13 (3) (2024) 165-179

Unnes Science Education Journal

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The Development of a Sustainability Literacy Instrument on Alternative Energy Contexts as an Effort to Promote Climate Change Mitigation

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DOI: http://dx.doi.org/10.15294/usej.v13i1.11606

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Article Info

Submitted 2024-08-11
Revised 2024-10-12
Accepted 2024-12-26

Keywords

Climate change mitigation; Development and validation; Education for sustainable development, High school education

Abstract

Research on sustainability literacy among high school students, particularly in the context of energy use and alternative energy, is limited, especially in developing countries like Indonesia. This study aims to fill this gap by developing and validating an instrument to assess sustainability literacy focused on alternative energy. Using the 4D model (define, design, develop, disseminate), the instrument was evaluated by two university lecturers and one high school teacher, achieving a validity score of 84.8%, classified as very good. A readability test with 10 students yielded a score of 91.8%, indicating easy comprehension. The instrument was tested on 70 students, and Rasch analysis, performed using Ministep software, revealed a strong fit with infit and outfit Mean Square (MNSQ) values close to 1.00 and Z-standard (ZSTD) values near 0.00. Reliability scores were 0.82 for knowledge, 0.84 for abilities, and 0.80 for mindset, indicating the instrument's dependability. Overall item reliability exceeded 0.90, confirming the tool's consistency. This validated instrument is a practical and reliable tool for assessing sustainability literacy in high school students, particularly in alternative energy education, and can support educational efforts aimed at mitigating climate change through enhanced understanding of sustainable energy solutions.

How to Cite

Suana, W., Aini, U. N., Ertikanto, C., & Distrik, I. W. (2024). The Development of a Sustainability Literacy Instrument on Alternative Energy Contexts as an Effort to Promote Climate Change Mitigation. *Unnes Science Education Journal*, 13(3), 165-179.

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p-ISSN 2252-6617
e-ISSN 2502-6232

INTRODUCTION

The Sustainable Development Goals (SDGs), launched by the United Nations in 2015, aim to achieve 17 key objectives for sustainable development, including Education for Sustainable Development (ESD) (Adam et al., 2021; Tristanada, 2018). ESD seeks to equip students with the ability to make informed decisions and take actions that enhance quality of life by integrating sustainability values into learning. This makes ESD an essential component in addressing the global sustainability challenges of the future (Tristanada, 2018). One of the critical areas within ESD is fostering sustainability literacy, which involves the capacity of students to critically identify sustainability problems and actively engage in creating sustainable solutions. Sustainability literacy not only provides students with a conceptual understanding but also equips them with action-oriented competences (Vesterinen & Ratinen, 2023).

In this context, climate change stands out as one of the most pressing sustainability challenges that demand immediate attention. To raise environmental awareness and resilience, the urgency of tackling climate change calls for concerted efforts throughout all educational systems (Oranga et al., 2023). The Intergovernmental Panel on Climate Change emphasizes the role of education in fostering a deep understanding of climate science and promoting behaviors that can mitigate its impacts (IPCC, 2021). This is particularly important in developing countries like Indonesia, where there is a pressing need to incorporate comprehensive sustainability education that extends beyond traditional environmental literacy to include specific topics such as alternative energy sources (Kuehl et al., 2023). Climate change's impact on biodiversity and global concerns about sustainable energy usage necessitates an education focused on sustainable development, given the deteriorating quality of the environment (Eshiemogie et al., 2022; Mensah, 2019).

Despite these global imperatives, the direction of ESD in Indonesia has not fully aligned with international objectives (Hawa et al., 2021). Current educational practices in Indonesia still heavily emphasize cultural responsibility and environmental awareness, necessitating improvements to achieve higher levels of sustainability literacy (Sutanto, 2017). Specifically, Indonesia's reliance on fossil fuels, which significantly contribute to greenhouse gas emissions, underscores the importance of integrating alternative energy education into the high school curriculum (Afriyanti et al., 2018). Without a strong foundation in sustainability literacy, students may lack the necessary competencies to address future energy challenges effectively. Moreover, research indicates that existing sustainability education in Indonesia tends to be fragmented and insufficiently focused on practical applications, highlighting the need for targeted educational tools that can assess and improve students' understanding of sustainable energy practices (Sutanto, 2017).

Sustainability literacy refers to the set of abilities, disposition, and information that enable people to make the conscious decision to build a sustainable future and direct them towards that end (Mason, 2019). It aims to empower students to act effectively and appropriately in response to sustainability challenges (Qureshi, 2020). Through sustainability literacy, students can be motivated to participate actively in eco-friendly community initiatives, contributing to a more resilient future (Qureshi, 2020). Research by Décamps et al. (2017) identified three key aspects of sustainability literacy: knowledge, skills, and mindset. These aspects were developed into eight indicators to ensure a coherent, pedagogical, and systemic framework, underscoring the necessity for valid and reliable assessment instruments to measure these competencies, particularly in alternative energy topics.

