



Low-Carbon Literacy Profile of Senior High School Students in Indonesia: Implications for Future Climate Change Mitigation

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ABSTRACT

Climate change represents a critical global challenge with profound impacts on human societies. One prominent strategy to mitigate its effects involves fostering low-carbon behavior, often termed low-carbon literacy. Although prior research has investigated various aspects of low-carbon literacy, there has been limited focus on high school students in Central Java, a region acutely impacted by climate change. This study evaluates the low-carbon literacy of high school students in Central Java, Indonesia. Using a validated survey instrument, the research measured three primary domains: knowledge, attitudes, and behaviors, through 31 items. The study sampled 400 high school students, revealing an overall literacy score of 4.3 out of 5 across these domains. Despite the relatively high average score, each domain exhibited specific deficiencies, underscoring the necessity to enhance low-carbon literacy further. A significant limitation of this study is the instrument's contextual specificity to Central Java, which calls for the development of more comprehensive assessment tools and the inclusion of a more geographically diverse sample in future investigations.

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INTRODUCTION

Global warming and climate change are significant factors contributing to environmental issues (Bhardwaj, [2024](#); Nda et al., [2018](#)). These phenomena are largely driven by the increasing concentration of CO₂ emissions, which serve as a major contributor to climate change (Zhong et al., [2021](#)). One of the primary sources of CO₂ emissions is power generation facilities (Shaw, Naskar, Das, & Chowdhury, [2021](#)). As Southeast Asia's largest energy consumer, Indonesia ranks as the fifth-largest CO₂ emitter globally, following China, the United States, and India (Nugroho, Fei-Lu, & Firmansyah, [2017](#)). A significant portion of energy consumption in Indonesia is allocated to electricity production.

The impacts of climate change manifest through an increase in extreme environmental phenomena affecting terrestrial and marine ecosystems. These impacts include alterations in precipitation patterns, rising temperatures, and sea level rise (Pedersen et al., [2022](#)). Climate change also contributes to various environmental and socio-economic challenges, such as coastal erosion, heightened risks of natural disasters, weather anomalies, and the potential extinction of biological species (Thaker, Smith, & Leiserowitz, [2020](#)). Effective climate change mitigation strategies are essential to minimize

these adverse effects (Deetman, Hof, & van Vuuren, [2014](#)). Mitigation efforts should be tailored to the specific characteristics of each region, as the manifestations of climate change vary across geographical areas. In Indonesia, particularly in Central Java, region-specific mitigation strategies are crucial to addressing local communities' unique climate-related challenges.

Central Java Province, Indonesia, is highly susceptible to various natural disasters resulting from climate change. The province possesses abundant natural resources and features a diverse geographical landscape, encompassing mountainous regions, highlands, lowlands, coastal areas, and urban and rural settlements (Isnaini, [2019](#)). Prolonged dry seasons further exacerbate drought risk, posing significant challenges to local communities. In response, in collaboration with local communities, the Central Java government has implemented disaster mitigation strategies, including infrastructure development, establishing early warning systems, and public education initiatives. These collective efforts aim to minimize the adverse impacts of natural disasters and enhance the region's resilience to future climate-related threats.

Disaster mitigation encompasses efforts to raise public awareness and foster environmental responsibility to minimize the occurrence and severity of natural disasters (Zheng, Ou, Chen, Wu, & Liu, [2022](#)). Climate change mitigation, in essence, involves proactive measures aimed at preventing or decelerating the progression of climate change and global warming. The younger generation plays a crucial role in reducing the impact of rising atmospheric CO₂ levels by enhancing their understanding of environmental sustainability and fostering a deeper connection with nature (Mardani, Streimikiene, Cavallaro, Loganathan, & Khoshnoudi, [2019](#)). Strengthening environmental literacy among youth is essential for fostering long-term climate resilience and promoting sustainable practices.

Student literacy can be enhanced by systematically integrating knowledge within school education, supported by a well-structured and comprehensive curriculum (Anderson, [2012](#)). The curriculum fosters literacy among students, particularly in secondary education, by shaping their cognitive development and critical thinking skills. In Indonesia, the education system has undergone several reforms, including curriculum modifications. The Merdeka (Independent) Curriculum's most recent curriculum promotes an autonomous and flexible learning process while emphasizing essential subject matter, character development, and competency-based learning. This curriculum aims to cultivate an innovative and adaptive learning culture that aligns with students' individual needs rather than imposing rigid instructional constraints.

