



Development and Feasibility of Environmental Knowledge Test Instruments With Low Carbon Education Content for Prospective Science Teachers

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Abstract:

This study aims to develop and measure the feasibility of an environmental knowledge test with low-carbon education content for prospective science teachers. This study is R&D using the ADDIE model. The content validity of the test was measured on three aspects by five experts, and the content validity coefficient of each test item was calculated using Aiken's formula. The analysis shows that the environmental knowledge test with low carbon education content is classified as strongly valid in 3 aspects with scores of 93.2% (aspect #1), 93.4% (aspect #2), and 94.4% (aspect #3) each. Analysis using Aiken's V also shows that all items of the environmental knowledge test with low carbon education content are in the high category with an average index of 0.92. This study concludes that ecological knowledge tests with low-carbon education content can be developed and are feasible for prospective science teachers to use. As the first environmental literacy test with LCE content, the results of this study provide a new base and reference for research, further development, or application of ecological literacy tests with LCE content.

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Introduction

The sustainability of human life depends on environmental quality. The sustainability of life and living depends on the sustainability of the environment. Poor environmental quality will lead to various ecological disasters that threaten human life. Indonesia's air quality index, according to IQAir in 2023, is the worst in ASEAN and 14th of 134 countries in the world with 37.1 points (IQAir, 2023). High concentrations of fine pollutants (PM 2.5) in the air trigger global warming and climate change, reducing the quality of life and human life expectancy. The Air Quality Life Index (AQLI) reveals that the average Indonesian is estimated to lose 2.5 years of life expectancy due to current air pollution (Lee & Greenstone, 2021). Building the ability of individuals to cope with global warming is urgent, and in this case, environmental education has a crucial role (Ichsan et al, 2023). Environmental teaching aims to grow and increase students' awareness and responsibility for the environment (Meilinda et al, 2017) and society. Global ecological threats require a refocusing on the substance and direction of environmental education to align with the latest environmental challenges, namely global warming and climate change due to air pollution. In other words, teaching about the environment needs to refer to the substance of low-carbon education (LCE).

Human behavior strongly affects environmental conditions. Thus, the quality of community environmental literacy, especially regarding current issues and problems that threaten the environment, such as global warming, will strongly determine the quality and sustainability of the environment. The good and bad aspects of an environment are due to low knowledge, attitudes, and behaviors of caring for the environment, and these three abilities are included in environmental literacy skills (Fetiana et al, 2022).

Poor environmental quality is closely related to low knowledge, attitudes, and environmental concerns (Agustin & Maisyaroh, 2020). A person's environmental literacy degree, including prospective science teachers, affects their behavior and actions toward the environment (Kurruppuarachichi et al, 2021). Environmental literacy is a structure of abilities regarding the environment (Bissinger & Bogner, 2018) which consists of knowledge, cognitive skills, concern, compassion, and behavior (Ashari et al, 2023; Maurer & Bogner, 2020; Szczytko et al, 2019).

Environmental knowledge is the concepts and values embedded in a person to understand and appreciate the interrelationships established between humans, culture, and their biophysical environment (Mulina et al, 2018). This is the foundation for developing a person's environmental literacy, especially regarding attitudes towards the environment. The attitude of care for the environment is closely related to the level of environmental knowledge (Sasea et al, 2023). In their research, Rasyid et al, (2023) discovered a positive and significant relationship between environmental knowledge and the development of students' environmental care attitudes at Universitas Khairun Ternate.

In the context of current environmental problems, the development of environmental literacy skills, especially knowledge and cognitive skills, must focus on the substance of low-carbon education, namely global warming and climate change. Measuring the level of environmental knowledge of prospective science teachers

requires a valid instrument. Previously, environmental literacy instruments were developed in general, such as Environmental Literacy Instrument for Adolescents (ELI-A).

In the context of current environmental problems, the development of environmental literacy skills, especially knowledge and cognitive skills, must focus on the substance of low-carbon education, namely global warming and climate change. Measuring the level of environmental knowledge of prospective science teachers requires a valid instrument. Previously, environmental literacy instruments were developed in general, such as *Environmental Literacy Instrument for Adolescents* (ELI-A) (Szczytko et al., 2019), and different content, for example *Environmental Literacy Instrument based on Spirituality* (ELIS) (Husamah et al, 2022). Developing an environmental knowledge test with low-carbon education content has not been conducted.

