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Pre-service teachers perceptions on low carbon literacy in Indonesian University

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Abstract

Low-carbon education, focused on CO_2 emission reduction, is crucial for preservice teachers to prepare future generations to address climate change. Yet, there is a significant gap in research on low-carbon literacy within this group, underscoring the need for further studies. This study investigates the score of low-carbon literacy among prospective teacher students, addressing the critical role of CO_2 emission reduction education in preparing future generations to tackle climate change. Despite the importance of low-carbon education, research on low-carbon literacy in student teachers remains limited. This study employed a survey utilizing a Likert-scale low-carbon literacy instrument. The survey was administered to 113 sixth-semester chemistry education students at Walisongo State Islamic University who had completed the Environmental Chemistry course. Results revealed that literacy of students across the cognitive, affective, and behavioral domains scored 3.367/4, 3.317/4, and 3.288/4, respectively. However, the responses in the cognitive, affective, and psychomotor domains exhibited inconsistencies, suggesting the presence of misconceptions. Robust positive correlations were observed among the three domains; however, the cognitive and psychomotor domains exhibited relatively low correlations. The study highlighted misconceptions about CO_2 emissions related to power generation, low confidence in implementing low-carbon activities, and a tendency to choose easier emission reduction actions. To enhance low-carbon literacy, future research should prioritize addressing and correcting misconceptions related to low-carbon concepts. Moreover, strengthening the quantitative literacy of pre-service teachers is essential, enabling them to better understand and assess carbon emissions from daily activities.

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Introduction

Excessive increases in CO_2 emissions contribute significantly to global average temperatures (Rhodes, 2019). Therefore, education aimed at reducing CO_2 emissions is critical for mitigating the impacts of global warming. This educational process can be implemented through both formal and informal channels (Allison Anderson, 2012). The concept of CO_2 emission reduction education is commonly referred to as Low Carbon Education (LCE) (Hudha & Permanasari, 2020), which emphasizes the importance of integrating environmental sustainability into educational frameworks to address climate change effectively.

Given the widespread consequences of global warming and climate change, it is imperative to implement low-carbon education (LCE) for the younger generation, particularly students and prospective teachers. LCE is an educational framework designed to cultivate a society that is conscious of CO_2 emissions, integrating this awareness into science and environmental education (Nurramadhani, Riandi, Permanasari, & Suwarma, 2022), and can be approached from a multidisciplinary perspective (Yli-panula, Jeronen, Koskinen, & Mäki, 2022). For LCE to be effective, it must encompass the foundational concepts of global warming and climate change, fostering knowledge, attitudes, and behaviors that align with low-carbon practices. Solutions to CO_2 emission challenges include both mitigation and adaptation strategies (Ratinen, 2021). One of the most effective approaches to reducing CO_2 emissions is through energy-saving education in daily activities (Mizuta, 2003).

Low-carbon education has the potential to significantly reduce individual carbon emissions, with estimates suggesting a reduction of 2.86 tons of CO_2 per person annually. This impact is comparable to that achieved through the adoption of solar panels or electric vehicles (Cordero, Centeno, & Todd, 2020). Given its importance, incorporating low-carbon behavior into educational institutions, particularly for prospective teachers, is both vital and strategic (Nurramadhani et al., 2022). As future educators, teachers play a crucial role in instilling low-carbon practices in students. Schools, being structured around a curriculum, provide a controlled and directed environment for this education. To effectively teach these concepts, teachers must be proficient in Climate Change Education (CCE), which includes understanding the causes of climate change, mitigation strategies, and adaptation methods (Ferguson, 2022; Y. Wang & Vasques, 2022).

The effective application of low-carbon knowledge into attitudes and behaviors is encapsulated in the concept of low-carbon literacy. Literacy in this context comprises three core domains: knowledge, attitude, and behavior (C. Liu & Cheng, 2022). Low-carbon literacy is defined as the comprehension of energy conservation and carbon emission reduction, along with its practical application in daily life (Hu, Horng, & Teng, 2013). It is essential for prospective teachers, including future chemistry educators, to develop low-carbon literacy. This necessity arises from the didactic model in chemistry education, which requires not only the transmission of chemical knowledge but also an emphasis on the relevance of this knowledge to everyday life. Furthermore, chemistry education should contribute to sustainable practices and address climate change issues (Sjöström, Eilks, & Talanquer, 2020).