The fundamental structure of the Merdeka (Independent) Curriculum includes a program aimed at strengthening the Profil Pelajar Pancasila (Pancasila Student Profile). This initiative can be implemented by fostering ethical responsibility toward nature, essential in addressing global climate change. One of the critical strategies for mitigating climate change is the reduction of carbon emissions, a concept widely recognized as low-carbon practices. Promoting low-carbon behavior has been

integrated into climate change education programs to enhance students' environmental awareness and sustainable practices (Muhammad Nur Hudha & Permanasari, [2020](#)).

Low-carbon education is a strategic initiative to foster a Low-Carbon Society through a sustainable and systematic education framework, beginning with schools and families. This educational approach encompasses several key components: knowledge acquisition, awareness development, behavioral adaptation, and practical application. Low-carbon literacy refers to an individual's capacity to comprehend environmental phenomena, make informed decisions, and implement appropriate actions to mitigate environmental degradation and promote sustainability (Nurramadhani, Riandi, Permanasari, & Suwarma, [2022](#)).

Several studies have examined low-carbon literacy across different educational levels. Findings indicate that low-carbon literacy's application and awareness aspects are consistently lower than the knowledge aspect among students (M. S. Amin, Permanasari, & Setiabudi, [2019](#)). A study on low-carbon literacy among university students in China revealed deficiencies in both understanding and behavioral implementation of low-carbon practices (Junting, [2024](#)). Similarly, research conducted in East Lombok found that students demonstrated limited engagement in low-carbon behaviors, with only a small proportion actively applying low-carbon literacy principles in their daily lives (Muhammad Syahrudin Amin, Permanasari, Setiabudi, & Hamidah, [2020](#)).

The limited impact of low-carbon literacy in Indonesia can be attributed to the lack of emphasis on low-carbon principles within the country's educational curriculum. There is no dedicated content specifically addressing low-carbon topics, despite the growing need for such material to be integrated into the curriculum to equip students with the necessary knowledge for the contemporary environmental context. According to an analysis, the existing educational materials have not sufficiently fostered awareness or understanding of the low-carbon concept (M. N. Hudha, Hamidah, Permanasari, & Abdullah, [2021](#)). Furthermore, research on low-carbon literacy among senior high school students remains scarce, particularly in regions impacted by climate change. This gap is particularly evident in Central Java Province, underscoring the need for further research.

METHOD

Research design

This study employed a survey to address the research objectives (John W. Creswell, [2018](#)). The survey was administered to 113 pre-service teachers, utilizing the low-carbon literacy instrument for data collection. The data collection was facilitated through an online questionnaire administered via Google Forms.

Respondents

The study included 400 high school student respondents residing in Central Java, comprising 201 females and 199 males. The respondents were selected from five districts/cities that were randomly chosen to represent the demographic composition of students in Central Java. Each district or city contributed 80 students, with 20 students drawn from the following categories: rural areas, coastal areas, urban areas, and mountainous regions. This sampling approach ensured a diverse representation of the province's various geographic and socio-economic contexts.

Instruments

The instrument used in this study is an adaptation of the low-carbon literacy scale developed for students by Hu, Horng, and Teng (2013). A detailed version of the instrument is presented in Table 1. The adapted instrument underwent empirical validation through a pilot test involving 30 students, during which questionnaires were distributed online. Following the validation process, the instrument's reliability was assessed across three dimensions—knowledge, attitude, and behavior—yielding a Cronbach's Alpha coefficient of 0.973, indicating high internal consistency.

Table 1. Low-Carbon Literacy Instrument

Dimensions of Low-carbon Literacy	Indicators	Item Numbers
Cognitive domain		
a. Low-carbon knowledge (KN)	Understanding the concept of low carbon as a mitigation strategy against climate change effects	1–5
b. Ecological cognition (EC)	Cognitive understanding of the extensive interactions between human activities and the environment	6–10
Affective domain		
c. Attitude (AT) & Value (AV)	Positive or negative evaluation of the low-carbon phenomenon and Valuation of the low-carbon phenomenon as a positive perspective	11–13
d. Sensitivity (SN)	Susceptibility to the attitudes, emotions, or conditions of others and cognition of the impact of one's behavior toward others	14–17
e. Locus of control (LC)	The degree to which individuals perceive themselves as having internal control, as opposed to attributing outcomes solely to external factors beyond their influence, in shaping events in their lives.	18–22
Behavior domain		
f. Action intention (AI)	Ideas or intentions that individuals have conceived for execution or creation	23–26
g. Action strategy (AS)	Action strategies encompassing the specific plans, procedures, and practices that individuals or communities undertake to adopt and promote low-carbon lifestyles or behaviors	28–31

Data Analysis

The data processing and analysis findings, including a descriptive analysis, are shown in tables along with the measurements of central tendency and standard deviation. A Pearson correlation was used to determine the relationship between the examined variables.

