Gen-z's readiness for renewable energy: Analysis of high school students' knowledge, perceptions, and attitudes

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Abstract
The transition to alternative energy sources is one of the key strategies for mitigating climate change. However, empirical research on the readiness of secondary school students in developing countries such as Indonesia remains limited, meaning that our understanding of the role of cognitive knowledge in shaping pro-environmental readiness is still inadequate. This study aims to examine the levels of knowledge, perceptions and attitudes of high school students regarding renewable energy in Indonesia. Additionally, it explores the relationship between their knowledge levels and attitudes. To achieve these objectives, quantitative research was conducted among 496 high school students in East Java Province using convenience sampling. Data were initially gathered using a validated knowledge test followed by a 5-point Likert scale questionnaire for perceptions and attitudes. The data were subsequently analyzed using descriptive statistics and Spearman's rank correlation. The result showed that 60 percent of the students were at a high level of knowledge. Meanwhile, students' perception was mixed, with some expressing uncertainty about the preparedness of the renewable energy technology in Indonesia. Their attitude was generally positive but was constrained by cost factors. The most important result of this study was a very weak but statistically significant positive correlation between knowledge and attitude. This result showed that knowledge alone was not sufficient to bring about a pro-environmental attitude. This was the reason to consider introducing more contextual learning on renewable energy.

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1. Introduction

Energy resource sustainability is currently one of the most critical issues in the world. The constant and excessive mining of fossil energy resources, including coal, petroleum, and natural gas, since the Industrial Revolution, has exhausted energy reserves and generated significant environmental pollution(Rahman et al., 2024). In addition, rapid population growth worldwide, technological advancements, and increasing energy demand have intensified the global energy challenge (Ramiz et al., 2024; Wang et al., 2024). Therefore, alternative energy sources are needed to overcome the depletion of fossil fuels. Renewable energy sources are then presented as an alternative to fossil fuels and are predicted to reduce environmental pollution and greenhouse gas emissions, which are also increasing due to their use (Higde, 2022; Yu et al., 2024). Renewable energy has the potential because it is often found in the natural environment and can be used continuously (Çelik, 2021; Ehrlich et al., 2022).

Although renewable energy offers a promising solution, its adoption greatly depends on public awareness. Individuals who are aware of these sources of energy will be sensitive to the proper and effective use of energy (Maciaszczyk et al., 2022). The energy transition also requires a shift that must be supported at the societal level , including younger generations. High school students play a critical role in promoting a cleaner and more sustainable energy system (Altassan, 2023; Dodi et al., 2024). Students' awareness and understanding of the significance of energy-related issues determine the extent to which they can contribute to environmental sustainability.

The importance of high school students in advancing the energy transition emphasises the role of schools as a key platform for developing their understanding of renewable energy. The role can be manifested by incorporation renewable energy materials into the physics curriculum, a strategic move to enhance energy literacy and reduce the environmental impact of fossil fuel consumption. However, integrating these materials into the school subject is not without challeges. One obvious challenge is students' awareness, which might not be equally distributed at this point. The trend was observed in the previous report by Pambudi et al (2024).

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They found a impressive gap. The level of awareness among secondary school students was in the middle category, at 57.5, while that among university students was considerably higher at 75.25. This disparity showed that classroom teaching alone was not enough to achieve the same degree of understanding across all levels.

These differences in awareness suggest that understanding renewable energy involves more than simple exposure to information and may be influenced by cognitive and psychological factors. Theoretical frameworks in environmental psychology, such as the Information-Deficit Model, typically argue that environmental inaction stems from insufficient knowledge. Therefore, the advocates of these theories believe that informing the public will naturally lead to pro-environmental behaviors (Suldovsky, 2016). However, modern frameworks, such as the Theory of Planned Behavior (TPB) by Ajzen (1991), suggest a more complex pathway in which knowledge does not directly determine behavior but instead shapes beliefs, which in turn influence attitudes and intentions. In this context, it is theoretically essential to distinguish between perception and attitude as two related but distinct constructs. Perception refers to an individual's cognitive appraisal and awareness of external conditions, such as how a student evaluates the feasibility or technological readiness of renewable energy infrastructure in their country. Attitude, on the other hand, represents an internal evaluative stance, encompassing affective and evaluative dispositions toward action, such as a student's personal willingness to support or adopt clean energy solutions despite potential barriers. Understanding the alignment or divergence between these two constructs is crucial for evaluating youth readiness. Despite this theoretical foundation, empirical application in youth contexts remains limited. The association between the knowledge and attitude of the students regarding renewable energy has not been adequately investigated. Yet, this relationship is consequential - a positive attitude is considered essensial in stimulating behaviors that facilitate the adoption of renewable energy sources (Asif et al., 2023). Among the factors that shape students' understanding and attitudes, energy literacy has been identified as particularly influential (García-Ferrero et al., 2021).