The critical role of prospective teachers in combating climate change contrasts with existing conditions, as evidenced by several studies indicating inadequate climate change literacy among future educators across various countries. Research reveals that prospective teachers in Ghana lack a fundamental understanding of climate change concepts (Nyarko & Petcovic, 2021), while those in Spain demonstrate similarly low levels of climate change comprehension, necessitating significant improvement (Corrochano, Ferrari, López-Luengo, & Ortega-quevedo, 2022). Additionally, some prospective teachers doubt the effectiveness of education in fostering more environmentally friendly attitudes (Meilinda, Rustaman, & Tjasyono, 2017). Beyond knowledge deficits, there is a pressing need to address CO_2 pollution mitigation actions among prospective teachers. For example, prospective teachers in

Finland struggle to differentiate between high and low-impact climate change mitigation actions and often fail to engage in mitigation efforts, sometimes shifting responsibility to others (Tolppanen & Kärkkäinen, 2021).

Knowledge alone does not necessarily translate into corresponding attitudes or behaviors. Several studies illustrate this disconnect. For instance, prospective teachers in the Philippines exhibit low levels of climate change awareness (Competente Ronnel Joseph T, 2019). In Malaysia, although prospective teachers demonstrate strong knowledge and attitudes regarding climate change, their practical application of mitigation and adaptation strategies remains insufficient (Nayan, Mahat, Hashim, Saleh, & Norkhaidi, 2020). Additionally, misconceptions about climate change knowledge are thought to influence attitudes, highlighting the need for enhanced Climate Change Education (CCE) training for science teachers in both America and Finland (Khalidi, Ramsey, Khalidi, & Ramsey, 2020; Yli-panula et al., 2022). Furthermore, teachers in western Norway with specific educational backgrounds have shown reluctance to teach CCE (Skarstein, 2020).

The conditions observed in various countries align with previous research indicating that only a limited number of higher education institutions have effectively integrated Climate Change Education (Y. Wang & Vasques, 2022). Consequently, it is recommended that universities enhance their focus on low-carbon education (Nurramadhani et al., 2022). Effective low-carbon education should aim to improve knowledge by addressing misconceptions (Khalidi et al., 2020; Nyarko & Petcovic, 2021; Tolppanen, Claudelin, & Kang, 2021a), utilize contextualized learning resources (Corrochano et al., 2022), and enhance awareness of climate change (Nurramadhani et al., 2022). Additionally, it should aim to increase awareness of climate change and global warming (Competente Ronnel Joseph T, 2019; Mashfufah, Nurkamto, Sajidan, & Wiranto, 2018), boost self-efficacy, and intensify low-carbon actions (Yli-panula et al., 2022). These educational improvements should also consider students' backgrounds (Skarstein, 2020), as well as internal, external, and demographic factors (T. Wang, Shen, Han, & Hou, 2021).

Studies on low-carbon literacy have been conducted across various fields. For instance, research has explored low-carbon literacy among tourism and hospitality students (Hu et al., 2013). Additionally, an investigation into exhibitors' understanding of low-carbon literacy has been carried out (C. Liu & Cheng, 2022). In the educational sector, studies have examined low-carbon behaviors among secondary school students by Norkhaidi et al. (2017) and assessed the level of low-carbon literacy among elementary school students in the context of daily life activities (Amin, Permanasari, Setiabudi, & Hamidah, 2020).

Prospective teacher students play a pivotal role in delivering low-carbon education to future generations; however, there is a notable lack of research on their low-carbon literacy. The absence of data on low-carbon literacy impedes the advancement of educational strategies. Therefore, it is crucial to investigate the level of low-carbon literacy among prospective teacher students at a university in Indonesia to inform and enhance future educational initiatives. This research was conducted to assess the low-carbon literacy of prospective teacher students who have completed environmental chemistry courses at Walisongo State Islamic University.