RESULTS & DISCUSSION

Result

The results of this study focus on the low-carbon literacy of senior high school students in Central Java. Low-carbon literacy is assessed across knowledge, attitude, and behavior. The detailed findings of the research are presented in Tables 2 through 6.

Table 2. Description of Low-Carbon literacy

	N	Minimum	Maximum	Mean	Std. Deviation
Cognitive	400	2.00	5.00	4.3550	.35727
Affective	400	3.25	5.00	4.3475	.31926
Behavior	400	2.89	5.00	4.3922	.32203
Valid N (listwise)	400				

Table 1 presents the descriptive statistics for three key domains: Cognitive, Affective, and Behavior, based on responses from 400 high school students. Each domain's scores range between a minimum and maximum value, indicating the spread of low-carbon literacy levels among the respondents. The Cognitive domain had scores ranging from 2.00 to 5.00, with an average (mean) of 4.3550 and a standard deviation of 0.35727, suggesting that students generally performed well but with some variation. The Affective domain showed a slightly higher minimum score of 3.25 and a mean of 4.3475, with a standard deviation of 0.31926, reflecting a narrower range of responses and consistent attitudes toward low-carbon behavior. In the Behavior domain, scores varied from 2.89 to 5.00, with an average of 4.3922 and a standard deviation of 0.32203, indicating a relatively high performance in behavioral aspects of low-carbon literacy. The consistency of high mean scores across all domains highlights a strong overall understanding and engagement with low-carbon practices among the students, though the variability, as indicated by the standard deviations, suggests areas where further improvement and more targeted educational interventions may be necessary. The table underscores the need to address the disparities within each domain to achieve a more balanced low-carbon literacy.

Table 3. Low Carbon Literacy Based on Gender

	N	Minimum	Maximum	Mean	Std. Deviation
Female	200	3.81	4.94	4.3585	.21420
Male	200	3.61	4.77	4.3673	.20810
Valid N (listwise)	200				

Table 3 provides descriptive statistics for low-carbon literacy scores, categorized by gender, from a sample of 200 female and 200 male respondents. For females, the scores ranged from a minimum of 3.81 to a maximum of 4.94, with an average (mean) score of 4.3585 and a standard deviation of 0.21420. This suggests that female respondents generally exhibited high levels of low-carbon literacy with relatively low variability in their scores. For male respondents, the scores ranged from 3.61 to 4.77, with a mean of 4.3673 and a standard deviation of 0.20810. This indicates that male participants also had high levels of low-carbon literacy, with slightly higher variability compared to females. Overall, both genders showed comparable mean scores, highlighting a general parity in low-carbon literacy between male and female students in this sample. The "Valid N (listwise)" indicates that all 200 participants from each gender provided valid responses.

Table 4. Correlations Among Domains of the Low-Carbon Literacy Instrument

		Cognitive	Affective	Behavior
Cognitive	Pearson Correlation	1	-.028	.383**
	Sig. (2-tailed)		.573	.000
	N	400	400	400
Affective	Pearson Correlation	-.028	1	-.011
	Sig. (2-tailed)	.573		.825
	N	400	400	400
Behavior	Pearson Correlation	.383**	-.011	1
	Sig. (2-tailed)	.000	.825	
	N	400	400	400

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

Table 4 presents the Pearson correlation coefficients between the Cognitive, Affective, and Behavior domains of low-carbon literacy among 400 high school students. The correlation between Cognitive and Affective domains is very low and not statistically significant ($r = -0.028$, $p = 0.573$). The correlation between Cognitive and Behavior domains is moderate and statistically significant ($r = 0.383$, $p < 0.01$), indicating that higher cognitive understanding is associated with more pro-environmental behaviors. In contrast, the correlation between the Affective and Behavior domains is negligible and not statistically significant ($r = -0.011$, $p = 0.825$). The significant correlation at the 0.01 level between Cognitive and Behavior highlights the importance of cognitive aspects in influencing students' environmental behaviors, whereas the affective domain appears to have minimal direct influence on behaviors in this context.

Table 5 presents data on ten questions (Q1 to Q10) used to assess the cognitive aspects of low-carbon literacy among 400 high school students. Each question (Q) is scored between a minimum of 1.00 or 2.00 and a maximum of 5.00, with varying mean scores and standard deviations. The mean

scores across the questions range from 4.2175 (Q3) to 4.5300 (Q7), indicating that students generally performed well in the cognitive domain of low-carbon literacy. Standard deviations range from 0.57177 (Q6) to 0.76594 (Q4), reflecting differences in variability across questions. Overall, the descriptive statistics suggest relatively high levels of cognitive understanding regarding low-carbon literacy, with some variations in responses to specific questions. The "Valid N (listwise)" confirms that all 400 students provided complete data across these ten items.