The Indonesian government has accelerated its commitment to energy transition through the National Energy General Plan (RUEN), targeting a 23% renewable energy mix by 2025 (Widyaningsih, 2017). However, achieving this ambitious target faces significant socio-technical barriers, including public skepticism, high investment costs, and a lack of local technical expertise (Sambodo et al., 2022). Therefore, the role of Generation Z, who will inherit the long-term impacts of these policies, is critical. Unfortunately, their readiness to carry the torch remains understudied. Several studies have been conducted to investigate renewable energy literacy among youth in developed countries (Altassan, 2023; García-Ferrero et al., 2021; Higde, 2022). In developing Southeast Asian contexts, particularly Indonesia, the studies remain predominantly oriented toward technical engineering evaluations or high-level policy analyses (Ang et al., 2022; Rahman et al., 2024). Empirical evaluations focusing on secondary school education are even more limited (Pambudi et al., 2024). In fact, studies have documented a gap between what students understand about the environment and their actual behavior, known as the knowledge-action gap. This study directly addresses this gap by investigating how high school students in East Java, Indonesia, evaluate clean energy technologies. Specifically, it examines whether their cognitive understanding translates into an affective disposition toward renewable energy adoption.

Based on this background, this study aims to analyse the levels of knowledge, perception, and attitude of senior high school students towards renewable energy.Additionally, it examines the relationship between their level of knowledge and attitude. This is the first quantitative study in Indonesia to identify a knowledge–attitude gap among students. The findings of this study are expected to serve as a basis for teachers in designing more contextual learning. Thus, students' knowledge may extend beyond factual understanding and develop into active participation in supporting a sustainable energy transition.

2. Method

2.1. Research Design and Participants

This study uses a quantitative approach. The population in this study consisted of all high school students in East Java, which, according to data from the Ministry of Education and Culture, numbered approximately 646,111 students. The research sample was obtain through convenience sampling, a non-probability sampling technique, because of the wide distribution of high schools in the Province of East Java. The proposed approach is to reduce the typical limitations of non-representativeness. The online questionnaire (via Google Forms) was distributed through a wide provincial network of physics teachers and active student communities. The cooperative strategy worked well in getting respondents from a urban centres (Surabaya) and suburban districts (Jember, Banyuwangi, Mojokerto) and helped to make the sample representative of a range of socio-economic backgrounds and institutional school types (Golzar et al., 2022). The data collection process took place from August to October 2025. From this process, 496 valid responses were collected. This number (N = 496) exceeded the minimum sample size recommended for a large population to achieve a 95% confidence level and a 5% margin of error. Thus, the data obtained was statistically robust enough to represent the conditions in the region.

2.2. Research Instrument

The research instrument was adapted from a comprehensive framework for assessing students' knowledge, perception and attitude towards renewable energy. Initially, the knowledge dimension was populated with a larger pool of items which were intended to measure students' basic understanding of renewable versus non-renewable sources of energy. After rigorous testing of construct validity and reliability, only seven knowledge items met the required psychometric thresholds and were retained for the final data collection. In addition to the knowledge test, the instrument measured student's perceptions (16 items) and attitudes (12 items) using a 5-point Likert scale based on the original scaling frame developed by Zyadin et al., (2012). The available answer choices include: Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), and Strongly Disagree (SD). Scores are given on a scale of 1 to 5, with SD = 1, D = 2, N = 3, A = 4, and SA = 5. The detailed dimensions, indicators, and sample items for each construct used in this study are presented in Table 1.