Method

This study employed a survey to address the research objectives (John W. Creswell, 2018). The survey was administered to a sample of 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 population comprised fifth-semester students enrolled in the Chemistry Education program at UIN Walisongo, Semarang, Central Java, Indonesia. To qualify as respondents, students were required to have completed environmental chemistry courses. A total of 113 students responded to the distributed questionnaires. Before participation, students voluntarily consented to complete the questionnaire via Google Forms. The collected data were subsequently analyzed using statistical methods. Detailed characteristics of the respondents who completed the questionnaire are presented in Table 1.

Table 1. Characteristics of Respondents

		n	**%**
Semester	5	103	91.15
	7	10	8.85
	19	5	4.42
Age(years)	20	68	60.18
	21	31	27.43
	22	8	7.08
	23	1	0.88
	Alia Madrasah	40	35.40
Type of School	Senior high school	55	48.67
	Boarding schools	11	9.73
	Vocational secondary school	7	6.19
	male	15	13.27
Gender identity	female	98	86.73
	rural settlement	88	77.88
Resident	urban area	11	9.73
	mountain settlement	9	7.96
	coastal settlements	3	2.65
Income of Parent	IDR <1.000.000	40	35.40
	IDR 1.000.000-2.000.000	36	31.86
	IDR 2.000.000-3.000.000	21	18.58
	IDR 3.000.000-4.000.000	9	7.96
	IDR 4.000.000-5.000.000	5	4.42
	IDR >6.000.000	2	1.77

Instrument

The measurement of low-carbon literacy utilized previously established instruments (Hu et al., 2013; C. Liu & Cheng, 2022). The instrument comprises 8 dimensions, encompassing a total of 28 items (18 positive and 10 negative), as detailed in Table 2. Student responses were recorded using a Likert scale with the following options: Strongly Agree, Agree, Disagree, and Strongly Disagree. The use of a Likert scale is appropriate for capturing human responses, and the selection of a four-point scale was intended to delineate students' tendencies towards agreement or disagreement.

The developed instrument consists of 28 items and was validated by three experts. Subsequently, the instrument was revised according to the feedback provided by the validators. The results were analyzed using the percentage of agreement, and the Aiken Index was calculated as 0.8574. Since the Aiken Index exceeds the threshold of 0.75, the instrument is deemed valid based on this index (Aiken, 1985).

Table 2. Low-Carbon Literacy Instrument

Dimensions of Low-carbon Literacy	Indicators	Item Numbers
Cognitive domain		
Low-carbon knowledge (KN)	Understanding the concept of low carbon as a mitigation strategy against climate change effects	1–7
Ecological cognition (EC)	Cognitive understanding of the extensive interactions between human activities and the environment	8–14
Affective domain		
Attitude (AT)	Positive or negative evaluation of the low-carbon phenomenon	15–21
Value (AV)	Valuation of the low-carbon phenomenon as a positive perspective	22–27
Sensitivity (SN)	Susceptibility to the attitudes, emotions, or conditions of others and cognition of the impact of one's behavior toward others	28–34
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.	35–43
Behavior domain		
Action intention (AI)	Ideas or intentions that individuals have conceived for execution or creation	44–52
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	53–60

Before use, the low-carbon literacy instrument was pretested with 35 chemistry education students. Reliability was assessed using Cronbach's alpha cut-off value, which should exceed 0.7 (Cho & Kim, 2015). The Cronbach's alpha value of 0.90 indicates strong internal consistency among the items. Additionally, the Item and Person Reliability scores were 0.87 and 0.97, respectively, demonstrating that the low-carbon literacy instrument is reliable.

A factorial analysis was performed to assess the validity of the instrument's internal structure, and the results showed that the analysis is available ($p < .001$). There exists a strong correlation between all the variables; the Kaiser-Meyer-Olkin test yielded a value of .70, the Chi-square value was 3.545E3, and the Bartlett sphericity test indicated 1770 degrees of freedom. The results are presented in Table 3. The KMO value is acceptable when it is more than 0.6. *Table 3* shows that the KMO value of 0.700 > 0.6, while the significance value of Bartlett’s test of sphericity was 0.000. It shows a strong relationship between the test item data sets.

