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Students' Critical Thinking Skills Profile on Renewable Energy Measured Using a Science Literacy-Based Physics Assessment Instrument

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Abstrak

Keterampilan berpikir kritis penting diteliti karena peserta didik perlu mampu menganalisis informasi, mengevaluasi bukti, dan menyusun keputusan ilmiah ketika menghadapi isu energi yang semakin kompleks. Penelitian ini bertujuan mendeskripsikan profil keterampilan berpikir kritis peserta didik SMA pada materi energi terbarukan yang diukur menggunakan instrumen penilaian fisika berbasis literasi sains. Penelitian ini menggunakan metode deskriptif kuantitatif dengan melibatkan 69 peserta didik kelas X SMA IPIEMS Surabaya. Instrumen penelitian berupa 20 butir soal uraian yang memuat stimulus kontekstual energi terbarukan, seperti artikel, tabel data, gambar, infografik, dan kasus sosial lingkungan. Butir soal dikembangkan berdasarkan lima indikator berpikir kritis Facione, yaitu interpretasi, analisis, evaluasi, eksplanasi, dan inferensi, serta diintegrasikan dengan kompetensi literasi sains PISA. Instrumen telah memenuhi kelayakan teoritis dengan rata-rata validitas 94%, seluruh butir dinyatakan valid secara empiris, dan reliabilitas berada pada kategori sangat tinggi. Hasil penelitian menunjukkan bahwa rata-rata skor berpikir kritis peserta didik sebesar 70,41 dan berkategori tinggi. Sebanyak 27 peserta didik berada pada kategori sangat tinggi, 20 peserta didik pada kategori tinggi, 15 peserta didik pada kategori cukup, 5 peserta didik pada kategori rendah, dan 2 peserta didik pada kategori sangat rendah. Indikator analisis memperoleh rata-rata tertinggi sebesar 75,54, sedangkan indikator eksplanasi memperoleh rata-rata terendah sebesar 67,07. Temuan ini menunjukkan bahwa peserta didik relatif kuat dalam mengidentifikasi hubungan informasi, tetapi masih memerlukan penguatan dalam menyusun penjelasan ilmiah yang runtut, logis, dan berbasis bukti. Secara teoretis, hasil ini mendukung keterkaitan antara literasi sains dan berpikir kritis. Secara empiris, instrumen berbasis literasi sains dapat digunakan untuk memetakan profil keterampilan berpikir kritis peserta didik pada materi energi terbarukan.

Kata kunci: Berpikir Kritis, Energi Terbarukan, Instrumen Asesmen, Literasi Sains

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Abstract

Critical thinking skills need to be investigated because students must be able to analyze information, evaluate evidence, and make scientific decisions when dealing with increasingly complex energy issues. This study aims to describe high school students' critical thinking skills profile on renewable energy as measured using a science literacy-based physics assessment instrument. This study employed a quantitative descriptive method involving 69 tenth-grade students at SMA IPIEMS Surabaya. The research instrument consisted of 20 essay items containing contextual renewable energy stimuli, such as articles, data tables, pictures, infographics, and socio-environmental cases. The items were developed based on five Facione critical thinking indicators, namely interpretation, analysis, evaluation, explanation, and inference, and were integrated with PISA science literacy competencies. The instrument met theoretical feasibility with an average validity of 94%, all items were empirically valid, and reliability was categorized as very high. The results showed that the mean critical thinking score was 70.41, categorized as high. A total of 27 students were in the very high category, 20 students were in the high category, 15 students were in the sufficient *category, 5 students were in the low category, and 2 students were in the very low category. The analysis indicator obtained the highest mean score of 75.54, while the explanation indicator obtained the lowest mean score of 67.07. These findings indicate that students were relatively strong in identifying relationships among information, but still need reinforcement in constructing coherent, logical, and evidence-based scientific explanations. Theoretically, these results support the relationship between science literacy and critical thinking. Empirically, the science literacy-based instrument can be used to map students' critical thinking skills profile on renewable energy topics.*

Keywords: *Assessment Instrument, Critical Thinking, Renewable Energy, Science Literacy*

Histori Naskah

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INTRODUCTION

The rapid development of science and technology in the 21st century demands that students not only understand concepts theoretically, but also think critically when confronting an increasingly complex array of real-world challenges (Lase, 2019). Modern educational paradigms no longer position students as passive recipients of information, but rather as active subjects who are expected to analyze, evaluate, and make decisions independently and responsibly. Critical thinking has emerged as one of the most essential competencies of this era, enabling individuals to examine information logically and systematically, evaluate evidence objectively, and draw well-reasoned conclusions based on sound judgment (Mulyani, 2022). Students who master this ability have been shown to perform better in solving complex problems, achieve higher academic outcomes, and are better prepared to navigate the rapidly changing dynamics of contemporary life (Juliyantika and Batubara, 2022). In the Indonesian educational context, the urgency of developing critical thinking is further reinforced by the Merdeka Curriculum, which explicitly positions critical reasoning as one of the core dimensions of the Profil Pelajar Pancasila that must be cultivated in every high school student (Rosmana *et al.*, 2022). However, critical reasoning ability does not emerge spontaneously; it must be gradually cultivated through thoughtfully designed learning processes that actively involve students in authentic situations requiring them to think and make decisions (Hadiryanto and Thaib, 2016).

