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Profile of Students' Scientific Literacy Skills on the ESD Theme in Renewable Energy Materials: A Case Study at SMA Negeri 15 Semarang, Indonesia

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Abstract. Science literacy is the ability to understand, communicate, and apply scientific knowledge to find solutions and to have sensitivity to self and the environment in making decisions based on scientific considerations. This study aims to acquire a profile of the science literacy skills of SMA Negeri 15 Semarang students. The study involved 606 students consisting of 290 students in the X class and 316 students in the XI class. Data was collected using the Education for Sustainable Development (ESD) science literacy instrument on Renewable Energy that refers to indicators developed by Gormally. ESD aims to empower individuals to act responsibly for the environment, economy, and society. The collected data is analyzed using descriptive statistics, i.e. average scores for each indicator, then the data is presented with a description. This study shows that the science literacy skills of students of SMA Negeri 15 Semarang need to be improved. The highest score is on making graphs accurately from data, while the lowest score is on making inferences, predictions, and conclusions based on quantitative data. Students' science literacy skills need to be improved through evaluation and practice of subjects involving science literature, learning with interactive media, and learning models that activate students.

Keywords: profile, scientific literacy, Education for Sustainable Development (ESD)

1. Introduction

In the 21st century, characterized by rapid technological advancement and social change, education plays a crucial role in equipping students with relevant skills [1]. One important provision that needs to be given to students in current education is scientific literacy [2] [3]. Scientific literacy is not just about understanding scientific concepts but also involves developing critical thinking skills, creativity, and adaptability to change [4]. The World Economic Forum also emphasizes the importance of mastering six basic literacy skills, one of which is scientific literacy as a 21st-century skill [5]. Based on these facts, strengthening basic literacy skills is a necessity for students, including scientific literacy skills [6].

According to Toharudin, scientific literacy is an individual's ability to understand science, communicate science, and apply scientific knowledge to find solutions to problems, thereby being able to act and have high sensitivity towards oneself and the surrounding environment in making decisions based on scientific considerations [7]. Generally, there are four interrelated aspects that become the focus of scientific literacy: knowledge, context, competence, and attitude [8, 9]. A person with good scientific literacy skills is able to apply their knowledge to identify questions, provide scientific explanations, build new knowledge, make conclusions based on various scientific evidence, and develop hypothetical thinking patterns, thereby contributing to solving various science-related issues [10]. Students who are aware and have good scientific literacy skills will be more capable of fostering care and responsibility for themselves, the environment, and society [11]. Moreover, scientific literacy has

the potential to build a generation with scientific views and attitudes and the ability to share knowledge and research results with society [12]. Therefore, scientific literacy plays an important role in preparing a generation capable of solving societal problems and difficulties scientifically [13].

In addition to the scientific literacy aspects developed by PISA, there are also scientific literacy indicators developed by Gormally (2012), known as the Test of Scientific Literacy Skills (TOSLS) indicators [3, 14, 15]. These scientific literacy skill indicators are simpler, easier to implement, and reflect scientific literacy skills [16]. The Test of Scientific Literacy Skills (TOSLS) indicators include: (1) identifying valid scientific opinions, (2) conducting effective literature searches, (3) understanding the elements of research design and how they impact findings/conclusions, (4) making accurate graphs from data, (5) solving problems using quantitative skills including basic statistics, (6) understanding and interpreting basic statistics, and (7) making inferences, predictions, and conclusions based on quantitative data. These indicators are in line with those developed by PISA [17] [18] [19].

One effort that schools can make to improve scientific literacy skills is by implementing Education for Sustainable Development (ESD) [20]. ESD can be defined as education that encourages changes in knowledge, skills, values, and attitudes to create a more sustainable and just society for all [21]. ESD aims to empower individuals to make decisions and take responsible actions for environmental integrity, economic viability, and a just society for present and future generations [22]. Thus, through ESD, students can be equipped with the knowledge, skills, values, and attitudes to process information, make decisions, and take responsible actions for the environment, economic sustainability, and a just society for current and future generations [23].