A factorial analysis was performed to evaluate the validity of the internal structure of the instrument. The results confirmed its adequacy ($p < 0.001$). The analysis revealed a strong correlation among all variables, with the Kaiser-Meyer-Olkin (KMO) measure yielding a value of 0.70. The Chi-squared value was 3.545×10^3, and Bartlett's test of sphericity indicated 1770 degrees of freedom. According to Kaiser (1960), a KMO value greater than 0.6 is considered acceptable. As presented in Table 3, the KMO value of 0.700 exceeds the threshold of 0.6, and Bartlett's test of sphericity has a significance value of 0.000. These results indicate a strong relationship among the test item datasets.

Table 3. The Result of KMO and Bartlett’s Tests

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.700
Bartlett's Test of Sphericity	Approx. Chi-Square	3.545E3
	df	1770
	Sig.	.000

Data Analysis

A descriptive analysis was performed for the data processing and analysis, and the results are displayed in tables with the central tendency and standard deviation measurements. The correlation between the variables under analysis was found using a Pearson correlation.

Results and Discussion

A descriptive analysis was conducted for data processing and interpretation, with results presented in tables that include central tendency and standard deviation measurements. The low-carbon literacy survey data were recorded and analyzed accordingly. Descriptive statistical results are detailed in Table 4. Low-carbon literacy is assessed across three primary domains: cognition, affective, and behavior. The average score for the cognition domain is

3.367 out of 4, which is the highest among the three domains. Conversely, the behavior domain received the lowest score, with an average of 3.288 out of 4, compared to the other domains.

Table 4. Description of Low-Carbon literacy

	N	Range	Min	Max	Mean	Std. Deviation	Variance
Cognition	113	1.86	2.14	4.00	3.367	.4563	.208
Affective	113	1.54	2.46	4.00	3.317	.3884	.151
Behavior	113	1.86	2.14	4.00	3.288	.4276	.183

To examine the correlation among the three domains, a correlation analysis was conducted using SPSS 21 software. The results indicated a strong correlation between the cognition and affective domains (0.759) and between the affective and behavior domains (0.743). However, the correlation between the cognition and behavior domains was lower (0.572). These findings suggest that high levels of knowledge do not necessarily translate into effective implementation of low-carbon behaviors. This observation is consistent with research conducted in Malaysia, which found that while prospective teacher students possess substantial knowledge and positive attitudes, their practice of climate change mitigation and adaptation remains inadequate (Nayan et al., 2020). Similarly, a study of pre-service teacher students in eastern Finland revealed that knowledge did not correlate with their willingness to engage in climate change mitigation actions (Tolppanen et al., 2021a).

Table 5. Correlations Among Domains of the Low-Carbon Literacy Instrument

Correlations

		Cognition	**Affective**	**Behavior**
Cognition	Pearson Correlation	1	**.759****	.572**
	Sig. (2-tailed)		.000	.000
	N	113	113	113
Affective	Pearson Correlation	.759**	1	**.743****
	Sig. (2-tailed)	.000		.000
	N	113	113	113
Behavior	Pearson Correlation	**.572****	.743**	1
	Sig. (2-tailed)	.000	.000	
	N	113	113	113

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

The descriptive analysis revealed average scores for the cognition, affective, and behavior domains of 3.367, 3.317, and 3.288, respectively. While these scores exceed the threshold of

3, a more detailed examination of each domain is warranted (see Table 6). An in-depth analysis of individual items yielded the following significant findings:

The Cognition domain

The Cognition Domain is divided into two subdomains: Low Carbon Knowledge (KN) and Ecological Cognition (EC). The average scores for all components within this domain exceed 3. However, one item, specifically KN2, received a lower score compared to the others. The results of the descriptive analysis are detailed below.

KN2: "I am aware that conserving electricity can lead to a reduction in CO_2 emissions."