Table 1. Research Instrument Specifications and Sample Items

Variable	Dimensions / Indicators	No. of Items	Sample Item	Source
Knowledge	Ability to distinguish between renewable and non-renewable energy sources; understanding of fundamental energy mechanisms.	7	"Which of the following energy sources is classified as a renewable?"	Adapted from Zyadin et al. (2012)
Perception	Cognitive appraisal of future energy scenarios and the utilization of renewable energy resources.	16	"Renewable energy is very important for the future of the country."	Adapted from Zyadin et al. (2012)
Attitude	Affective readiness; personal willingness to adopt renewable energy and absorb potential additional financial costs.	12	"I am willing to use energy-saving devices even if they are slightly more expensive"	Adapted from Zyadin et al. (2012)

2.3. Data Collection Procedures and Analysis

The collected data were analysed using SPSS software version 27, which includes general descriptive statistics, frequencies, and non-parametric tests. For knowledge, scores were calculated based on the percentage of correct answers and then categorised into five levels, as shown in Table 2.

Table 2. Categories of Students' Knowledge Levels Based on Percentage Scores

Percentage Interval (%)	Category
80 – 100	Very good
60 – 79	Good
40 – 59	Fair
20 – 39	Poor
< 20	Very poor

(Sugiyono, 2022)

Meanwhile, analysing the relationship between knowledge and attitude used the Kolmogorov–Smirnov test (sample size > 50). The test results showed that the attitude and perception variables had a significance value of $p < 0.05$, which means that both were not normally distributed. Thus, the analysis of the relationship between components was conducted using a non-parametric test, specifically Spearman's Rank correlation (r_s). The interpretation of the correlation strength refers to the criteria (Cohen, 2013) as shown in Table 3.

Table 3. Criteria for the Strength of Relationship Based on Spearman Correlation Values

R value	Category of Relationship Strength	Interpretation
0.00 – 0.19	Very weak / Almost no relationship	The relationship between variables is almost invisible
0.20 – 0.39	Weak	Low relationship between two variables
0.40 – 0.59	Moderate	A fairly significant but not strong relationship
0.59 – 0.79	Strong	A fairly high relationship between two variables
0.70 – 1.00	Very strong	Very strong relationship between two variables

3. Results and Discussion

This study involved 496 students from various cities and districts in East Java province. Based on gender characteristics, 32.7% of respondents were male, and 67.3% were female, with ages ranging from 15 to 18 years. The following are the research results.

3.1. Students' Renewable Energy Knowledge

Students' knowledge of renewable energy was measured using a dichotomous test consisting of 7 questions. Figure 1 presents the comprehensive data on their renewable energy knowledge distribution in order to visually examine the variation in students' cognitive levels. As shown in Figure 1, the students' level of knowledge was generally high, with 60% of respondents (N = 298) falling into the Very Good category.