Table 5. Descriptive Statistics of the Cognitive Domain

	N	Minimum	Maximum	Mean	Std. Deviation
Q1	400	1.00	5.00	4.3075	.58206
Q2	400	2.00	5.00	4.4800	.69340
Q3	400	1.00	5.00	4.2175	.73930
Q4	400	1.00	5.00	4.3425	.76594
Q5	400	1.00	5.00	4.2475	.74339
Q6	400	2.00	5.00	4.3300	.57177
Q7	400	2.00	5.00	4.5300	.60000
Q8	400	2.00	5.00	4.3625	.58903
Q9	400	2.00	5.00	4.3650	.67298
Q10	400	2.00	5.00	4.3675	.63911
Valid N (listwise)	400				

Table 6. Descriptive Statistics of Affective Domain

	N	Minimum	Maximum	Mean	Std. Deviation
Q11	400	2.00	5.00	4.2575	.61411
Q12	400	1.00	5.00	4.4550	.64344
Q13	400	2.00	5.00	4.3525	.61170
Q14	400	2.00	5.00	4.2700	.63884
Q15	400	2.00	5.00	4.3400	.71110
Q16	400	1.00	5.00	4.2000	.66037
Q17	400	3.00	5.00	4.4550	.62766
Q18	400	1.00	5.00	4.3125	.61709
Q19	400	2.00	5.00	4.5150	.62108
Q20	400	3.00	5.00	4.3075	.58635
Q21	400	3.00	5.00	4.3325	.65423
Q22	400	3.00	5.00	4.3725	.60387
Valid N (listwise)	400				

Table 6 summarizes the responses to twelve questions (Q11 to Q22) designed to measure the affective aspects of low-carbon literacy among 400 high school students. The scores for these questions range from a minimum of 1.00 or 2.00 up to a maximum of 5.00, with mean scores varying across the

items. The mean scores range from 4.2000 (Q16) to 4.5150 (Q19), indicating generally high affective engagement with low-carbon concepts among the students. The standard deviations vary from 0.58635 (Q20) to 0.71110 (Q15), showing some differences in the consistency of responses across the items. The "Valid N (listwise)" confirms that all 400 respondents provided complete data for these twelve questions, suggesting a strong overall affective orientation toward low-carbon literacy within this sample.

Table 7. Descriptive Statistics of Behavior

	N	Minimum	Maximum	Mean	Std. Deviation
Q23	400	2.00	5.00	4.3800	.57570
Q24	400	2.00	5.00	4.4850	.62510
Q25	400	1.00	5.00	4.3350	.60306
Q26	400	1.00	5.00	4.3925	.69617
Q27	400	3.00	5.00	4.4025	.60944
Q28	400	2.00	5.00	4.3275	.58831
Q29	400	3.00	5.00	4.4950	.58380
Q30	400	2.00	5.00	4.3050	.55475
Q31	400	2.00	5.00	4.4075	.59778
Valid N (listwise)	400				

Table 7 presents data on nine questions (Q23 to Q31) that assess the behavioral aspects of low-carbon literacy among 400 high school students. The scores for these questions range from a minimum of 1.00 or 2.00 to a maximum of 5.00, with various mean scores and standard deviations. The mean scores for the behavior domain range from 4.3050 (Q30) to 4.4950 (Q29), indicating a generally high level of engagement in pro-environmental behaviors. The standard deviations, ranging from 0.55475 (Q30) to 0.69617 (Q26), suggest some variability in how consistently students exhibit these behaviors. The "Valid N (listwise)" confirms that all 400 students provided complete data for these nine questions, showing a strong overall behavioral commitment to low-carbon practices within the sample.

Discussion

Low-carbon literacy refers to applying knowledge related to CO₂ emissions to mitigate their increasing levels over time. The process through which knowledge is translated into behavior involves complex cognitive and behavioral change stages. This study, however, focuses on examining the domains of low-carbon literacy using the instrument developed for this purpose. The low carbon literacy measurement results in the activity domain, as shown in Table 1, demonstrate positive outcomes, with all three aspects achieving a commendable score of 4.3/5. However, the measurement also revealed areas of low achievement, with a score of 2/5 in certain aspects. This indicates a need to further strengthen the knowledge and application of low-carbon behavior. This finding aligns with research on the low Eco literacy of high school students, which is associated with sustainable living practices (Paryanti,

Pursitasari, & Rubini, [2021](#)). Additionally, studies have highlighted students' limited literacy in energy conversion (Nugraha, Rochman, & Nasrudin, [2022](#)), which contributes to a poor understanding of energy acquisition processes. Consequently, energy-saving attitudes aimed at reducing CO₂ emissions are not effectively realized. This is further supported by data indicating that students in Adiwiyata schools also exhibit low literacy levels (Meilinda, Prayitno, & Karyanto, [2017](#)). These findings underscore the need to enhance literacy in CO₂ emission control across the three interconnected aspects to foster lasting knowledge and sustainable behavior (Pickering, Schoen, Botta, & Fazio, [2020](#)).