Item KN2 has an average score of 2.6991, which is the lowest within the Cognition Domain. Detailed analysis reveals that 44.3% of students scored below 3 (Disagree or Strongly Disagree) on this item. This indicates that nearly half of the students are unaware that conserving electricity can reduce CO_2 emissions. Additionally, 48.7% of respondents' answers to KN2 were inconsistent with their responses to KN3, which states: "I know that coal-fired power plants produce a significant amount of CO_2 gas." The discrepancy suggests a lack of understanding among some students regarding the predominant use of coal in power plants in Indonesia and its associated CO_2 emissions. This underscores the need for improved education for chemistry students concerning the use of coal as a fuel and its environmental impact. Given that CO_2 emissions from electricity use in households can be substantial, with approximately 6,150 kg CO_2 equivalent per year (Nahar & Verma, 2018), it is crucial to enhance electricity efficiency to mitigate CO_2 emissions and address climate change (Mahi, Ismail, Phoong, & Isa, 2021).

The findings of this study align with existing research indicating that pre-service teachers generally exhibit low levels of knowledge regarding climate change education (Competente Ronnel Joseph T, 2019; Moshou & Drinia, 2023; Tolppanen, Claudelin, & Kang, 2021b) Specifically, pre-service chemistry teachers also demonstrate insufficient understanding. Although they possess some knowledge about climate change, their comprehension of related concepts such as global warming, the greenhouse effect, and their interconnections remains unclear or incorrect (Wan, Ding, & Yu, 2023).

The characteristics of the climate change phenomenon necessitate tangible action; however, the absence of immediate visibility and the difficulty in directly measuring changes contribute to widespread misconceptions of the concept (Molthan-hill, Worsfold, Nagy, Leal, & Mifsud, 2019). These findings underscore the necessity for the development of courses aimed at enhancing both content knowledge and pedagogical content knowledge. Such advancements are crucial for fostering a more professional teaching approach and for effectively engaging students in climate change education (Beach, 2023; Favier, Gorp, Cyvin, & Cyvin, 2021). A comprehensive understanding of low-carbon concepts does not inherently translate into low-carbon behaviors. Such a transformation necessitates mediation through personal engagement with scientific principles and a strong trust in climate science knowledge(Larrain et al., 2024).

Table 6: Description of The Cognition Domain

	N	Min	Max	Mean	Std. Deviation
KN1	113	1.00	4.00	3.6460	.54968
KN2	113	1.00	4.00	**2.6991**	1.05123
KN3	113	1.00	4.00	3.3628	.68220
KN4	113	1.00	4.00	3.3805	.90946
EC1	113	2.00	4.00	3.6372	.58343
EC2	113	1.00	4.00	3.1858	.92146
EC3	113	2.00	4.00	3.6637	.52798

The Affective domain

The Affective Domain comprises four subdomains: Attitude (AT), Value (AV), Sensitivity (SN), and Locus of Control (LC). Descriptive analysis of each item within this domain revealed that three items exhibited lower average scores compared to others. Detailed results of the descriptive analysis for the Affective Domain are presented in Table 7. The specifics of these items are as follows:

AV2: "I believe that the efficient utilization of fossil fuel-based electricity can contribute to a reduction in CO_2 emissions."

The average score for AV2 was 2.8230, indicating that 37.2% of students responded with scores below 3 (Disagree & Strongly Disagree). This suggests a need to enhance students' understanding of how efficient use of electricity can contribute to reducing CO_2 emissions. Furthermore, 35.4% of student responses to AV2 were inconsistent with responses to KN3: "I know that coal-fired power plants produce a lot of CO_2 gas." This discrepancy implies that a robust knowledge base does not necessarily translate into corresponding attitudes, highlighting the need for targeted interventions to improve attitudes. These findings are consistent with research emphasizing the necessity of preparing students to lead sustainable development practices (Leal Filho et al., 2020). To effectively translate knowledge into action, it is crucial to strengthen self-efficacy, as supported by existing literature (Baldwin, Pickering, & Dale, 2022).

LC1: "I believe that increasing the amount of information on the impacts of global warming and climate change will enhance individuals' awareness and likelihood of adopting low-carbon behaviors."

The average score for LC1 is 2.7965, with 36.2% of students responding with "Disagree" or "Strongly Disagree." This low score suggests a need to reinforce the belief that disseminating information on the impacts of global warming and climate change is crucial for enhancing awareness and promoting low-carbon behaviors (Alison Anderson, 2009). Despite this, it is important to recognize that possessing knowledge alone does not necessarily translate into the adoption of behaviors aimed at reducing CO_2 emissions.

