1)$$

Remark:

Reliability (%): percentage of reliability

A : score from the validator that gave the highest score

B : score from the validator that gave the lowest score

After obtaining the reliability percentage score, the results are interpreted descriptively following the criteria in Table 3.

Table 3. Criteria for assessing the reliability of science literacy tests instruments

Reliability (%)	Category
$75 < x \leq 100$	Very Reliable
$50 < x \leq 75$	Reliable
$25 < x \leq 50$	Quite Reliable
$x < 25$	Unreliable

A science literacy test instrument is said to be reliable if it has a reliability value of > 75.00%. This means that at least 75.00% of the total assessment must be agreed upon among the appraisers. The achievement of a 75.00% agreement percentage indicates that the majority of assessments have been agreed upon by the assessors and the results are reliable (Arikunto, 2017).

The data analysis technique of the students' science literacy level uses quantitative descriptive analysis with the calculation of the following equation.

$$\text{Scientific literacy score} = \left(\frac{\text{obtained score}}{\text{maximum score}} \right) \times 100 \quad (2)$$

After obtaining the science literacy score from the calculation of the equation above, the score is interpreted according to the criteria presented in Table 4.

Table 4. Interpretation of scientific literacy score

Score	Category	Description
$75.00 < x \leq 100.00$	Advance	This student already has the ability to reflect on the content of the discourse to make decisions regarding the concept very well, so that without guidance, students are able to solve problems presented smoothly
$50.00 < x \leq 75.00$	Proficient	Students already have the ability to understand texts literally and can solve the concept problem well without must be guided
$25.00 < x \leq 50.00$	Basic	Students are able to search for information in the science texts presented. However, guidance is still needed in selecting information that is currently relevant understand the concept of heat when looking for the truth of the concept in question
$x < 25.00$	Need Special Intervention	Students at this level have great mastery of concepts minimum. Students need to be accompanied starting from recording data and doing it. Discussion to validate the results of data recording. Discussions can be held with friends who are competent or proficient.

The data obtained from this science literacy test will be analyzed based on the science competencies tested in the questions (Firdaus & Asmali, 2021).

Results and Discussion

In this study, the science literacy competency profile of junior high school students on sustainable energy materials was analyzed to identify students' understanding and skills in the context of sustainable energy that is increasingly relevant. The results show that the majority of students' science literacy competencies in understanding the concept of sustainable energy are at the basic level. However, these results are at varying levels, with some aspects showing good mastery, while others require more attention.

Before the student science literacy test instrument is tested on students, the instrument is tested for validity and reliability. Validity and reliability data are shown in Table 5.

Table 5. Data validity and reliability

Question Number	Construct Validity					Content Validity				
	1 st	2 nd	3 rd	Mod	Category	1 st	2 nd	3 rd	Mod	Category
1	4	4	4	4	Very Valid	4	4	4	4	Very Valid
2	3	4	4	4	Very Valid	3	3	3	3	Valid
3	4	4	3	4	Very Valid	4	4	4	4	Very Valid
4	4	4	3	4	Very Valid	4	4	4	4	Very Valid
5	4	3	4	4	Very Valid	4	3	3	3	Valid
6	4	4	4	4	Very Valid	4	3	4	4	Very Valid
7	4	3	3	3	Valid	4	3	3	3	Valid
8	4	4	4	4	Very Valid	4	4	3	4	Very Valid
9	3	4	4	4	Very Valid	3	3	4	3	Valid
10	4	4	3	4	Very Valid	4	4	4	4	Very Valid
Reliability	0.91426					0.92855				
Average						0.92140				
Reliability (%)						92.14				
Category						Very Reliable				

The validity results show that the instrument is very valid with a reliability of 92.14% (very reliable). High validity indicates that this instrument is effective in measuring science literacy according to the set goals, while high reliability indicates the consistency of test results at various times and groups. Thus, the results of these tests can be trusted to aid decision-making in education and design better learning interventions (Sudirman et al., 2020).

Based on the tests carried out, the test results are obtained as presented in Figure 1 as follows.

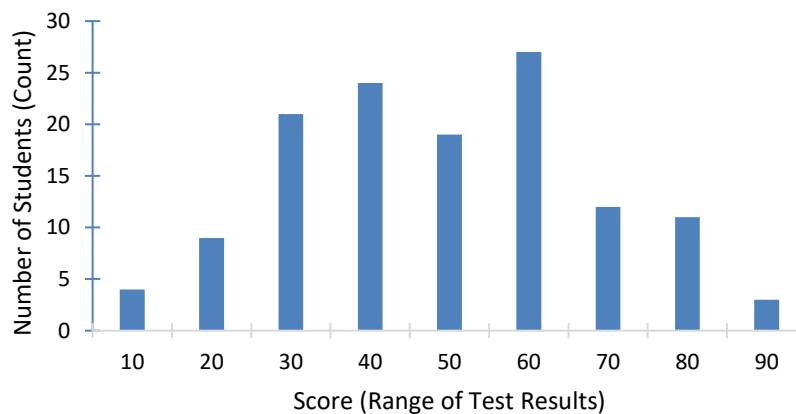


Figure 1. Total points distribution of scientific literacy test

Figure 1 explains the science literacy test scores obtained by 130 students. The descriptive statistics from the results of the science literacy test for students can be seen in Table 6.