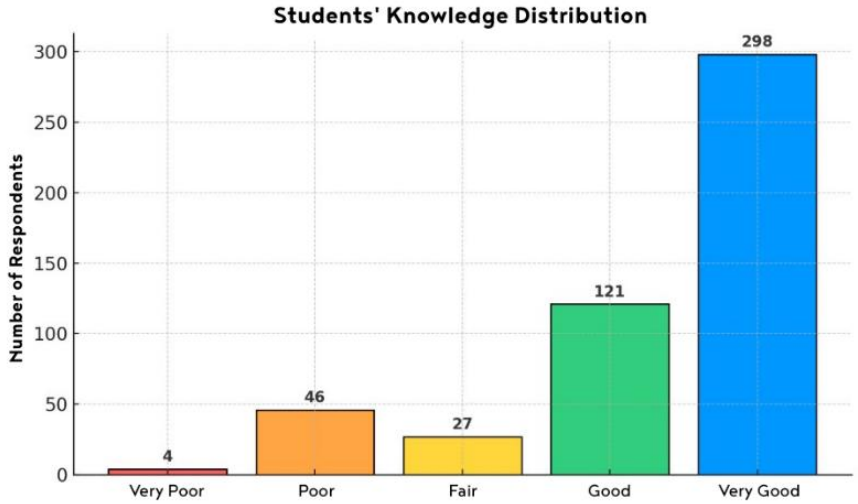

Figure 1. Students' Knowledge Distribution

A review of all items showed that students were very accurate in the identification of familiar sources of renewable energy. Solar and wind energy were the simplest to discover with error rates of 9 and 10 percent, respectively. Comparatively, the item on bioethanol posed the greatest challenge, with 33 percent of students failing to put it in the correct classification. The high error rate regarding bioethanol (33%) reveals a critical cognitive misconception in science education. Students frequently experience conceptual confusion between bio-based alternative fuels and fossil-based chemicals because the term ethanol or alcohol is predominantly associated in secondary school chemistry with industrial solvents rather than clean transportation fuel (García-Ferrero et al., 2021). Furthermore, while solar and wind energy are heavily popularized by mass media and visually integrated into physics textbooks as standard examples, bioenergy concepts remain abstract and underrepresented in the current Indonesian high school physics curriculum (Pambudi et al., 2024, Muslim et al., 2021). This lack of curricular visibility directly hinders students from developing a systemic understanding of biomass as a viable renewable energy alternative (Abdurrahman et al., 2023). There were also identification errors on fossil energy sources such as natural gas with 22% and petroleum with 18%. This trend of responses suggested that there was a disparity in the level of student comprehension. The students were quite conversant with renewable energy that frequently featured in learning or the media such as solar and wind. However, there was no understanding of more complicated forms of alternative energy such as biofuel (ethanol). These results showed that the knowledge of students was more rote than conceptual and reflected the lack of full understanding of the concept. This condition makes it difficult for them when dealing with less popular examples of renewable energy.

3.2. Students' Renewable Energy Perception

Students' perceptions of renewable energy were tested using 16 statements, with assessments using a 5-point Likert scale described as follows: strongly agree (SA) = 5 points, agree (A) = 4 points, neutral (N) = 3 points, disagree (D) = 2 points, and strongly disagree (SD) = 1 point. Table 4 shows the percentage distribution and mode of students' responses regarding perceptions towardrenewable energy.

Table 4. Students' Perceptions of Renewable Energy

Perceptions of renewable energy	SA (%)	A (%)	N (%)	D (%)	SD (%)	Mode
Renewable energy is very important for the future of the country	55	32	10	1	2	Strongly agree
Renewable energy can replace fossil fuels	17	42	34	7	1	Agree
The government should start investing funds in renewable energy development	39	39	20	2	1	Strongly agree
Education about renewable energy must be provided from an early age	39	41	18	1	1	Agree
Renewable energy has a positive impact on the environment	43	38	15	2	2	Strongly agree
Society will support the use of renewable energy	22	44	32	2	1	Agree

Perceptions of renewable energy	SA (%)	A (%)	N (%)	D (%)	SD (%)	Mode
Renewable energy technology is advanced enough to replace fossil fuels	10	34	44	9	3	Neutral
Society is not interested in using renewable energy due to a lack of information	9	31	39	14	6	Neutral
Every school should have a real project involving renewable energy	30	41	25	2	2	Agree
Renewable energy can address climate change	25	38	30	5	2	Agree
Renewable energy is important for Indonesia's future	46	39	12	2	1	Strongly agree
Renewable energy is safer for the environment than fossil fuels	30	35	31	3	2	Agree
Renewable energy has not yet been sufficiently introduced in schools	16	41	32	8	3	Agree
Renewable energy can be used as a solution to the scarcity of fossil fuels	33	36	26	2	2	Agree
The use of renewable energy can help the lives of people in remote areas	38	39	19	2	2	Agree
Renewable energy can be used in everyday life if supported by simple technology.	28	45	20	4	2	Agree

From the data in Table 4, it can be seen that students have idealistic thinking, as evidenced by their responses to the statements "renewable energy is vital for the future" and "the government should start investing funds in renewable energy," with answers indicating strong agreement. The students' idealistic thinking is also reinforced by their agreement with several other idealistic statements, such as "the general public will support the use of renewable energy" and "every school should have a project related to renewable energy."