LC3: "I believe that the effectiveness of a low-carbon lifestyle can be enhanced through the active participation of all family members."

The average score for LC3 is 2.8053, indicating that approximately 37.2% of students exhibit low confidence in the statement. The adoption of low-carbon behaviors in individuals is influenced by various demographic, internal, and external factors (T. Wang et al., 2021). Typically, the initiation of low-carbon behaviors is driven by internal factors, which are subsequently reinforced by external influences, such as habitual practices. When certain habits become normalized, individuals are more likely to emulate a low-carbon lifestyle. Effective implementation of a low-carbon lifestyle often requires robust community support, with the family unit playing a crucial role in maintaining low-carbon principles (Choi & Sung, 2011; R. Liu, Ham, Ding, Jiang, & Zhang, 2022). Families are particularly influential in promoting low-carbon practices through everyday activities, such as electricity use. To enhance the effectiveness of low-carbon practices within the family, the role of the family head is pivotal (Xia, Liu, Han, Gao, & Lan, 2022).

Table 7. Description of The Affective Domain

	N	Min	Max	Mean	Std. Deviation
AT1	113	1.00	4.00	3.4336	.66650
AT2	113	1.00	4.00	3.5664	.61056
AT3	113	1.00	4.00	3.1416	.80030
AV1	113	1.00	4.00	3.5575	.62590
AV2	113	1.00	4.00	**2.8230**	.86839
AV3	113	2.00	4.00	3.5929	.63579
SN1	113	2.00	4.00	3.5575	.59669
SN2	113	1.00	4.00	3.1858	.88185
SN3	113	1.00	4.00	3.5841	.59350
LC1	113	1.00	4.00	**2.7965**	.85731
LC2	113	2.00	4.00	3.5929	.54506
LC3	113	1.00	4.00	**2.8053**	.89501
LC4	113	1.00	4.00	3.4867	.68289

The affective domain is crucial in fostering low-carbon behavior, necessitating targeted reinforcement (Brosch, 2021). A viable approach to strengthening this domain involves engaging students in addressing local environmental challenges related to global warming. This approach is supported by research indicating that direct involvement in environmental problem-solving enhances understanding and application of concepts such as global warming, climate change, and carbon emission measurement and reduction (Nazarenko & Kolesnik, 2018; Rousell & Cutter-mackenzie-knowles, 2019) Increased student participation in such activities not only deepens their knowledge but also boosts their confidence in implementing CO_2 reduction strategies. Therefore, frequent engagement in practical problem-solving activities is likely to enhance students' efficacy and commitment to reducing carbon emissions.

Problem-solving should employ local or contextual issues to enhance the relevance and applicability of the solutions developed. This approach aligns with the principles of situated learning, which posits that knowledge is inherently context-dependent rather than transferable across different situations (Hendricks, 2001). Situated learning asserts that knowledge is not merely an abstract entity that can be detached from its original context (e.g., classroom) and applied elsewhere (e.g., workplace), but is instead bound to specific situations. Effective learning involves engaging with real-world conditions to ensure that knowledge is both relevant and practical. Research supports the efficacy of situated learning, demonstrating its benefits in various domains: it can enhance learner performance (Zheng, 2010), improve critical thinking skills (Monroy-licht, Collante-padilla, & González-hernandez, 2016), and facilitate the acquisition of skills and knowledge (Billett, 1996; Hedegaard, 2009; Marsden, Franklin, Newton, & Middleton, 2010).

The Behavior domain

The Behavior domain encompasses two subdomains: Action Intention (AI) and Action Strategy (AS). Within each subdomain, two items were identified with lower average scores relative to the other items. A comprehensive overview of the low-carbon literacy scores within the Behavior domain is provided in Table 8. Specific items demonstrating lower average scores include:

AI4: “I prioritize the use of public transportation for travel.”