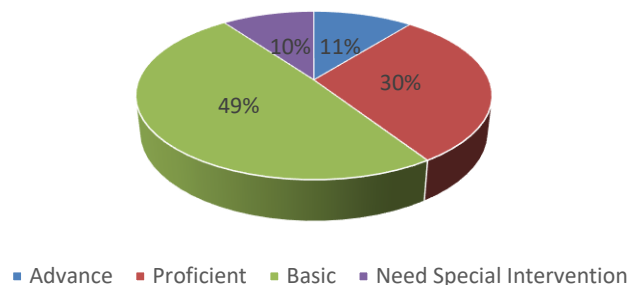
Table 6. Descriptive statistic of scientific literacy test result

Descriptive Statistics	Value Statistics
Number of subjects	130.00
Minimum score	10.00
Maximum score	90.00
Average score	49.00
Standard deviation	1.82

This table displays basic information related to the results of science literacy tests, including the number of participants, score range, average score, and standard deviation. This gives an overview of the distribution and variation of the scores obtained in the test. The results of the science literacy test of students can then be categorized according to their level of science literacy in Table 7 and Figure 2.

Table 7. Interpretation of scientific literacy test

Score	Number of Students	Student Distribution (%)	Category
$75.00 < x \leq 100.00$	14	10.76	Advance
$50.00 < x \leq 75.00$	39	30.00	Proficient
$25.00 < x \leq 50.00$	64	49.23	Basic
$x < 25.00$	13	10.00	Need Special Intervention

**Figure 2.** Interpretation of scientific literacy test by pie chart

Based on Table 7 and Figure 2, it can be seen that as many as 10.76% of students have advanced science literacy, 30.00% of students have proficient science literacy, 49.23% of students have basic science literacy, and 10.00% of students have need special intervention science literacy. This indicates that there is a serious problem in the literacy level of students. This data shows the need for special attention and intervention to improve the literacy level of most students, especially those in the basic to need special intervention category. This is in accordance with research conducted by Rizky (2024) which shows that the science literacy ability of junior high school students is in the low category. There are several factors that cause low science literacy of students. Elhai (2023) stated that the factor of low science literacy of students is due to traditional science learning habits that ignore the importance of science literacy as an ability that students must have. Students are used to only answering questions without understanding the diagram well. In addition, students are not used to doing science literacy test questions and lack understanding of the basic concepts taught by teachers (Dewi et al., 2024).

The results of the science literacy test reviewed based on the science literacy competency indicators are presented in Figure 3.

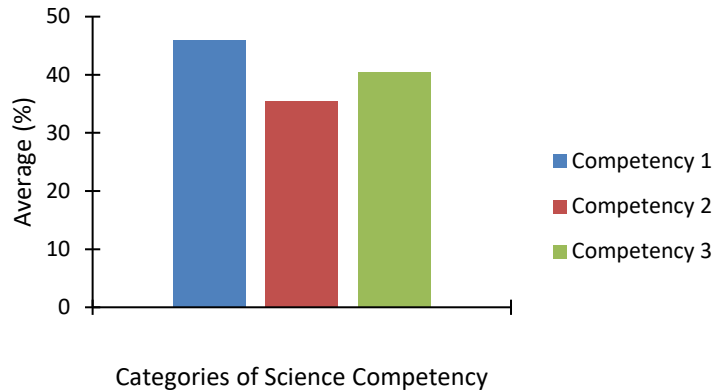


Figure 3. Average scientific literacy based on science competency indicators

The data in Figure 3 shows the average percentage of correct answers for the three indicators of students' science competence. Science Competency 1, which deals with explaining scientific phenomena, had the highest score of 45.95%. Indicator 3, about researching and evaluating scientific information, is in the middle with a score of 40.45%. Meanwhile, Science Competency 2, which involves the construction and evaluation of scientific investigation designs, reached the lowest value of around 35.40%. These three indicators are overall in the low category, with a value range of 26.00-50.00%. This low performance can be caused by a lack of basic understanding of science taught, conventional learning, and a lack of supporting facilities (Ilhami et al., 2024). Although learners are able to find information in scientific texts, they have difficulty choosing relevant information for decision-making (Pörtner et al., 2024). These findings point to the need for a more effective learning approach, especially to improve skills in Science Competency 2. It is recommended to implement integrated learning strategies that can help students better understand science concepts and apply them in daily life (Dinata et al., 2024).