In practice, the critical thinking ability of Indonesian students remains low and has yet to reach the expected level. The results of the 2022 Programme for International Student Assessment (PISA) placed Indonesia 68th out of 81 participating countries in science literacy, with an average score of 383, below the OECD average and lower than Indonesia's 2018 performance (Yusmar and Fadilah, 2023). A similar situation is found specifically within the context of high school physics learning. Ahzari and Akmam (2025) documented that the average critical thinking achievement of high school students in physics learning reached only 27.80%, classified as inadequate, with the inference and evaluation indicators being the weakest at 24.00% and 28.00%, respectively. These findings are consistent with those of Fuad (2017), who consistently showed that the critical thinking ability of Indonesian students, both nationally and in international comparisons, has yet to reach an optimal level. This situation is a serious concern given that critical thinking serves as a vital foundation for students to participate actively and meaningfully in a society increasingly shaped by advances in science and technology.

The low level of critical thinking ability among students is inseparable from various problems in classroom learning practices. Physics instruction in many schools remains dominated by lecture-based methods, formula memorization, and teacher-centered approaches, leaving students with little opportunity to engage in higher-order thinking processes (Cahyana *et al.*, 2017). The limited use of experiments, problem-based discussions, and contextual exploration of scientific phenomena further contributes to insufficient stimulation of students' analytical and evaluative capacities (Hamdani et al., 2012). Beyond instructional factors, the limitation of available assessment instruments is equally fundamental. The assessments commonly used in classrooms tend to rely on items that measure factual knowledge and memorization rather than higher-order reasoning. Yet quality assessment instruments serve not only as tools for evaluating learning outcomes but also as diagnostic instruments capable of providing in-depth information about students' cognitive profiles, enabling educators to design more targeted and responsive instructional strategies. Calma and Davies (2021) firmly assert that essay-based items are far more capable of measuring critical thinking comprehensively than multiple-choice items, as the essay format allows students to articulate their processes of analysis, reasoning, and conclusion-drawing in a structured and sequential manner. Accordingly, the development of assessment instruments specifically designed to measure critical thinking has become an urgent need in physics education today. Critical thinking ability is closely related to science literacy, and the two can be integrated within a mutually reinforcing framework for instrument development. Science literacy, as defined by the OECD (2023) through the PISA framework, encompasses three core scientific competencies: explaining phenomena scientifically, designing and evaluating scientific inquiry, and critically interpreting data and scientific evidence. These three competencies overlap substantially with Facione's (2015) critical thinking indicators, which include interpretation, analysis, evaluation, inference, and explanation. Students with higher levels of science literacy generally demonstrate stronger critical thinking performance (Cahyana *et al.*, 2017). Rahayuni (2016) further affirms that science literacy encompasses the ability to apply scientific knowledge in everyday contexts, critically analyze scientific information, and make evidence-based decisions, competencies that are inherently critical and analytical in nature. The convergence of these two domains suggests that a science literacy-based physics assessment instrument has the potential to simultaneously measure and map students' critical thinking skills within a single integrated, efficient, and comprehensive framework.

The topic of renewable energy offers a relevant, strategic, and stimulus-rich context for the development of such an assessment instrument. This topic is included in the Merdeka Curriculum as part of the Grade X physics syllabus for the second semester and bears high relevance to various global issues facing society today, ranging from the energy crisis and the environmental impact of fossil fuel use to the urgency of transitioning toward sustainable energy sources. The context of energy-related problems requires students to explain scientific phenomena, analyze data, evaluate arguments, and make contextually grounded decisions based on scientific evidence, making it highly suitable as the basis for developing a science literacy-based instrument oriented toward measuring critical thinking (Anggraeni *et al.*, 2023). Furthermore, the study of renewable energy provides students with opportunities to develop scientific awareness alongside social and environmental responsibility, in alignment with the spirit of 21st-century science education that emphasizes the active role of the younger generation in addressing sustainability challenges (OECD, 2025). Several prior studies have attempted to develop critical thinking assessment instruments in the context of physics learning. Ardiyanti and Nuroso (2021) developed a critical thinking assessment instrument for high school physics learning, yielding a validity coefficient of 0.85 and a reliability coefficient of 0.79, with all items declared valid and suitable for measuring students' critical thinking skills. Anggraini *et al.*, (2025) produced a similar instrument with valid and reliable items for measuring critical thinking skills. While the contributions of these studies are significant, a notable gap remains in the existing literature. Instruments that explicitly integrate science literacy competencies with critical thinking indicators in the context of renewable energy have not been widely developed, despite this topic's high curricular urgency and social relevance. The development of such an instrument would not only fill this gap but also provide a practical contribution in the form of a measurement tool that physics teachers can use directly to diagnose and map students' critical thinking skills more comprehensively.