The average score for item AI4, which is 2.7611, indicates that 36.3% of students responded with "Disagree" or "Strongly Disagree." This result contrasts with item SN2, which has a higher average score of 3.1858, indicating agreement with the use of mass transportation (e.g., buses, trains) to reduce CO_2 emissions. This discrepancy suggests that while students may exhibit a certain level of sensitivity to CO_2 emissions, factors such as gender, age, income, education level, taxation, subsidies, previous behaviors, intrinsic motivation, cost, comfort, and infrastructure may influence their actual behaviors, resulting in suboptimal implementation of low-carbon activities (T. Wang et al., 2021). This issue highlights the need for climate change education to account for the specific context of the community when addressing emission reduction. Enhancing students' understanding of low-emission transportation options and integrating this knowledge with actionable strategies has the potential to improve low-carbon behavior (Moshou & Drinia, 2023).

Table 8. Description of The Behavior Domain

	N	Min	Max	Mean	Std. Deviation
AI1	113	1.00	4.00	3.3097	.70811
AI2	113	1.00	4.00	3.4425	.64001
AI3	113	1.00	4.00	3.5310	.61340
AI4	113	1.00	4.00	**2.7611**	.88916
AS1	113	1.00	4.00	3.4690	.64186
AS2	113	1.00	4.00	3.6106	.61866
AS3	113	1.00	4.00	**2.8938**	.95770

In addition to AI4, another item with a low average score is AS3: "I care about environmentally friendly energy campaigns held by the private sector or the government." The average score for AS3 is 2.8938, with 33.6% of students expressing disagreement or strong disagreement. This indicates relatively low student engagement with government initiatives aimed at addressing the impacts of global warming and climate change. The observed disinterest in government programs suggests a need for tailored interventions that consider the diverse characteristics of the student population, including educational background, economic status, familial circumstances, and geographical location. To enhance understanding and support for low-carbon initiatives, it is essential to incorporate quantitative literacy (QL) into educational practices. QL involves the use of data to analyze and interpret emissions and their impacts, providing a rational basis for increasing low-carbon activities. For instance, QL can help in evaluating the effectiveness of various environmental campaigns and in making data-driven decisions to optimize carbon reduction efforts.

> *While watching a YouTube video, 0.2 g of carbon dioxide is being emitted every second, which, considering an average 3–4 min video, equals 36 g. While this might not seem too much, the yearly total of all videos watched is 252,000 metric tons of CO_2, which is the same amount that 52,500 cars emit in a year*(Dósa & Russ, 2020).

The data indicate that viewing YouTube videos significantly impacts annual CO_2 emissions, with the cumulative emissions being substantial. This finding highlights the potential for increased awareness regarding the emissions associated with various activities(Kováčová, Held, & Kotuľáková, 2024). Such data can help elucidate the extent to which everyday actions contribute to CO_2 emissions. Consequently, this understanding can enhance the public's receptivity to government campaigns or educational initiatives addressing climate change, as it underscores the pervasive nature of emissions in daily life (Dósa & Russ, 2020).
Furthermore, the outcomes derived from carbon emission calculation activities can be effectively disseminated through social media platforms. This approach aims to foster increased awareness and provide valuable insights to a broader audience, encouraging more informed responses to activities contributing to CO_2 emissions(Stoddart, Koop-Monteiro, & Tindall, 2024).

Conclusion

The survey results indicate that students attained mean scores of 3.367, 3.317, and 3.288 in the cognitive, affective, and behavioral domains of low-carbon literacy, respectively, on a scale of 4. However, the analysis identifies several key issues: prevalent misconceptions about CO_2 emissions from power plants, a lack of student confidence in executing low-carbon initiatives, and a propensity to choose emission reduction strategies that, while easily achievable, have limited effectiveness. To enhance low-carbon literacy and address misconceptions, it is recommended to strengthen the foundational understanding of climate change phenomena through project-based activities, such as calculating CO_2 emissions from household electricity consumption or transportation usage. Implementing such projects can reinforce students' quantitative literacy regarding CO_2 emissions by providing empirical evidence of their contributions to daily life. This approach is expected to inspire informed actions aimed at reducing CO_2 emissions effectively.

Credit Authorship Contribution Statement

Eko Yuliyanto: Conceptualization, Methodology, Software, Visualization, Formal analysis, Writing–original draft, Writing – review & editing. **Atik Rahmawati**: Writing–review & editing, Supervision, Project administration.

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