However, the students' idealistic thinking must be tempered with the reality they face today, where their confidence turns to doubt when given the statement "renewable energy technology is advanced enough to replace fossil fuels." This suggests that students agree with and support the use of clean and renewable energy. However, they are unsure whether the technology in Indonesia is adequate and ready for renewable energy to replace fossil fuels at this time. The students' doubts about technology in Indonesia are not without reason because, according to Sambodo et al. (2022), Indonesia still faces many challenges in utilizing renewable energy, such as economic problems because not many investors are interested in renewable energy technology in Indonesia, the lack of skilled workers in the field of renewable energy, and the lack of personnel capable of conducting research and development.

3.3. Students' Renewable Energy Attitude

The students' attitudes towards renewable energy were tested using 12 statements, with a 5-point Likert scale assessment described as follows: strongly agree (SA) = 5 points, agree (A) = 4 points, neutral (N) = 3 points, disagree (D) = 2 points, and strongly disagree (SD) = 1 point. Table 5 shows the percentage distribution and mode of students' responses regarding attitudes toward renewable energy.

Table 5. Students' Attitudes toward Renewable Energy

Attitude	SA (%)	A (%)	N (%)	D (%)	SD (%)	Mode
I am interested in learning more about renewable energy	31	46	18	3	2	Agree
I want to participate in a renewable energy project at school	23	41	29	4	2	Agree
I would recommend my family to use renewable energy	16	49	30	4	1	Agree
I believe that I can play a role in protecting the environment through the use of renewable energy.	22	41	32	4	1	Agree
If available, I would choose products or tools that use renewable energy	16	46	33	3	2	Agree
I am willing to learn more about renewable energy	27	44	23	5	2	Agree
I am interested in participating in a renewable energy project at school	21	42	31	4	1	Agree
I am willing to share information about the importance of renewable energy with my friends.	16	46	32	4	1	Agree
I want to contribute to energy conservation efforts at home	27	47	21	3	1	Agree
I support the use of solar panels in schools as a tangible application of renewable energy.	29	40	25	4	2	Agree
I am willing to use energy-saving devices even if they are slightly more expensive	9	29	48	10	3	Neutral
If there is a renewable energy campaign program, I am willing to participate as a volunteer	14	29	46	9	2	Neutral

Table 5 shows that students responded positively to the statements "*I am interested in learning more about renewable energy" and "I want to participate in renewable energy projects at school*." However, their good intentions were hindered by the actual actions they had to take, as they responded neutrally or hesitantly to the statement "I am willing to use energy-saving devices even if they are slightly more expensive." This means that students support the use of renewable energy, but they are still hesitant to spend relatively higher costs for its implementation. This is supported by García-Ferrero et al (2021) who stated that if the benefits of using renewable energy cannot be felt immediately or if the costs incurred are considered disproportionate, support for the use of renewable energy will decline. Therefore, students' positive attitudes toward renewable energy do not always translate into positive actions in support of its implementation.

The relatively positive attitudes displayed by students, despite their only moderate perceptions of renewable energy, can be attributed to the affective and value driven nature of attitudes. Benzehaf et al. (2025) noted that students tend to perceive environmental protection as an urgent moral responsibility, indicating that attitudes are shaped not only by cognitive understanding but also by emotional responses and personal values. This is consistent with the attitudinal component of the Theory of Planned Behavior, which links individuals' beliefs about outcomes to their personal and moral evaluations. Therefore, students do not necessarily require a deep conceptual understanding of renewable energy to develop favorable attitudes toward it. Instead, their positive stance is likely rooted in environmental values that have been internalized through formal education and social influences. This view is further reinforced by Sardianou & Kougias (2025), who found that pro environmental attitudes are the most consistent and strongest predictor of youth support for renewable energy. Furthermore, Sardianou & Kougias(2025) emphasized that the role of knowledge in shaping attitudes toward renewable energy is not straightforward. Although greater knowledge tends to broaden students' general support for renewable energy, it may at the same time reduce their enthusiasm when real world compromises or local disadvantages come into consideration. In addition, meaningful gaps in students' understanding of specific energy related subjects continue to exist. Despite this, students are still capable of holding broadly positive views on sustainability, even when their actual grasp of renewable energy concepts remains limited. This situation reflects what scholars have referred to as the awareness, attitude, and action gap, a well established phenomenon in which positive attitudes do not necessarily result in corresponding behaviours (Benzehaf et al., 2025). In other words, expressing support for renewable energy does not automatically drive students to take concrete steps toward its implementation. For this reason, educational efforts that go beyond raising awareness and focus on building deeper, more meaningful understanding of renewable energy are urgently needed to encourage students to move from passive support to active and sustained engagement with sustainable energy practices.