Several studies have reported variations in students' higher-order thinking skills in physics learning. Ahzari and Akmam (2025), found that the average critical thinking achievement of high school students was only 27.80%, indicating that students still experience difficulties in several critical thinking indicators. Similarly, Wardi and Jauhariyah (2023), reported that students' science literacy competencies on atomic structure and radioactivity varied across indicators, suggesting differences in students' abilities to explain scientific phenomena, evaluate scientific investigations, and interpret scientific evidence. These findings indicate the importance of profiling students' cognitive abilities to identify their strengths and weaknesses in specific indicators. However, studies examining the profile of students' critical thinking skills on renewable energy topics using a science literacy-based physics instrument are still limited.

Based on the foregoing discussion, this study focuses on describing the profile of high school students' critical thinking skills on renewable energy topics using a science literacy-based physics assessment instrument. The instrument used in this study had been developed and validated to ensure its appropriateness for measuring critical thinking skills in the context of renewable energy. Therefore, the main focus of this article is not the instrument development process, but the profile of students' critical thinking skills as reflected in their performance across Facione's critical thinking indicators.Specifically, this article focuses on the profile of high school students' critical thinking skills on renewable energy topics as measured by a science literacy-based physics instrument. Based on the background above, this study is directed toward describing the profile of Grade X students' critical thinking skills on renewable energy as measured using a science literacy-based physics assessment instrument. The profile is examined through two main aspects: the overall distribution of students across critical thinking categories and their achievement across each critical thinking indicator. This focus directly addresses the research problem by showing not only the general level of students' critical thinking skills, but also the specific strengths and weaknesses reflected in the indicators of interpretation, analysis, evaluation, explanation, and inference. The mapping of students' critical thinking profiles provides diagnostic information that is highly valuable for educators in understanding students' cognitive strengths and weaknesses, thereby serving as a basis for designing more effective and targeted instructional strategies (Juliyantika and Batubara, 2022).

METHOD

This study employed a quantitative descriptive approach to examine students' critical thinking skills profiles on the topic of renewable energy at SMA IPIEMS Surabaya. The study was conducted during the first semester of the 2026/2027 academic year and involved 69 students, consisting of 35 students from Class X Merdeka 2 and 34 students from Class X Merdeka 4. Data were collected through a critical thinking skills test. This study employed a quantitative descriptive method to describe students' critical thinking skills profile on renewable energy. The participants were 69 tenth-grade students at SMA IPIEMS Surabaya, consisting of 35 students from Class X Merdeka 2 and 34 students from Class X Merdeka 4. The research instrument was a science literacy-based physics assessment instrument consisting of 20 essay items on renewable energy. The items were designed using contextual stimuli, including short articles, tables, pictures, infographics, and real-life cases related to renewable energy. Each item was aligned with science literacy competencies based on the PISA framework and five critical thinking indicators adapted from Facione, namely interpretation, analysis, evaluation, explanation, and inference. The instrument had previously been validated by experts and tested empirically to ensure that it was appropriate for measuring students' critical thinking skills. Student responses were scored using an analytic rubric, and the obtained scores were converted into a scale of 0-100. The analysis included students' overall critical thinking score, the distribution of students across critical thinking categories, and descriptive statistics for each indicator, including mean, median, mode, minimum score, maximum score, and standard deviation.

The appendix presents the blueprint of the science literacy-based physics assessment instrument used in this study. The complete test consisted of 20 essay items supported by contextual stimuli on renewable energy. Each item was mapped to a renewable energy subtopic, a science literacy competency, a critical thinking indicator, and an item prompt focus.

Table 1. Instrument Blueprint and Item Prompts

Item	Renewable Energy Subtopic	Science Literacy Competency	Critical Thinking Indicator	Item Prompt Focus
1	Urgency of household electricity needs	Explaining phenomena scientifically	Analysis	Analyze factors affecting the effectiveness of solar panels for household electricity needs.
2	Urgency of household electricity needs	Interpreting data and scientific evidence	Interpretation	Interpret data on electricity consumption before and after solar panel installation.

Item	Renewable Energy Subtopic	Science Literacy Competency	Critical Thinking Indicator	Item Prompt Focus
3	Urgency of household electricity needs	Evaluating and using scientific information	Evaluation	Evaluate arguments and decide whether solar panel installation is appropriate.
4	Forms of energy	Explaining phenomena scientifically	Explanation	Explain energy transformation in daily phenomena based on scientific concepts.
5	Forms of energy	Designing and evaluating scientific inquiry	Evaluation	Evaluate the validity of an experiment related to gravitational potential energy.
6	Forms of energy	Using scientific information for decisions	Inference	Draw a conclusion or predict consequences based on energy transformation information.
7	Energy conversion and conservation	Explaining phenomena scientifically	Analysis	Analyze energy conversion and conservation in a renewable energy system.
8	Energy conversion and conservation	Interpreting data and scientific evidence	Evaluation	Evaluate energy efficiency data in a conversion process.
9	Energy conversion and conservation	Using scientific information for decisions	Inference	Infer the most appropriate energy conversion solution based on evidence.
10	Sources of energy	Explaining phenomena scientifically	Explanation	Explain energy conversion in a hydropower system based on its components.
11	Sources of energy	Designing and evaluating scientific inquiry	Evaluation	Evaluate hydropower system efficiency and suggest design improvement based on data.
12	Sources of energy	Using scientific information for decisions	Evaluation	Evaluate health, economic, and energy reserve information related to coal-fired power plants.