The following is a picture of how to work on a student scientific literacy test on each indicator.

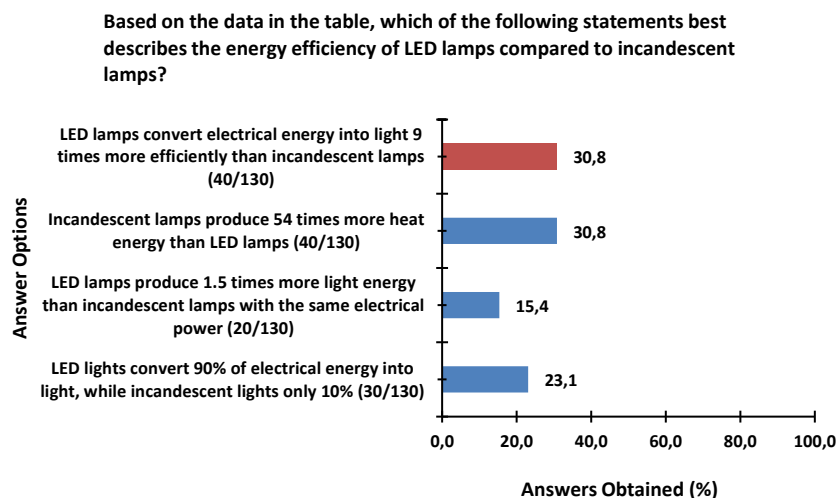


Figure 4. Results of the scientific literacy test for students in science competency 1

The questions in Figure 4 test students' ability to explain scientific phenomena through graph data, especially regarding the energy efficiency of LED lamps compared to incandescent lamps. The results showed that only 30.80% of the students chose the correct statement, which is that LED lights are 90.00% more efficient in converting electrical energy into light. This indicates that many learners still have difficulty interpreting the graph data and relating it to the concept of energy efficiency. This ability is very important in science literacy, as it involves understanding concepts, analyzing data, and applying scientific knowledge in a practical way (Dewi et al., 2024).

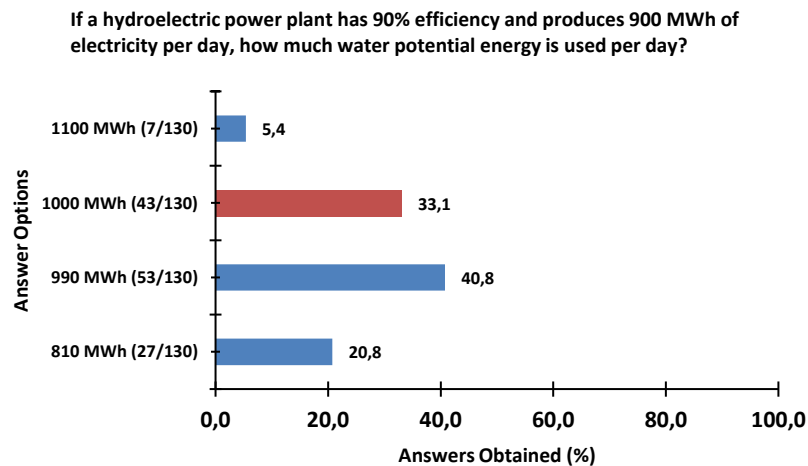


Figure 5. Results of the scientific literacy test for students in science competency 2

The questions in Figure 5 test students' ability to interpret data and perform calculations, which is an important aspect of science literacy. The question asked students to calculate the potential energy of water used by hydropower plants per day based on efficiency and electricity output. The results showed that only 33.10% of students answered correctly (1000 MWh), indicating difficulties in applying the concept of efficiency and performing inverse calculations. This highlights the need to improve students' abilities in mathematical reasoning as well as the evaluation and interpretation of results. The low percentage of correct answers indicates the importance of focusing on quantitative analysis skills and conceptual understanding in the context of scientific inquiry. This ability is particularly relevant to the science literacy indicators needed to evaluate experimental designs and draw appropriate conclusions (Ilhami et al., 2024).