In physics education, one of the appropriate ESD-themed materials to be taught is Renewable Energy [24]. ESD considers renewable energy as a key element in achieving sustainable development goals. Through this material, teachers can teach that the concept of renewable energy is a solution to reduce greenhouse gas emissions, increase energy access, and support economic growth [25]. Students can also be invited to actively participate in designing projects to utilize renewable energy sources.

Until now, the low level of students' scientific literacy remains a significant educational problem that needs to be resolved in Indonesia [26] [27]. This is evident from the scientific literacy achievement data of Indonesian students conducted by the OECD (Organisation for Economic Co-operation and Development) in the PISA (Programme for International Student Assessment) assessment [28]. This assessment is conducted every three years, and Indonesia has participated since 2000 until now.

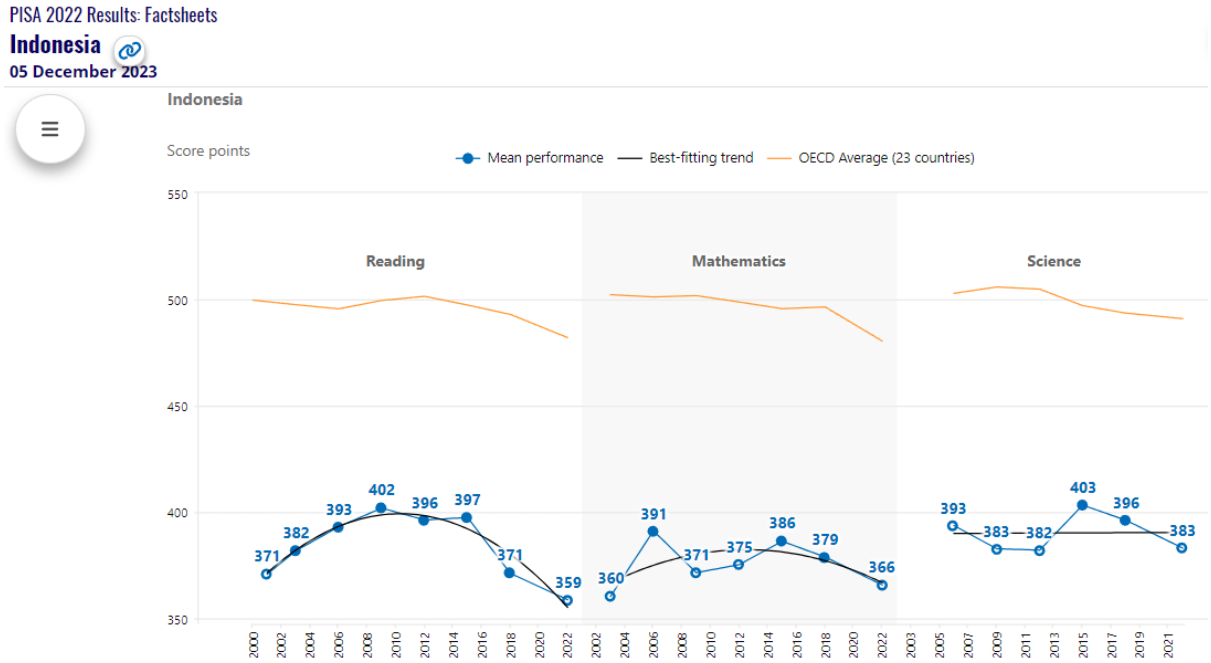

Figure 1. PISA Scores Achievement of Indonesia from 2000 to 2022 from the OECD website [29].

The 2022 PISA results [30] show a decline in learning outcomes internationally post-pandemic. Indonesia's ranking in PISA 2022 did increase by 5-6 positions compared to 2018, but Indonesia still experienced a decline in scores in each assessed subject, namely reading, mathematics, and science [31]. From Figure 1, the average score of Indonesian students is still lower compared to the OECD average score. In reading literacy, Indonesian students scored 359, 123 points lower than the OECD average score of 482. For mathematics literacy, Indonesian students scored 366 points, 114 points lower than the OECD average score of 480. Meanwhile, for science literacy, the score was 383, still 108 points lower than the OECD average score of 491. Despite the decline in scores, Indonesia's ranking increased from the previous period. For reading literacy, Indonesia's ranking in PISA 2022 rose by 5 positions, for mathematics literacy by 5 positions, and for science literacy by 6 positions. According to the Minister of Education and Culture, this shows that the increase in Indonesia's position in PISA 2022 indicates good resilience in facing the Covid-19 pandemic [32].