Item	Renewable Energy Subtopic	Science Literacy Competency	Critical Thinking Indicator	Item Prompt Focus
13	Renewable and non-renewable energy	Explaining phenomena scientifically	Interpretation	Interpret information about national energy mix and renewable energy potential.
14	Renewable and non-renewable energy	Interpreting data and evidence	Interpretation	Interpret data comparing renewable and non-renewable energy sources.
15	Renewable and non-renewable energy	Using scientific information for decisions	Evaluation	Evaluate the feasibility of renewable energy use based on scientific and social considerations.
16	Impact of energy exploration and use	Explaining phenomena scientifically	Evaluation	Evaluate environmental impacts of fossil energy exploration and use.
17	Impact of energy exploration and use	Using scientific information for decisions	Inference	Infer consequences of energy use for environmental sustainability.
18	Local renewable energy potential	Explaining phenomena scientifically	Explanation	Explain the working principle of a local renewable energy technology.
19	Local renewable energy potential	Interpreting data and evidence	Inference	Infer the feasibility of local renewable energy based on available data.
20	Local renewable energy potential	Interpreting data and evaluating inquiry	Analysis	Analyze wind-speed data and evaluate the feasibility of a wind power plant.

Students' critical thinking profiles were determined based on their performance on the 20 essay items, which were assessed using a scoring rubric specifically developed for this study. Scores for each critical thinking indicator were obtained by summing the scores from all relevant items and converting them into percentages of the maximum possible scores. The overall critical thinking score was calculated using Equation (1).

$$\text{Score} = \frac{\sum \text{score obtained}}{\sum \text{maximum score}} \times 100\% \qquad ...(1)$$

Table 2. Category for Students' Critical Thinking Profiles

Value Range	Category
81-100	Very High
61-80	High
41-60	Sufficient
21-40	Low
0-20	Very Low

The analysis focused on five critical thinking indicators: interpretation, analysis, evaluation, inference, and explanation. This analysis was conducted to identify students' strengths and weaknesses across the different dimensions of critical thinking within the context of renewable energy. Furthermore, the distribution of students across critical thinking categories was presented in percentages and visualized using diagrams to facilitate interpretation of the overall critical thinking profile.

RESULTS AND DISCUSSION

The implementation phase was carried out by administering the test instrument to 69 Grade X students at SMA IPIEMS Surabaya. The classification results showed that 27 students (39.13%) were in the very high category, 20 students (28.99%) in the high category, 15 students (21.74%) in the moderate category, 5 students (7.25%) in the low category, and 2 students (2.90%) in the very low category. As presented in Figure 1, the majority of students (68.12%) fell into the high to very high categories, indicating that science literacy-based stimuli with real-life contexts were effective in activating students' higher-order cognitive processes. This is consistent with Masithoh and Jauhariyah (2024) who stated that science literacy-based instruments on renewable energy topics can comprehensively represent students' competency profiles.

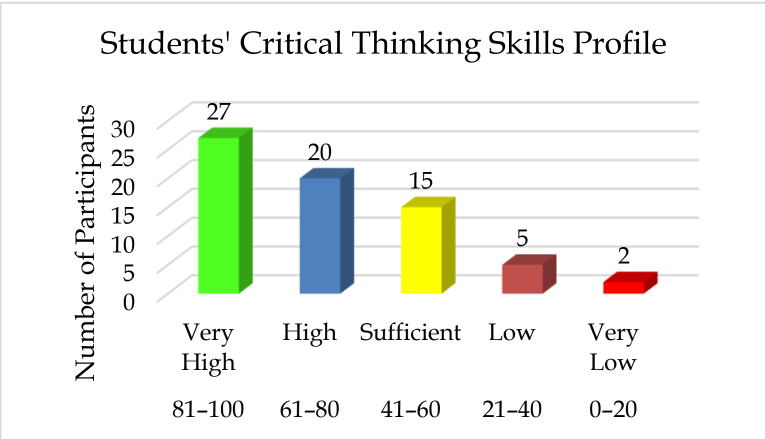

Figure 1. Distribution of Students' Critical Thinking Skills Profile

Further analysis of each indicator revealed a hierarchical achievement pattern, in which the analysis indicator obtained the highest mean score of 76, followed by interpretation and inference both scoring 70, evaluation at 69, and explanation recording the lowest score of 67, as illustrated in Figure 2. All indicators were categorized as high. The analysis indicator achieved the highest score because the ability to identify cause-and-effect relationships is more readily facilitated by contextual stimuli closely related to students' daily experiences. Wijayanti and Siswanto (2020) affirmed that in energy-related topics, the ability to analyze is the most easily mastered skill because students are more accustomed to identifying causal relationships than constructing independent scientific explanations.