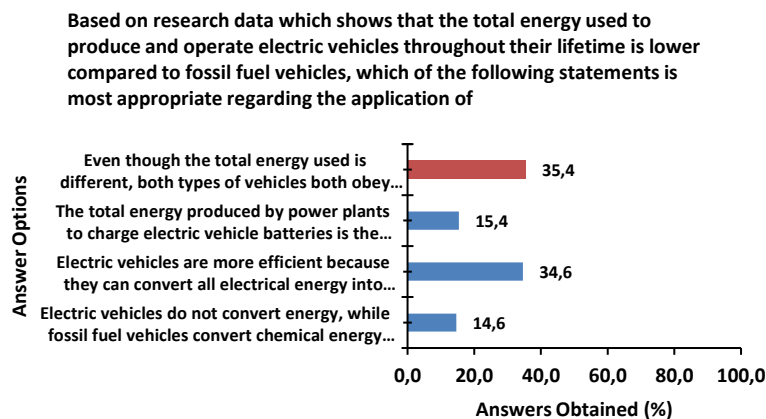


Figure 6. Results of the scientific literacy test for students in science competency 3

The questions in Figure 6 test students' ability to evaluate and use scientific information to make appropriate conclusions, in accordance with the scientific literacy indicators mentioned. The purpose of the question is to identify the most accurate statement regarding energy use in electric vehicles based on research data. The results showed that only 35.40% of students answered correctly, choosing the option stating that even though the total energy used is different, both types of vehicles both obey the law of conservation of energy, where energy only changes form, does not disappear or increase. This low percentage of correct answers indicates the difficulty of the majority of students in analyzing complex data and integrating information from various aspects (production and operations) to make comprehensive conclusions (Alhusni et al., 2024).

The theme of gender equality is widely promoted so that the OECD always discusses the results of science literacy by comparing the scores of male and female students (Kemendikbudristek, 2023). Therefore, this study will discuss the comparison between genders as a form of science literacy profile of students. The results obtained by male and female students are shown in Figure 7.

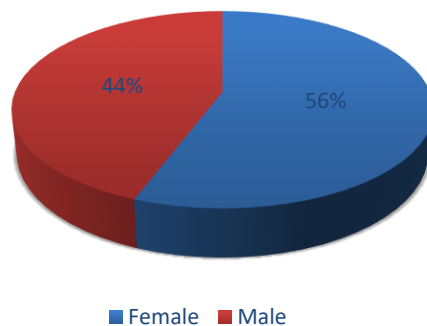


Figure 7. Scientific literacy result comparing among gender

Based on Figure 7, the score of scientific literacy girls is higher than boys. This result shows some improvements in the skills of students. Based on the results of the research, the researcher argued about the need for efforts to improve scientific literacy skills. One way that physics teachers can do is the application of scientific literacy in learning is needed to prepare students who are literate (Oberleiter et al., 2023). The implication of this scientific literacy results in the next research will be applied in making learning plans (Hung & Wu, 2024). These findings indicate the need for efforts to improve science learning, especially in sustainable energy materials, as sustainable energy plays a crucial role in addressing global environmental challenges and ensuring a more sustainable future. The growing importance of sustainable energy is evident in its potential to reduce environmental impacts, promote energy independence, and create new economic opportunities. Understanding sustainable energy concepts is essential for students to make informed decisions about energy consumption and contribute to environmental conservation efforts. Additionally, these findings emphasize the importance of evaluating and improving teaching methods to develop science literacy that is more effective in preparing students to face future challenges, particularly in navigating the transition toward renewable energy sources and sustainable practices.

The importance of inquiry-based learning and argumentation in the context of science literacy is very relevant to the results of this study (Fakhriyah et al., 2023). Inquiry-based learning encourages students to be actively involved in the learning process, where they not only receive information, but also ask questions, design experiments, and analyze data (Muhamad et al., 2024). In this way, students learn to think critically and creatively, which

is an essential skill in facing future challenges, especially in the field of sustainable energy (Kumar et al., 2024). In addition, the argumentative approach in science learning helps students to develop the ability to debate and defend their opinions based on scientific evidence (Ozge et al., 2023). This not only improves their understanding of science concepts, but also trains them to communicate effectively and think analytically (Mazita et al., 2024). In the context of complex issues such as climate change and the use of renewable energy, the ability to argue well is crucial.

By integrating these two approaches, it can create a more dynamic and interactive learning environment. Students are encouraged to collaborate, share ideas, and learn from each other, which in turn can improve their science literacy. They will be better equipped to engage in discussions related to contemporary scientific issues and make informed and responsible decisions (Berndt et al., 2021). Therefore, it is important for educators to design a lesson plan that not only focuses on mastering the material, but also integrates inquiry-based learning and argumentation. This will ensure that students not only understand the theory, but are also able to apply it in real-life situations, making them better prepared to face the challenges ahead.

Conclusion

The results of this study indicate that the level of scientific literacy among junior high school students on sustainable energy materials is relatively low, as reflected by the average scores in the three PISA science competencies: explaining scientific phenomena (45.50%), designing and evaluating scientific research as well as interpreting data (35.40%), and using scientific information for decision-making (40.00%). These findings highlight the urgent need to enhance science learning strategies, particularly for sustainable energy materials, through the integration of inquiry-based learning and argumentation to foster students' ability to apply scientific concepts in real-world contexts. Strengthening these competencies is essential to prepare students for future challenges and to improve their overall scientific literacy.

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