The validity of an instrument stems from the accuracy of its measurement substance. A test is valid when it can measure the substance that must be measured (Bahri & Supahar, 2019). Content validity ensures that all measurement items created have the feasibility and accuracy of measuring the knowledge domain to be measured. Content validity aims to assess the test's ability to represent the domain to be measured by comparing the test with the test grid (Basuki & Hariyanto, 2014) through a process of rational analysis by a competent panel of experts. The overall score of the expert assessment will be analyzed and used to calculate the content validity coefficient using Aiken's formula (Ramadhan et al, 2020). The formulation of the problem in this study is how to develop and feasibility of environmental knowledge tests with low carbon education content. This study aims to develop a feasible environmental knowledge test with low-carbon education content for prospective science teachers.

Research Method

This study is development research (R & D) using the ADDIE model with a structured and logical work sequence, where each step's output will be used as input in the next step (Cahyadi, 2019). The process of developing this instrument is carried out up to the development stage, which is described as follows:

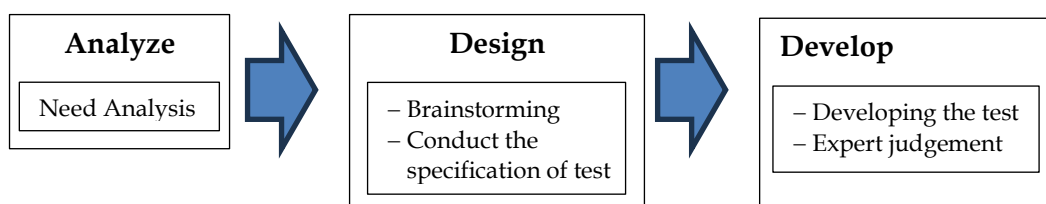


Fig. 1. Step of developing instrument

Referring to Figure 1, the first stage of this research is to deepen the environmental problems of environmental knowledge measurement needs in the context of environmental problems and challenges, especially global warming and climate change. Second, conduct an in-depth study of the type of test, test framework, low carbon education content, and appropriate difficulty level, and compile a test specification. The third stage is to compile the complete test consisting of two abilities,

knowledge and cognitive skills regarding the environment and global warming (Khoirunnisa et al, 2023). Moreover, assess its feasibility by experts. The feasibility assessment of the environmental knowledge test with low-carbon education content includes suitability for indicators (aspect #1), language (aspect #2), and suitability for student development (aspect #3). In this study, the assessment was obtained from 5 experts, and the results were analyzed descriptively (Eq. 1). Furthermore, the assessment results from the expert were also analyzed to determine the content validity coefficient of each test item using Aiken's formula (Eq. 2).

Results and Discussion

An environmental knowledge test with low-carbon education content was developed using the ADDIE development model. This model uses a system approach with a sequential and systematic process, and the output of each stage is used as input for the next stage (Cahyadi, 2019). The stages of the process carried out in the development of environmental knowledge tests with low-carbon education content are as follows:

1. Analysis

Global warming and climate change pose a real threat to the sustainability of life globally. This is due to the increasing emission of greenhouse gases in the atmosphere. Fossil energy consumption is the most significant contributor to greenhouse gases that cause global warming and climate change, namely CO₂, CH₄, O₃, and Nox (Botta et al, 2019). *The Energy Institute* (2024) released global energy and emissions data in 2023, where CO₂ emissions from the energy sector amounted to 35,1229.8 million tons, up 1.6% from the previous year of 34,579.6 million tons. Likewise, carbon emissions from gas combustion in 2023 amounted to 317.4 million tons, an increase of 7% from 2022, which was only 296.6 million tons (The Energy Institute, 2024). This has led to many impacts, such as shifts in seasonal or weather patterns, extreme weather and natural disasters, famine, and food crises are also common; these are some of the facts that the impacts of climate change are a further effect of the increase in Earth's temperature (Boto-Garcia & Buccioli, 2020).

Building knowledge about the natural functions of the environment and the role of individuals in maintaining and preserving it, especially in reducing emissions and efficient use of energy, is important (Lusheng Zheng et al, 2014; Suryanti, 2018). On the one hand, the lack of understanding of low-carbon issues is also a significant cause of the failure of low-carbon implementation (Permanasari et al, 2019). This low-carbon education environmental knowledge test was developed based on one of the pillars of environmental literacy, environmentally informed (NEEF, 2015), which measures individual understanding of environmental problems and issues. The components of environmental literacy are divided into several categories, namely cognitive (knowledge), skills, cognitive skills, affective, and behavioral (Maurer & Bogner, 2020; Szczytko et al, 2020). In general, the construction of the environmental knowledge test with low carbon education content is formulated and presented in Figure 2.