Table 3. Average Achievement Scores of Students' Critical Thinking Skills by Indicator

Critical Thinking Indicator	Average Score	Category
Interpretation	70	High
Analysis	76	High
Evaluation	69	High
Explanation	67	High
Inference	70	High

Conversely, the explanation indicator obtained the lowest score because it requires not only conceptual understanding but also the ability to construct and communicate explanations of *why* and *how* a process occurs in a coherent and structured manner. A common error found was that students wrote incomplete or inaccurate scientific concepts. Consequently, the explanation indicator tended to achieve lower scores because it requires the construction of logical scientific explanations, a skill that demands intensive practice and deep conceptual understanding. Compared to Ahzari and Akmam (2025) who reported an average critical thinking score of only 27.80% in the poor category, the present study yielded substantially higher results, which can be attributed to the use of science literacy-based stimuli that proved more effective in activating critical thinking skills than conventional physics problems.

Table 4. Descriptive Statistics of Students' Critical Thinking Skills

Variable	Mean	Median	Mode	Minimum	Maximum	Std. Deviation	Category
Overall score	70.41	76.00	92	20.00	98.00	19.69	High
Interpretation	70.29	70.00	60	20.00	100.00	20.86	High
Analysis	75.54	84.00	92	20.00	100.00	22.37	High
Evaluation	69.15	74.29	80	20.00	100.00	21.56	High
Explanation	67.07	68.00	84	20.00	100.00	20.87	High
Inference	70.43	80.00	100	20.00	100.00	26.70	High

The descriptive statistics show that the overall mean score of students' critical thinking skills was 70.41, which falls into the high category. The median score was 76.00, indicating that half of the students achieved scores equal to or higher than this value. The most frequent score was 92, while the minimum and maximum scores were 20.00 and 98.00, respectively. The standard deviation of 19.69 indicates that students' critical thinking skills varied considerably across participants. Among the five critical thinking indicators, analysis obtained the highest mean score of 75.54, followed by inference at 70.43, interpretation at 70.29, evaluation at 69.15, and explanation at 67.07. Although all indicators were categorized as high, the differences among the indicators indicate that students demonstrated stronger performance in identifying relationships among information and drawing conclusions than in constructing complete and coherent scientific explanations.

The analysis indicator obtained the highest mean score among all critical thinking indicators. This result indicates that students were relatively able to identify relevant information, recognize relationships among concepts, and connect the stimulus with renewable energy concepts. In the context of a science literacy-based assessment, the stimulus presented in the items helped students use contextual information as a basis for reasoning. This finding is consistent with Facione's critical thinking framework, which positions analysis as the ability to identify relationships among statements, questions, concepts, descriptions, or other forms of representation. Empirically, this result is also in line with the finding of Wijayanti and Siswanto (2020), who stated that in energy-related topics, analytical skills tend to be more easily mastered because students are more familiar with identifying cause-and-effect relationships than constructing independent scientific explanations.

The discussion of student responses on the analysis indicator is presented through appropriate and inappropriate responses, as shown in Figure 2 and Figure 3. The appropriate response shows that the student was able to identify the factors affecting the effectiveness of solar panels, such as sunlight intensity, roof position, weather conditions, and installation area. The student also related these factors to the amount of electrical energy that could be produced. In contrast, the inappropriate response shows that the student did not focus on the factors affecting the effectiveness of solar panels, but instead wrote general benefits such as reducing electricity costs and lowering electricity bills. These answers are more accurately categorized as the impacts or advantages of using solar panels, not as factors that determine their effectiveness. This difference indicates that some students still had difficulty distinguishing between causal factors and general consequences in the context of renewable energy technology.

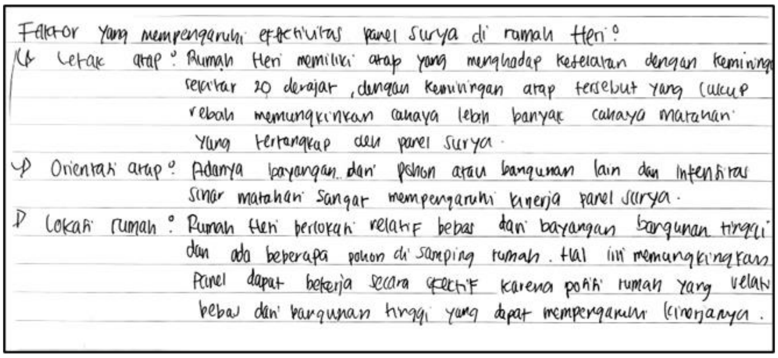
Faktor yang mempengaruhi effektivitas panel surya di rumah Heri :
1. Letak atap : Rumah Heri memiliki atap yang menghadap ketelatan dengan kemiringan sekitar 20 derajat, dengan kemiringan atap tersebut yang cukup rebah memungkinkan cahaya lebih banyak cahaya matahari yang tertangkap oleh panel surya.
2. Orientasi atap : Adanya bayangan dari pohon atau bangunan lain dan intensitas sinar matahari sangat mempengaruhi kinerja panel surya.
3. Lokasi rumah : Rumah Heri berlokasi relatif bebas dari bayangan bangunan tinggi dan ada beberapa pohon di samping rumah. Hal ini memungkinkan panel dapat bekerja secara efektif karena posisi rumah yang relatif bebas dari bangunan tinggi yang dapat mempengaruhi kinerjanya.