Several previous studies on the scientific literacy profiles of high school students in various regions in Indonesia show low scientific literacy skills [33]. A study conducted by Bagasta on the Profile of Scientific Literacy Skills of Students in One of the State High Schools in Sragen City showed that the average scientific literacy skills of students were low [34]. The research results indicate that students' scientific literacy skills based on indicators are as follows: identifying valid scientific opinions at 20% (very low); literature search at 60% (moderate); understanding research design elements at 36.67% (low); making graphs at 40% (moderate); problem-solving at 36.67% (low); understanding and interpreting basic statistics at 20% (very low); and drawing conclusions at 23.33% (low). Another study by Rahmadani on the Profile of Scientific Literacy Skills of High School Students in Karanganyar showed similar results [15]. The percentage of achievement for the indicator of identifying valid scientific opinions was 55.56% (low); conducting effective literature searches was 48.89% (very low); understanding research design elements was 37.78% (very low); making accurate graphs from data was 57.78% (low); solving problems using quantitative skills including basic statistics was 53.33% (very low); understanding and interpreting basic statistics was 60% (moderate); and making inferences, predictions, and conclusions based on quantitative data was 62.23% (moderate).

Various studies on students' scientific literacy profiles have been conducted. However, studies on scientific literacy profiles tend to be general and not directed towards specific themes. The ESD theme can be one of the research themes on scientific literacy that needs to be developed. Additionally, research on the scientific literacy profiles of high school students in Semarang City is still rare. Therefore, the purpose of this study is to reveal the profile of scientific literacy skills of students on the ESD theme at SMA Negeri 15 Semarang on Renewable Energy materials.

2. Methods

This research used a descriptive quantitative research method conducted from November 2023 to January 2024. The variable studied in this research is scientific literacy skills. This study involved tenth and eleventh-grade students of SMA Negeri 15 Semarang as the research population. There are a total of 10 classes in the tenth grade and 10 classes in the eleventh grade, with a total of 606 students as respondents, aged 15-17 years, in accordance with PISA guidelines.

The profile of scientific literacy competence was measured using an assessment instrument consisting of 20 multiple-choice questions based on indicators developed by Gormally (2012). The test instrument was ESD-themed with Renewable Energy materials. The test was conducted individually for 60 minutes. The test instrument had previously been tested for validity using the Pearson product-moment correlation and reliability using Cronbach's Alpha. Based on the item analysis conducted by experts, the test used to measure scientific literacy skills consisted of 20 valid and reliable items with a reliability level of 0.635.

To analyze the obtained data, the researcher processed the numerical data and then presented the data with discussions in descriptive form. The quantitative data used in this study were the results of the ESD-themed scientific literacy test on Renewable Energy materials completed by students of SMA Negeri 15 Semarang. Correct answers received a score of 1, while incorrect or unanswered items received a score of 0. The profile of scientific literacy skills of students at SMA Negeri 15 Semarang

was shown by the percentage of students' scientific literacy skills in each category, calculated using equation:

$$x_i = \frac{Ni}{N} x100\% \quad (1)$$

where $\underline{x_i}$ is the percentage of students' scientific literacy skills in each category, Ni is the number of students in a particular category, and N is the total number of respondents.

Then, the percentage of scientific literacy skill scores for each indicator was calculated using equation:

$$\underline{L_i} = \frac{\underline{x_i}}{x_i\, max} x100\% \quad (2)$$

where $\underline{L_i}$ is the percentage of scientific literacy skills for each indicator, $\underline{x_i}$ is the average score for each indicator, dan $x_i\, max$ is the maximum score for each indicator.