Regarding gender, the overall achievement in low carbon literacy remains strong, with scores ranging from 3.61 to 4.94, as detailed in Table 2, though further improvement is necessary. A detailed analysis of each domain in this study revealed several noteworthy findings. As presented in Table 3, a positive correlation of 0.383 was observed between knowledge and behavior. This correlation highlights the importance of strengthening knowledge, particularly by addressing misconceptions, to facilitate the development of low-carbon behaviors. These findings are consistent with previous research, suggesting that enhancing knowledge can significantly contribute to forming sustainable behaviors (Tasquier & Pongiglione, [2017](#)). As shown in Tables 4, 5, and 6, all aspects of the domains exhibit an average score of 4/5, indicating a relatively positive condition. However, when considering the minimum score of 1/5, there remains a clear need for further reinforcement in each domain. Strengthening these domains should be tailored to the geographical contexts of the students, as varying geographical conditions can have distinct impacts on climate change (Rawat, Kumar, & Khati, [2023](#)). For instance, students residing in the southern part of Java Island experience less pronounced climate change impacts than those living in the northern regions. For example, students along the northern coast of Java are facing the adverse effects of flooding due to rising sea levels (Anindita, Putri, Hasibuan, & Tambunan, [2021](#)). The transformation of knowledge into low-carbon behavior in the context of low-carbon education is influenced by several factors (Liu, Liu, & Su, [2021](#)).

Addressing these factors is crucial for ensuring significant progress in promoting the adoption of low-carbon lifestyles in Indonesia, particularly Central Java. This study, however, is constrained by the use of instruments developed by the researchers, each of which has inherent limitations that must be considered when evaluating the findings. The results of this study offer valuable insights for educators, emphasizing the importance of continuing to develop curricula that foster the formation of low-carbon behaviors among students (Putri, Huda, & Nikmah, [2023](#)). By equipping students with adequate low-carbon literacy at the secondary education level, they will be better prepared to address the more complex climate change challenges they encounter in higher education.

The study's findings underscore the critical role of low-carbon literacy in fostering sustainable behaviors among high school students. The commendable average score of 4.3/5 across the cognitive, affective, and behavioral domains highlights a generally positive trend in understanding and practicing

low-carbon principles. However, the low score of 2/5 in certain aspects reveals significant gaps in students' knowledge and behaviors, suggesting the need for targeted educational interventions. The positive correlation between knowledge and behavior emphasizes the importance of robust knowledge dissemination to encourage sustainable practices. These findings are consistent with existing literature, suggesting that increasing knowledge can significantly contribute to the development of sustainable behaviors, essential for mitigating CO₂ emissions.

The study is constrained using self-developed instruments, which may have inherent limitations in comprehensively capturing the nuances of low-carbon literacy across different contexts. Additionally, the study's focus on a specific geographical region—Central Java—limits the generalizability of the findings to broader populations. The variability in geographical impacts of climate change further complicates the interpretation of the data, as students in different regions may face distinct environmental challenges that influence their low-carbon literacy and behaviors.

Future research should aim to develop more comprehensive and universally applicable assessment tools to evaluate low-carbon literacy across diverse geographical contexts. Expanding the sample to include students from various regions will provide a more representative understanding of low-carbon literacy and its determinants. Moreover, longitudinal studies could offer insights into the progression of low-carbon literacy over time and the long-term impact of educational interventions. Integrating tailored educational programs that address regional environmental challenges can also enhance the effectiveness of low-carbon literacy education.

CONCLUSION

The assessment of low-carbon literacy among high school students in Central Java revealed that the knowledge domain achieved a score of 4.3/5, indicating that students possess a satisfactory literacy level. However, the application of these aspects requires further improvement. This study is limited by using instruments specific to Central Java, suggesting the need for future research employing more comprehensive instruments and a broader range of representative respondents. Enhancing low-carbon literacy should be tailored to local conditions, considering the diverse geographical characteristics of Central Java. Such geographical diversity contributes to variations in the impacts of climate change phenomena across the region.

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