Figure 2. Student Response on The Analysis Indicator (Appropriate)

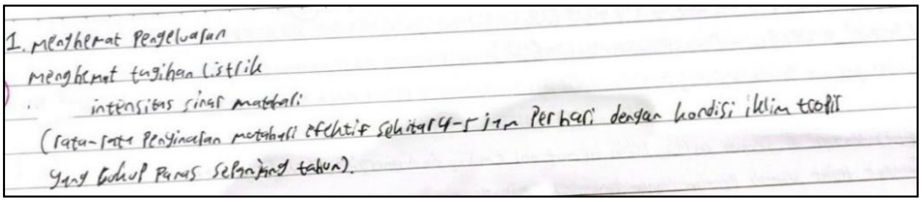
1. menghemat pengeluaran
menghemat tagihan listrik
intensitas sinar matahari
(rata-rata penyinaran matahari efektif sekitar 4-5 jam perhari dengan kondisi iklim tropis yang cukup panas sepanjang tahun).

Figure 3. Student Response on The Analysis Indicator (Inappropriate)

The explanation indicator obtained the lowest mean score among the five critical thinking indicators, although it remained in the high category. This result indicates that constructing scientific explanations was more challenging for students than identifying information or analyzing causal relationships. The item representing this indicator presented a daily-life phenomenon related to energy transformation. Students were required to explain the process of energy transformation and provide scientific reasoning. From the perspective of science literacy, this task is related to the competence of explaining phenomena scientifically because students needed to use relevant scientific concepts, connect the forms of energy involved, and construct explanations based on scientific principles.

The discussion of student responses on the explanation indicator is presented through appropriate and inappropriate responses, as shown in Figure 4 and Figure 5. The appropriate response shows that the student was able to explain the energy transformation process coherently and scientifically, starting from the kinetic energy produced when the ball was kicked, the change in kinetic energy while the ball moved through the air due to gravity and air resistance, and the transformation of kinetic energy into vibrational energy in the net when the ball stopped. In contrast, the inappropriate response shows that the student did not explain the energy transformation process in the phenomenon, but merely wrote a definition of potential energy that was not relevant to the context of the question. This difference indicates that some students were not yet able to distinguish between scientifically explaining a process and merely recalling or writing a concept definition.

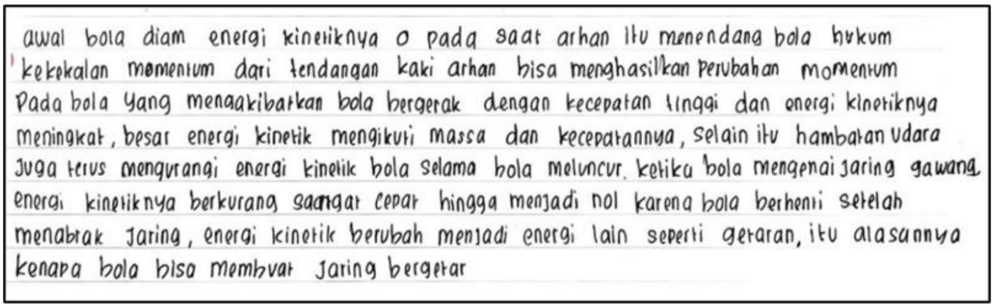
awal bola diam energi kinetiknya 0 pada saat arhan itu menendang bola hukum
kekekalan momentum dari tendangan kaki arhan bisa menghasilkan perubahan momentum
pada bola yang mengakibatkan bola bergerak dengan kecepatan tinggi dan energi kinetiknya
meningkat, besar energi kinetik mengikuti massa dan kecepatannya, selain itu hambatan udara
juga terus mengurangi energi kinetik bola selama bola meluncur. ketika bola mengenai jaring gawang
energi kinetiknya berkurang sangat cepat hingga menjadi nol karena bola berhenti setelah
menabrak jaring, energi kinetik berubah menjadi energi lain seperti getaran, itu alasannya
kenapa bola bisa membuat jaring bergetar

Figure 4. Student Response on The Explanation Indicator (Appropriate)

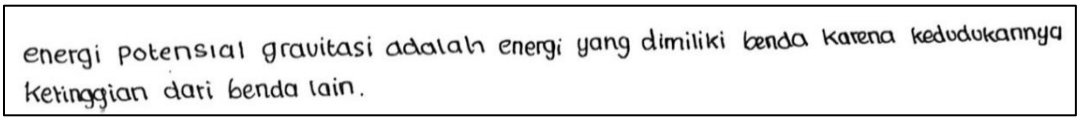
energi potensial gravitasi adalah energi yang dimiliki benda karena kedudukannya
ketinggian dari benda lain.