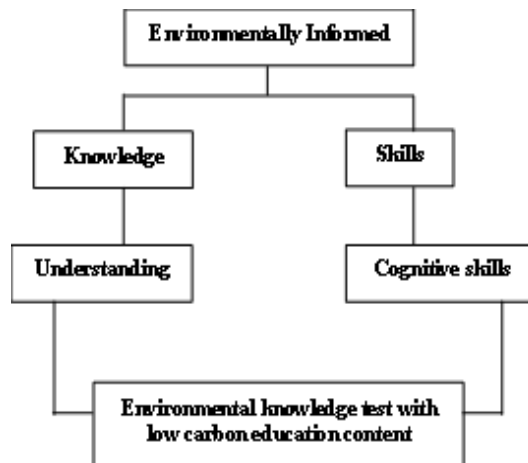


Fig 2. The structure of environmental knowledge test with low carbon education content

Figure 2 illustrates that creating an environmentally informed individual requires establishing a construction of understandings about environmental problems and global warming issues, which is based on his knowledge and cognitive skills for analyzing and understanding data and environmental conditions. Therefore, the test of environmental knowledge with low-carbon education content is created based on these two main abilities.

2. Design

Environmental literacy is an ability built-in absolute terms and can be measured even with quantitative standards (Shephard et al, 2014) and applied in positive actions or behaviors towards the environment. These skills and positive behaviors can only be acquired through learning and practice. With the current environmental realities and challenges, fostering environmental literacy should be oriented towards strengthening the understanding of low carbon. Both commonly intend to respond to concerns about ecological damage resulting from energy and fuel consumption (Weng et al, 2018). The substances of environmental knowledge with low carbon education content measured in this study are presented in Table 1.

Table 1. Environmental knowledge with low carbon education test grids

Aspect measured	Indicators	Σ items
Knowledge about the Environment and Global Warming	Knowledge about environmental issues and global warming	3
	Knowledge about physical systems and ecological systems	4
	Knowledge about the relationship between components in the environment	3
	Knowledge about social, cultural, and political systems related to the environment, especially global warming	2
	Knowledge about an appropriate action strategies to address global warming	4
Cognitive Skills related to Global Warming	Ability to analyze, synthesize, and evaluate information, or data related to the environment and global warming.	7
Total		23

Table 1 presents the construction of an understanding of environmental conditions and problems, especially global warming, which are developed based on knowledge and cognitive skills.

3. Develop

In the current context, environmental knowledge is interpreted as knowledge that includes cognitive aspects of the environment and related issues such as energy use, pollution, waste recycling, etc (Veisi et al, 2018). The environmental knowledge test with low carbon education content developed in this study aims to measure two domains of environmental literacy: understanding and cognitive skills regarding the latest environmental issues and problems. The test consists of 3 questions: multiple-choice and multiple-choice. This is based on the consideration that this test not only explores the knowledge of prospective science teachers but also the cognitive skills of students, precisely the ability of students to organize, interpret, and connect the knowledge they already have to solve a problem (Nelliraharti, 2020).

Another key process in developing the environmental knowledge test with low carbon education content is to measure the quality and feasibility of the test instrument. The validity of the test is determined by content validity through the assessment and agreement of a team of experts in the scientific domain being measured (Pandra & Aswarliansyah, 2023; May Dawati el al, 2017). The assessment of the test by the expert team includes three aspects, namely suitability to the indicators (aspect #1) written in Table 3, Linguistics (aspect #2) presented in Table 4, and suitability to student development (aspect #3) displayed in Table 5.

$$P = \frac{x}{x_i} \times 100\% \quad \dots\dots\dots \text{eq.1}$$

P = percent of validation achievement

x = score of validator

x_i = ideal score

The quality and feasibility of the environmental knowledge test instrument with low carbon education content refers to the following guidelines (Akbar, 2013).

Table 2. Criteria of test validity

Achievement (%)	Category	Qualification
81 – 100	Very Good	Strongly Valid, feasible without revision
61 – 80	Good	Valid, feasible with minor revision
41 – 60	Moderate	Less Valid, major revision and not recommended to use
21 – 40	Not Good	Not Valid, not feasible
0 – 20	Strongly Not Good	Strongly Invalid, not used

Table 2. is a criterion for determining the level of quality and feasibility of each item of the environmental knowledge test with low carbon education content. Where only good and perfect test items are considered suitable for use, content validity aims to ensure that the measurement instrument includes an adequate and representative

set of items that reveal concepts (Hendryadi, 2014), so each item must have the feasibility to be used in the measurement process. This study also analyzed the assessment results from the expert panel and calculated the content validity coefficient of each test item using the Aiken formula (Aiken, 1985) as follows:

$$V = \frac{\sum s}{n(c-1)} \dots \text{eq.2}$$

V = Item validity index

s = score (r - I_o)

n = number of experts

c = rating scale

r = score from each expert

I_o = lowest score

Overall, the results of measuring the validity of the environmental knowledge test instrument with low carbon education content for prospective science teachers in aspect #1 are presented in table 3 below:

Table 3. Validity of environmental knowledge test with LCE content in aspect #1

Test Indicator	Item	Score	Achievement (%)	Qualification
Knowledge about environmental issues and global warming	1	23	92	Strongly Valid
	4	21	84	Strongly Valid
	6	25	100	Strongly Valid
Knowledge about physical systems and ecological systems	3	23	92	Strongly Valid
	11	23	92	Strongly Valid
	12	21	84	Strongly Valid
	15	24	96	Strongly Valid
Knowledge about the relationship between components in the environment	2	23	92	Strongly Valid
	8	24	96	Strongly Valid
	22a	24	96	Strongly Valid
Knowledge about social, cultural, and political systems related to the environment, especially global warming	7	24	96	Strongly Valid
	14	23	92	Strongly Valid
Knowledge about appropriate action strategies to address global warming	5	23	92	Strongly Valid
	9	24	96	Strongly Valid
	10	25	100	Strongly Valid
	13	22	88	Strongly Valid
Ability to analyze, synthesize, and evaluate information or data related to the environment and global warming	16	24	96	Strongly Valid
	17	24	96	Strongly Valid
	18	23	92	Strongly Valid
	19	23	92	Strongly Valid
	20	24	96	Strongly Valid
	21	22	88	Strongly Valid
	22b	24	96	Strongly Valid

Regarding conformity with indicators (aspect #1), all environmental knowledge test items with low carbon education content are categorized as strongly valid, with an average achievement of 93.2%. The results of the expert assessment of the environmental knowledge test instrument in this study are presented in Table 4 below:

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Table 4. Validity of environmental knowledge test with LCE content in aspect #2

Test Indicator	Item	Score	Achievement (%)	Qualification
Knowledge about environmental issues and global warming	1	24	96	Strongly Valid
	4	23	92	Strongly Valid
	6	23	92	Strongly Valid
Knowledge about physical systems and ecological systems	3	21	84	Strongly Valid
	11	21	84	Strongly Valid
	12	22	88	Strongly Valid
	15	22	88	Strongly Valid
Knowledge about the relationship between components in the environment	2	24	96	Strongly Valid
	8	25	100	Strongly Valid
	22a	24	96	Strongly Valid
Knowledge about social, cultural, and political systems related to the environment, especially global warming	7	25	100	Strongly Valid
	14	23	92	Strongly Valid
Knowledge about appropriate action strategies to address global warming	5	23	92	Strongly Valid
	9	24	96	Strongly Valid
	10	23	92	Strongly Valid
	13	22	88	Strongly Valid
Ability to analyze, synthesize, and evaluate information or data related to the environment and global warming	16	25	100	Strongly Valid
	17	24	96	Strongly Valid
	18	25	100	Strongly Valid
	19	25	100	Strongly Valid
	20	23	92	Strongly Valid
	21	22	88	Strongly Valid

In the linguistics aspect (aspect #2), the quality of all environmental knowledge test items with low carbon education content is classified as strongly valid, with an average achievement of 93.4%. Moreover, the last aspect assessed by experts is the suitability for student development (aspect #3) and the development of students (aspect #3). The analysis results (table 5) show that the environmental knowledge test items with low carbon education content are all valid with an average of 94.4% and are categorized as strongly valid.

Table 5. Validity of environmental knowledge test with LCE content in aspect #3

Test Indicator	Item	Score	Achievement (%)	Qualification
Knowledge about environmental issues and global warming	1	21	84	Strongly Valid
	4	24	96	Strongly Valid
	6	25	100	Strongly Valid
Knowledge about physical systems and ecological systems	3	24	96	Strongly Valid
	11	25	100	Strongly Valid
	12	23	92	Strongly Valid
	15	22	88	Strongly Valid
Knowledge about the relationship between components in the environment	2	22	88	Strongly Valid
	8	24	96	Strongly Valid
	22a	25	100	Strongly Valid

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Knowledge about appropriate action strategies to address global warming	7	24	96	Strongly Valid
	14	23	92	Strongly Valid
	5	21	84	Strongly Valid
Ability to analyze, synthesize, and evaluate information or data related to the environment and global warming	9	25	100	Strongly Valid
	10	25	100	Strongly Valid
	13			Strongly Valid
Knowledge about appropriate action strategies to address global warming		22	88	
	16	22	88	Strongly Valid
	17	24	96	Strongly Valid
	18	25	100	Strongly Valid
	19	24	96	Strongly Valid
	20	24	96	Strongly Valid
	21	24	96	Strongly Valid
	22b	25	100	Strongly Valid

Furthermore, the feasibility level of environmental knowledge test items with low carbon education content is measured using the validity index proposed by Aiken (eq. 2). The calculation results are grouped according to the test item validity index criteria (Febriandi et al, 2019) that illustrated in table 6.