3.4. The Relationship Between Students' Knowledge and Attitudes

The first step in analysing the data on the relationship between students' knowledge and attitudes toward renewable energy is to perform a normality test using the Kolmogorov-Smirnov test with the help of SPSS 27. The normality test was conducted to determine the appropriate analysis technique, whether to use parametric or non-parametric analysis. The normality test is very crucial because it determines the validity of data and ensures that the results of data analysis are not misleading (Gosselin, 2024). Table 6 presents the results of the Kolmogorov-Smirnov normality test for attitudes and perceptions variables.

Table 6. Kolmogorov–Smirnov Normality Test for Attitude and Perception Variables

	Kolmogorov-Smirnova Statistic	df	Sig.
Attitude	.073	496	<.001
Perception	.075	496	<.001
a. Lilliefors Significance Correction			

Table 6 shows that the Kolmogorov-Smirnov normality test of students' attitudes and perceptions, using 496 students, produced a significance (Sig.) of 0.001, indicating that the value obtained was less than 0.05; therefore, the data were not normally distributed. Therefore, to test the correlation between attitudes and knowledge, a non-parametric test was used, namely Spearman's rho correlation test. Table 7 present the Spearman's rho test results to analyze the correlation between attitude and knowledge.

Table 7. Spearman Correlation Test Results between Students' Knowledge and Attitudes

			Attitude	Knowledge
Spearman's rho	Attitude	Correlation Coefficient	1.000	.134**
		Sig. (2-tailed)	.	.003
		N	496	496
	Knowledge	Correlation Coefficient	.134**	1.000
		Sig. (2-tailed)	.003	.
		N	496	496

**. Correlation is significant at the 0.01 level (2-tailed).

Based on the analysis results in Table 7, a correlation coefficient value (rs) of 0.134 was obtained. According to Cohen's criteria, this value indicates a very weak relationship between students' knowledge and attitudes, although it is statistically significant ($p = 0.003$, $p < 0.01$) due to the large sample size. This empirical finding directly refutes the traditional Information Deficit Model, confirming that high cognitive or factual awareness does not automatically translate into a strong affective commitment to environmental actions. This model has been widely criticised because it oversimplifies attitude formation by treating it merely as a cognitive output, ignoring the complex interplay of personal values, social norms, and emotional experiences that underpin genuine attitudinal change (Choi et al., 2023; Grant, 2023; Potvin & Bélanger, 2024).

Within this framework, knowledge is not positioned as a direct determinant of attitude. Instead, attitude emerges from the interaction between personal beliefs, subjective norms, and perceived behavioural control constructs that are conceptually distinct from cognitive knowledge (Hagger & Hamilton, 2024). While students possess the factual knowledge required to score well on a test, their attitude formation is heavily moderated by situational and external barriers, such as perceived high costs and low institutional trust in technology readiness. Theoretical knowledge gained passively in classrooms remains isolated from personal values and daily financial realities, explaining why a student can be highly knowledgeable yet hesitant to accept the economic sacrifices associated with green technologies. This observation was in line with (Allum et al., 2008) who showed a generally positive relationship between scientific knowledge and attitudes though with a small effect. A recent cross-country study by Sturgis et al. (2024) also had similar results. The analysis signalled that the values of the regression coefficients were between 0.17 and 0.24. These values suggested that despite the positive and significant impact of knowledge on attitudes, the impact was not very large. The poor correlation showed that not only knowledge contributed to the attitude of the person. Attitude was formed as a result of a personal experience, values, personality, social influence, and cultural environment. The possibility of easily remembering attitudes through direct experience and personal participation had a stronger influence on behaviour compared to simple theoretical knowledge (Albarracin & Shavitt, 2018).