Figure 5. Student Response on The Explanation Indicator (Inappropriate)

Theoretically, the lower achievement in the explanation indicator can be understood because explanation requires students not only to know what happens in a phenomenon, but also to explain why and how the process occurs in a logical, coherent, and evidence-based manner. In Facione's critical thinking framework, explanation involves the ability to state results, justify procedures, and present arguments based on evidence. Empirically, this finding is consistent with previous studies indicating that students' difficulty in explaining scientific phenomena is often influenced by the habit of memorizing concepts without deeply connecting them to real-life scientific contexts. Therefore, the findings of this study suggest that physics learning on renewable energy should provide more opportunities for students to practice constructing scientific explanations and evidence-based arguments, not only selecting or identifying correct answers.

CONCLUSION

This study answered the research question by showing that Grade X students' critical thinking skills profile on renewable energy, as measured using a science literacy-based physics assessment instrument, was generally in the high category. The overall mean score was 70.41. The distribution showed that 27 students (39.13%) were in the very high category, 20 students (28.99%) were in the high category, 15 students (21.74%) were in the sufficient category, 5 students (7.25%) were in the low category, and 2 students (2.90%) were in the very low category. Based on the indicator profile, analysis obtained the highest mean score at 75.54, followed by inference at 70.43, interpretation at 70.29, evaluation at 69.15, and explanation at 67.07. The comparison among indicators indicates that students were stronger in identifying relevant information and relationships among concepts than in constructing coherent scientific explanations. Therefore, physics learning on renewable energy should provide more structured opportunities for students to practice scientific explanation, argumentation, and evidence-based justification. Future research may involve wider samples and compare profiles across schools, learning models, or other physics topics.

AUTHOR CONTRIBUTIONS

Alifya Crystal Jasmine Zafira Zahra Budimansyah: Conceptualization, Methodology, Formal Analysis, Investigation, dan Writing - Original Draft; **Mukhayyarotin Niswati Rodliyatul Jauhariyah**: Methodology, Validation, dan Supervision.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no financial conflicts of interest or personal relationships that could have influenced the results reported in this manuscript.

DECLARATION OF ETHICS

The authors declare that the research and manuscript preparation have complied with ethical standards for research and publication, in accordance with scientific principles, and are free from plagiarism.

DECLARATION OF ASSISTIVE TECHNOLOGIES IN THE WRITING PROCESS

The authors declare that Generative Artificial Intelligence and other assistive technologies were not used excessively in the research and manuscript writing process. Specifically, ChatGPT was used in a limited manner to assist with the development of initial ideas, the preparation of the writing framework, language refinement, and the improvement of sentence clarity. The authors have reviewed and edited all AI-generated content to ensure accuracy, completeness, and compliance with ethical and scientific standards, and take full responsibility for the final version of the manuscript

REFERENCES

Ahzari, S., and Akmam, A. (2025). Analyzing students' critical thinking as a basis for developing interactive physics multimedia with generative learning and cognitive conflict strategies. *Jurnal Pendidikan Fisika, 13*(2), 163-176. DOI: https://doi.org/10.26618/jpf.v13i2.17702

Anggraeni, S. N., Sholehatennafiah, V., Purwanti, N. Y. N., Pujiningtyas, E. B., Mahartika, D., Sudarti, and Subiki. (2023). Analisis korelasi kemampuan literasi sains dengan kemampuan memecahkan permasalahan konsep energi terbarukan pada mahasiswa pendidikan fisika. *Jurnal Sosial Humaniora Sigli, 6*(2), 132-141. DOI: https://doi.org/10.47647/jsh.v6i2.1514

Ardiyanti, F., and Nuroso, H. (2021). Pengembangan instrumen penilaian untuk mengukur kemampuan berpikir kritis pada materi dinamika partikel secara online. *Jurnal Riset dan Kajian Pendidikan Fisika, 8*(2), 83-90. DOI: https://doi.org/10.12928/jrkpf.v8i2.21173

Cahyana, U., Kadir, A., and Gherardini, M. (2017). Relasi kemampuan berpikir kritis dalam kemampuan literasi sains pada siswa kelas IV sekolah dasar. *Sekolah Dasar: Kajian Teori dan Praktik Pendidikan, 26*(1), 14-22. DOI: https://doi.org/10.17977/um009v26i12017p014