The scoring scale used ranged from 0–100 with criteria from "very poor" to "very good." The criteria for scientific literacy assessment are presented in Table 1 [35].

Table 1. Scientific literacy assessment criteria.

Interval (%)	Criteria	Code
85-100	Very Good	VG
70-84	Good	G
55-69	Fair	F
50-54	Poor	P
0-49	Very Poor	VP

3. Results and Discussion

Based on the calculations and analysis, the profile of scientific literacy skills of students at SMA Negeri 15 Semarang for each category was obtained. The data on students' scientific literacy skills profile are presented in Table 2.

Table 2. Profile of scientific literacy skills at SMA Negeri 15 Semarang.

Category of Scientific Literacy Skills	Number of Students	Percentage
Very Good	30	4,95%
Good	90	14,85%
Fair	204	33,66%
Poor	78	12,87%
Very Poor	204	33,66%
Total	606	100%

According to Rubba, a person with good scientific literacy skills has the following characteristics: (1) a positive attitude towards science; (2) the ability to use scientific concepts; (3) extensive knowledge of research results; (4) knowledge of scientific concepts and principles and their application in technology and society; (5) knowledge of the relationships between science, technology, society, and human values; and (6) the ability to make decisions and analyze values to solve societal problems related to science [36]. From Table 2, it can be seen that only 19.8% of SMA Negeri 15 Semarang students have good scientific literacy skills, 33.66% have fair scientific literacy skills, and 46.35% still have poor scientific literacy skills. This indicates that most students do not have good scientific literacy skills.

Based on Table 3, it is found that the average score of scientific literacy skills of SMA Negeri 15 Semarang students in this study is 54.42%. This average score falls into the "Poor" category. Thus, it is necessary to implement learning that involves students in the scientific process. This process includes formulating scientific questions, conducting investigations, using cognitive skills to explain natural phenomena, and drawing conclusions based on facts obtained through the investigation process. It is also known that the lowest percentage score is on the indicator of making inferences, predictions, and conclusions based on quantitative data, with a score of 40.04%, categorized as "Very Poor." This indicates that students are not accustomed to activities focused on research and analysis of research results, so activities that can train students' abilities to optimize their skills in making inferences,

predictions, and conclusions based on quantitative data are needed. Meanwhile, the highest percentage score is on the indicator of making accurate graphs from data, with a score of 70.35%, categorized as "Good." This informs that students tend to be able to visualize data or understand data visually.

Table 3. Percentage Scores per Indicator of Scientific Literacy Skills of SMA Negeri 15 Semarang Student

Indicator	Question Numbers	Average	Category
1. Identifying valid scientific opinions;	1,2,3	55,06	Fair
2. Conducting effective literature searches;	4,5,6	57,37	Fair
3. Understanding research design elements and their impact;	7,8,9	51,21	Poor
4. Making accurate graphs from data;	10,11,12	70,35	Good
5. Solving problems using quantitative skills, including basic statistics;	13,14	66,58	Fair
6. Understanding and interpreting basic statistics;	15,16,17	40,32	Very Poor
7. Making inferences, predictions, and conclusions based on quantitative data;	18,19,20	40,04	Very Poor
	Rata-rata	54,42	Poor

3.1. *Indicator 1: Identifying valid scientific opinions*

The scores for Indicator 1 can be seen in Table 4. Indicator 1 consists of questions that identify valid scientific opinions. These questions identify whether students can think critically and distinguish scientific opinions in society, review scientific research, data, and results to make decisions on science-related issues. In this indicator, there are 3 questions containing articles, and students are asked to choose the most appropriate argument based on the article. The number of students who correctly answered 1 question is 31.52%, correctly answered 2 questions is 45.54%, correctly answered 3 questions is 14.19%, and incorrectly answered all 3 questions is 8.75%. From Table 3, the average score for Indicator 1 is 55.06%. This indicates that SMA Negeri 15 Semarang students are quite capable of identifying scientific arguments.

Table 4. Percentage scores for indicator 1.