Table 6. V Aiken's validity coefficient criteria

V Aiken's	Category
0,81 - 1,0	High
0,61 - 0,80	High enough
0,21 - 0,60	Moderate
0,0 - 0,20	Low

The test item validity index is calculated in groups on all indicators and separately on each item of the environmental knowledge test with low carbon education content. The results of the calculation and analysis of Aiken's index of items in groups for each indicator are presented in table 7 below:

Table 7. V Aiken's environmental knowledge test with LCE content in each indicator

Indicator	Σ Items	ΣS	Indeks V	Category
Knowledge about environmental issues and global warming	3	18,23	0,91	High
Knowledge about physical systems and ecological systems	4	17,56	0,88	High
Knowledge about the relationship between components in the environment	3	18,89	0,94	High
Knowledge about appropriate action strategies to address global warming	2	18,66	0,93	High
Ability to analyze, synthesize, and evaluate information or data related to the environment and global warming	4	18,24	0,91	High
Ability to analyze, synthesize, and evaluate information, or data related to the environment and global warming	7	18,80	0,94	High

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In addition to grouping each indicator, the Aiken index of each item on the environmental knowledge test with low carbon education content was also analyzed. The results of the calculation and analysis of the Aiken index value of each item are presented in Table 8 below:

Table 8. V Aiken's of environmental knowledge test with LCE content items

Test items	V-Index	Category	Qualification
item 1	0,88	High	Feasible
item 2	0,90	High	Feasible
item 3	0,88	High	Feasible
item 4	0,88	High	Feasible
item 5	0,87	High	Feasible
item 6	0,97	High	Feasible
item 7	0,97	High	Feasible
item 8	0,97	High	Feasible
item 9	0,97	High	Feasible
item 10	0,97	High	Feasible
item 11	0,90	High	Feasible
item 12	0,85	High	Feasible
item 13	0,85	High	Feasible
item 14	0,90	High	Feasible
item 15	0,88	High	Feasible
item 16	0,93	High	Feasible
item 17	0,95	High	Feasible
item 18	0,97	High	Feasible
item 19	0,95	High	Feasible
item 20	0,93	High	Feasible
item 21	0,88	High	Feasible
item 22	0,97	High	Feasible

Validity is an absolute requirement of an instrument before it is used. Content validity is the process of ensuring test items are assessed by the content or material (Pandra & Aswarliansyah, 2023). The essence of the Aikens V Index is a description of the level of agreement of the experts that an instrument can measure the required competencies in the research subjects. Retnawati revealed that Aiken's V value index, when less than 0.4, is said to be less valid, 0.4 to 0.8 is said to be moderate validity, and above 0.8 is said to be very valid Pandra & Aswarliansyah (2023).

Table 8 shows that the range of Aiken's v values of the environmental knowledge test with low carbon education content is 0,85 – 0,97. Of the 22 test items, eight items (items 1, 3, 4, 5, 12, 13, 15, 21) have a correlation index value below 0.90. However, overall, the average value of Aiken's V of environmental knowledge test with low carbon education content is 0.92, which means that all items of environmental knowledge test with low carbon education are categorized as very valid and suitable for use.

Conclusion

Referring to the data and analysis conducted, it was concluded that the development of environmental knowledge tests with low-carbon education content was successfully carried out. These results are shown from the assessment by five

experts on three aspects of the test, all categorized as very valid, with an average of 93.7%. Aiken's V index analysis also shows that all environmental knowledge test items with low carbon education content are feasible, with an average V index of 0.92. Many other types of tests can be used to measure students' environmental knowledge and cognitive skills.

As the first research, especially in Indonesia, that produced environmental knowledge tests with low-carbon education content, the findings in this study will provide a new baseline and reference in research on measuring environmental literacy and low-carbon education. However, the ecological knowledge tests with low-carbon education content produced in this study still need to be tested further to ensure their reliability when implemented on real subjects. The next researchers can develop this instrument further in theory and practice by developments in the study of the environment and low carbon education, learning needs, and the character of research subjects.

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