Calma, A., and Davies, M. (2021). Critical thinking in business education: Current outlook and future prospects. *Studies in Higher Education, 46*(11), 2276-2290. DOI: https://doi.org/10.1080/03075079.2020.1716324

Darmawati, D., Wahyuni, S., Anggraeni, R. T., Parno, P., and Kusairi, S. (2025). Development of science literacy-based assessment instrument integrated with renewable energy context to measure students' critical thinking skills. *AIP Conference Proceedings, 3274*(1), 020001. DOI: https://doi.org/10.1063/5.0232625

Facione, P. A. (2011). *Critical thinking: What it is and why it counts*. Insight Assessment. Available at: https://insightassessment.com/iaresource/critical-thinking-what-it-is-and-why-it-counts/

Facione, P. A. (2015). *Critical thinking: What it is and why it counts*. Insight Assessment. Available at: https://insightassessment.com/iaresource/critical-thinking-what-it-is-and-why-it-counts/

Fuad, N. M., Zubaidah, S., Mahanal, S., and Suarsini, E. (2017). Improving junior high schools' critical thinking skills based on test three different models of learning. *International Journal of Instruction, 10*(1), 101-116. DOI: https://doi.org/10.12973/iji.2017.1017a

Hadiryanto, S., and Thaib, D. (2016). Peningkatan kemampuan berpikir kritis siswa SMP melalui pembelajaran berbasis masalah pada konsep respirasi. *EduHumaniora: Jurnal Pendidikan Dasar, 8*(1), 55-65. DOI: https://doi.org/10.17509/eh.v8i1.5122

Hamdani, M., Prayitno, B. A., and Karyanto, P. (2019). Meningkatkan kemampuan berpikir kritis melalui metode eksperimen. *Proceeding Biology Education Conference: Biology, Science, Environmental, and Learning, 16*(1), 139-145. Available at: https://jurnal.uns.ac.id/prosbi/article/view/38412

Juliyantika, T., and Batubara, H. H. (2022). Tren penelitian keterampilan berpikir kritis pada jurnal pendidikan dasar di Indonesia. *Jurnal Basicedu, 6*(3), 4731-4744. DOI: https://doi.org/10.31004/basicedu.v6i3.2869

Lase, D. (2019). Pendidikan di era revolusi industri 4.0. *SUNDERMANN: Jurnal Ilmiah Teologi, Pendidikan, Sains, Humaniora dan Kebudayaan, 12*(2), 28-43. DOI: https://doi.org/10.36588/sundermann.v1i1.18

Masithoh, N. D., and Jauhariyah, M. N. R. (2024). Analisis profil kompetensi literasi sains peserta didik yang diukur menggunakan instrumen berbasis kelas pada materi energi terbarukan. *Inovasi Pendidikan Fisika, 13*(3), 184-190. DOI: https://doi.org/10.26740/ipf.v13n3.p184-190

Mulyani, A. Y. (2022). Pengembangan critical thinking dalam peningkatan mutu pendidikan di Indonesia. *DIAJAR: Jurnal Pendidikan dan Pembelajaran, 1*(1), 100-105. DOI: https://doi.org/10.54259/diajar.v1i1.226

OECD. (2023). *PISA 2022 results (Volume I): The state of learning and equity in education*. OECD Publishing. DOI: https://doi.org/10.1787/53f23881-en

OECD. (2025). *PISA 2025 science framework*. OECD Publishing. Available at: https://www.oecd.org/en/publications/pisa-2025-science-framework_a3d03b9c-en.html

Rahayuni, G. (2016). Hubungan keterampilan berpikir kritis dan literasi sains pada pembelajaran IPA terpadu dengan model PBM dan STM. *Jurnal Penelitian dan Pembelajaran IPA, 2*(2), 131-146. DOI: https://doi.org/10.30870/jppi.v2i2.926

Rosmana, P. S., Iskandar, S., Fauziah, H., Azzifah, N., and Khamelia, W. (2022). Kebebasan dalam kurikulum prototype. *AS-SABIQUN, 4*(1), 115-131. DOI: https://doi.org/10.36088/assabiqun.v4i1.1683

Wardi, L. Z., and Jauhariyah, M. N. R. (2023). Analisis profil kompetensi literasi sains siswa SMA pada materi inti atom dan radioaktivitas. *Inovasi Pendidikan Fisika, 12*(2), 74-80. DOI: https://doi.org/10.26740/ipf.v12n2.p74-80

Wijayanti, R., and Siswanto, J. (2020). Profil kemampuan berpikir kritis siswa SMA pada materi sumber-sumber energi. *Jurnal Penelitian Pembelajaran Fisika, 11*(1), 109-113. DOI: https://doi.org/10.26877/jp2f.v11i1.5533

Yusmar, F., and Fadilah, R. E. (2023). Analisis rendahnya literasi sains peserta didik Indonesia: Hasil PISA dan faktor penyebab. *LENSA (Lentera Sains): Jurnal Pendidikan IPA, 13*(1), 11-19. DOI: https://doi.org/10.24929/lensa.v13i1.283