Student Score	Number of Students	Percentage
0	53	8,75%
1	191	31,52%
2	276	45,54%
3	86	14,19%
	606	100,00%

3.2. *Indicator 2: Conducting effective literature searches*

Table 5. Percentage scores for indicator 2.

Student Score	Number of Students	Percentage
0	63	10,40%
1	183	30,20%
2	220	36,30%
3	140	23,10%
	606	100,00%

In this indicator, there are 3 questions involving literature searches from a cited article. Indicator 2 scientific literacy questions (4, 5, and 6) assess students' ability to evaluate the validity of information from various sources and distinguish types of sources that can be used. From Table 5, it can be seen that 30.20% of students correctly answered 1 question, 36.30% correctly answered 2 questions, 23.10% correctly answered 3 questions, and 10.40% incorrectly answered all 3 questions. From Table 3, the

average score for Indicator 2 is 57.37%. This shows that SMA Negeri 15 Semarang students are quite capable and effective in conducting literature searches.

3.3. *Indicator 3: Understanding research design elements and their impact on findings/conclusions*

Table 6. Percentage scores for indicator 3.

Student Score	Number of Students	Percentage
0	73	12,05%
1	219	36,14%
2	230	37,95%
3	84	13,86%
	606	100,00%

The scientific literacy aspect in Indicator 3 is the ability to understand the elements in research design, which can be obtained through the use of scientific data, proving, and comparing scientific information found in the surrounding environment. In this indicator, there are 3 questions to assess students' knowledge about research design stages, such as observation, hypothesis, independent variables, control variables, dependent variables, and theoretical foundations. As seen in Table 6, for questions 7, 8, and 9, 36.14% of students correctly answered 1 question, 37.95% correctly answered 2 questions, 13.86% correctly answered 3 questions, and 12.05% incorrectly answered all 3 questions. In Table 3, the average score for Indicator 3 is 51.21%. This indicates that SMA Negeri 15 Semarang students are still lacking in understanding the elements and stages of research. Students' understanding of research design is low because science learning tends to be textbook-based.

3.4. *Indicator 4: Making accurate graphs from data*

Table 7. Percentage scores for indicator 4.

Student Score	Number of Students	Percentage
0	28	4,62%
1	116	19,14%
2	223	36,80%
3	239	39,44%
	606	100,00%

Graphs are an integrated part of obtaining functional literacy because scientific claims are supported by quantitative data. Graphs in scientific literacy can be understood by students by interpreting specific data through various types of graphs based on their use. In questions 10, 11, and 12, students identified the appropriate graph format to represent different types of data and interpreted the data in a graph. From Table 7 19.14% of students correctly answered 1 question, 36.80% correctly answered 2 questions, 39.44% correctly answered 3 questions, and only 4.62% could not answer all 3 questions. Based on the data in Table 3, the average score for this indicator is 70.35%, placing students' skills in the "Good" category. This also shows that students tend to find it easier to understand data in visual form.

3.5. *Indicator 5: Solving problems using quantitative skills, including basic statistics*

Table 8. Percentage scores for indicator 5.

Student Score	Number of Students	Percentage
0	90	14,85%
1	225	37,13%
2	291	48,02%
	606	100,00%

In this indicator, students were given two questions related to the ability to solve problems quantitatively using basic statistical methods such as calculating the average of a series of data. Students were presented with data in table form and determined the effectiveness based on the average data and concluded the data in the table. Based on the data in Table 8, it is seen that 37.13% of students correctly

answered 1 question, 48.02% correctly answered both questions, and 14.85% incorrectly answered both questions. This indicator falls into the "Fair" category. Thus, SMA Negeri 15 Semarang students are quite capable of using quantitative skills and applying basic statistics.

3.6. *Indicator 6: Understanding and interpreting basic statistics*

Table 9. Percentage scores for indicator 6.