Internal and external factors were observed to have some contributions. For example, Boer & Fischer (2013) articulated that the foundation of the motivation interacting with the social environment included values, personality, and hereditary (genetic) factors. Karimah & Hanurawan (2023) further identified family, friends, and media as strong social factors with the best influence at adolescence stage. Alves et al.(2025) also observed that a complex environment could lead to prejudiced or retrogressive attitudes determined by the diversity of the social groups encountered. The trend showed the importance of understanding these factors in order to design effective methods of changing attitudes and behaviour. Evans & Durant(1995) supported the role of various factors on attitudes by showing that the high level of knowledge did not necessarily assist to be supported. Moreover, high knowledge can be negatively related actually on morally sensitive issues. This shows the capacity of a deeper insight to render a personal more critical and not just supportive.

Although this study did not directly manipulate or examine instructional interventions, the identified knowledge attitude gap theoretically points toward the potential benefits of experiential pedagogy. Instructional models such as contextual learning widely suggested in environmental literature as mechanisms to bridge this gap (Albarracin & Shavitt, 2018; Higde, 2022). By allowing students to engage with localized, real-world energy problems, such models might appeal to emotional domains and personal values, which are far more potent in shaping long-term attitudes than passive rote memorization. Future instructional research is required to evaluate the empirical efficacy of these pedagogical interventions within the Indonesian classroom context.

The results showed that knowledge was not sufficient to influence the positive attitude of the students towards renewable energy. This has significant implications that learning strategies in physics in schools needs to be revised and created. Educators need to focus on the transmission of factual knowledge or cognitive aspects and be proactively constructive in terms of values and character or affective aspects to establish positive attitudes. Direct experience-based learning such as project-based learning is part of the methods that can support the needs because no academic theory is required to be passively memorized by the students. This model allows students to directly engage with actual experiences that can appeal to the emotional aspect and personal values which are more effective in the creation of attitudes (Albarracin & Shavitt, 2018).

This study has several limitations that need to be considered when interpreting the findings. First, data collection used self-report measures, which are prone to bias. There is a possibility that respondents gave answers that were considered socially desirable (social desirability bias) rather than reflecting the actual situation. Second, this study design is correlational, so it can only explain the relationship between variables but cannot confirm causality. This means that high knowledge cannot be claimed as the direct cause of attitude change, or vice versa. Third, the sampling technique used was convenience sampling. This technique has limitations in terms of representativeness because the sample was taken based on availability and ease of access. As a result, the results of this study have limitations in terms of generalizability to a broader population of students with different characteristics.

4. Conclusion

This study presents a conceptual synthesis of Generation Z readiness for renewable energy transition in East Java, Indonesia. The results show a small gap between cognitive knowledge, perception and attitude. High school students do show a good command of factual knowledge concerning well-publicized sources of clean energy, but this is mostly superficial knowledge, as shown by their limited understanding of less well-known energy sources such as bioethanol. There was also an immense tension between students' environmental idealism and pragmatism: they support national renewable energy policies broadly, but are unsure about the current state of Indonesia's technological infrastructure and remain hesitant about personal financial commitments such as paying more for energy-saving devices. This dynamic is shown in the very weak, but statistically significant, correlation between knowledge and attitude (rs = 0.134). Overall, the findings indicate that educational approaches that only aim at transferring knowledge are not sufficient to stimulate active pro-environmental commitments in youth. Future educational policies should be in the direction of curricula that are more engaging for affective domains and personal values to bridge this knowledge-attitude gap. Future research ought to extend beyond cross-sectional design to longitudinal or experimental approaches. In particular, future studies would benefit from empirically assessing the impact of active learning models, such as project-based learning, on students' emotional engagement with sustainability issues. Further qualitative investigations would also enable deeper insight into the socioeconomic and structural factors underlying students' financial hesitancy to clean energy adoption.

Author Contributions

Nila Mutia Dewi: Conceptualization, Data curation, Formal analysis, Investigation, Writing– original draft; Rif'ati Dina Handayani: Formal analysis, Methodology, Supervision, Validation, Writing–review & editing original draft; Umi Uswatun Khasanah: Conceptualization (supporting), Formal analysis (supporting). All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

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The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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