Student Score	Number of Students	Percentage
0	152	25,08%
1	242	39,93%
2	145	23,93%
3	67	11,06%
	606	100,00%

In this indicator, there were three questions (15, 16, and 17). In these questions, students were presented with data in table form and then asked to interpret the data and draw conclusions based on basic statistics, such as the average value. Additionally, students were asked to determine the appropriate reason why statistics were used to draw conclusions. From Table 9, it was found that out of the three questions presented, 39.93% of students correctly answered 1 question, 23.93% correctly answered 2 questions, 11.06% correctly answered all 3 questions, and 25.08% of students did not answer the questions correctly. From Table 3, the average score for this indicator is 40.32%. Thus, it can be said that SMA Negeri 15 Semarang students are still very lacking in understanding and interpreting basic statistics. This is because students are not yet able to analyze the issues being studied that involve basic statistics. Students need to be trained to interpret basic statistical data.

3.7. *Indicator 7: Making inferences, predictions, and conclusions based on quantitative data.*

Table 10. Percentage scores for indicator 7.

Student Score	Number of Students	Percentage
0	142	23,43%
1	252	41,58%
2	160	26,40%
3	52	8,58%
	606	100,00%

This seventh indicator is present in questions 18, 19, and 20. This indicator aims to assess students' ability to draw conclusions based on tables of research observation data. From Table 10 and Figure 9, it is seen that 41.58% of students correctly answered 1 question, 26.40% correctly answered 2 questions, only 8.58% correctly answered all 3 questions, and 23.43% could not answer any of the questions correctly. From Table 3, the score for this indicator is only 40.04%. This shows that SMA Negeri 15 Semarang students are still very lacking in making inferences, predictions, and conclusions based on quantitative data. This relates to students' abilities in Indicator 6, where the inability to interpret data results in incorrect conclusions.

Based on the analysis of students' answers and the percentage scores, it can be concluded that the scientific literacy skills of SMA Negeri 15 Semarang students are still in the "Poor" category. This is supported by data from Table 3. This statement is reinforced by previous research which states that low scientific literacy skills are caused by learning that does not involve scientific literacy, selection of teaching materials, and the application of learning models that tend to be textbook-based, and the lack of teachers' knowledge in conducting evaluations involving scientific literacy [37]. Another important factor is that students more often use gadgets for social media and games rather than learning activities [38]. This shows that the appropriate use of media is needed to optimize the use of gadgets in learning. Technological advancements should increase students' scientific literacy. Other research also reveals that interactive learning media such as e-books, e-modules, virtual laboratories, and animation videos have a positive impact on improving scientific literacy skills in students who are in the "Fair" or "Poor" categories [38]. From several previous research results, efforts to improve scientific literacy skills can

be made through evaluations and exercises involving scientific literacy, learning with interactive media, and learning models that activate students.

Despite the analysis results mapping the profile of scientific literacy skills of SMA Negeri 15 Semarang students, this study also has limitations. Although the sample size representing the study is quite large, with 606 students, there are still some students who could not participate due to certain issues. Further research is recommended to plan a more appropriate study time so that student participation is more optimal.

4. Conclusion

This study collected the profile of scientific literacy skills of students at SMA Negeri 15 Semarang. The results showed that, on average, students' scientific literacy scores were 54.42%, categorized as "Poor." Furthermore, the study results were categorized into several indicators that fall into the categories of good, fair, poor, and very poor. The indicator in the "Good" category is making accurate graphs from data. Indicators in the "Fair" category include: identifying valid scientific opinions, conducting effective literature searches, and solving problems using quantitative skills including basic statistics. The indicator in the "Poor" category is understanding research design elements and their impact on findings/conclusions. The indicators in the "Very Poor" category are understanding and interpreting basic statistics and making inferences, predictions, and conclusions based on quantitative data. Based on the data obtained from this study, efforts to improve students' scientific literacy skills need to be made. Teachers need to conduct learning using teaching materials and practice questions and evaluations involving scientific literacy. The use of interactive learning media also needs to be implemented to facilitate students in learning with the gadgets they have. Moreover, further research on the profile of students' scientific literacy skills also needs to be conducted. Such research will provide information for teachers to implement more effective learning to improve students' scientific literacy skills.

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