However, recent studies highlight ongoing challenges in implementing and raising awareness of sustainability, particularly among university students and the general public (Chen et al., 2022; Kuehl et al., 2023). For example, research conducted in China demonstrates high levels of sustainability knowledge, attitudes, and behaviours among students, primarily focusing on environmental dimensions (Chen et al., 2022). Similarly, studies in Kuwait reveal low environmental literacy among teachers and students, along with a notable absence of sustainability issues in school curricula (Al Qattan & Gray, 2023). While these studies provide valuable insights, they are largely centred on general environmental literacy and are primarily conducted in developed or moderately developed countries. This contrasts sharply with the context of Indonesia as a developing nation, where the challenges are distinct and require more tailored educational interventions.

A review of existing literature reveals the development of several instruments to assess sustainability literacy, though most have focused on broad sustainability concepts rather than specific areas such as alternative energy. For instance, the Assessment of Sustainability Knowledge (ASK) is a well-known instrument that measures general

sustainability knowledge across environmental, economic, and social domains (Mason, 2019; Zwickle & Jones, 2018). Additionally, Null et al. (2021) assessed environmental literacy, behaviours, attitudes, and lifestyle factors among college students, while Aikowe and Mazancová (2022) evaluated pro-environmental awareness among university students through a sustainability literacy test. However, these instruments lack specificity in addressing the nuances of energy sustainability, which is critical in the context of Indonesia's reliance on fossil fuels.

Other instruments, such as the New Environmental Paradigm (NEP) and the Sustainability Attitudes Scale (SAS), are designed to gauge attitudes towards sustainability rather than providing a comprehensive assessment of knowledge or skills (Zwickle & Jones, 2018). The Sustainability Literacy Test (Sulitest) has been widely used to assess sustainability knowledge on a global scale, but its broad international focus makes it less effective in addressing the specific needs and challenges faced by students in developing countries like Indonesia (Décamps et al., 2017; Kuehl et al., 2021). Waltner et al. (2019) developed and validated an instrument to measure student sustainability competencies, focusing on a broad range of sustainability topics without specific emphasis on energy use.

The Rasch Model has been widely used to provide accurate and trustworthy assessment tools in a variety of educational contexts, but its application to sustainability literacy is still rather small. For example, without utilizing the advantages of the Rasch Model, Ozdemir (2021) created sustainability literacy scores using conventional validation methods like factor analysis. However, when assessing scientific inquiry literacy, research like that conducted by Darman et al. (2024) has shown how well the Rasch Model works to eliminate biases and guarantee item reliability across a range of demographic groups. Despite these advantages, there hasn't been much research done on using the Rasch Model to evaluate sustainability literacy, especially for high school students.

Additionally, Baierl and Bogner's (2024) study examined environmental knowledge gains and retention using the Rasch Model, demonstrating how the model can account for differences in students' attitudes and retention of information. Similarly, the Rasch Model's capacity to manage intricate, multifaceted structures was reinforced when Kariri et al. (2023) utilized it to evaluate a psychological empowerment scale used in sustainability research. Further confirming the Rasch Model's utility in sustainability research, Zainordin et al. (2023) employed it to evaluate crucial success variables for sustainability implementation in Malaysian higher education institutions.

This study aims to address these gaps by developing a valid, reliable, and practical assessment instrument for sustainability literacy focused on alternative energy topics at the high school level. This instrument is expected to measure students' understanding, creative thinking, and behavior in sustainability contexts, thereby contributing to enhanced sustainability education in Indonesia.

METHOD

Research Design

This study employs a research and development approach to create an assessment instrument for sustainability literacy focusing on alternative energy topics. The research adopts the 4D development model by Thiagarajan et al. (1974), which includes four stages: define, design, develop, and disseminate (Figure 1).

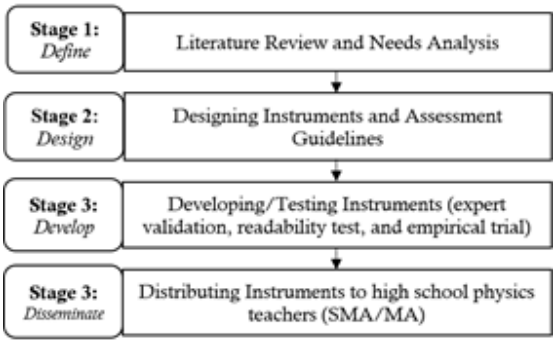

Figure 1. 4D Development Model

Development Stages

In the define stage, the need for the assessment instrument was identified through a literature review and empirical analysis. The literature review focused on sustainability literacy in alternative energy topics, drawing from national and international journals and books. Empirical analysis included interviews with physics teachers to determine the types of instruments currently used, their effectiveness in measuring knowledge, skills, and mindsets, and the challenges faced in creating assessment tools.

Moving into the design stage, this stage included a comprehensive grid outlining the indicators to be measured, detailed usage instructions, the format of the instrument, scoring rubrics, scoring guidelines, and a summary of the assess-

ment. The initial instrument consisted of 24 multiple-choice questions, divided into knowledge (10 items), skills (6 items), and mindset (8 items), based on indicators developed by Décamps et al. (2017), as illustrated in Table 1.

Table 1. Dimension, Indicator, and Number of Item of the Instrument

Dimension	Indicator	Number
Knowledge	Identifying renewable and non-renewable energy sources in sustainable human life.	1
	Explaining the ecological impacts caused by excessive energy use.	1
	Describing social perspectives on the impacts of energy use.	1
	Analyzing the effects of excessive energy use on global systems.	1
	Analyzing the impact of energy source usage on the economy in sustainable life.	1
	Explaining individual efforts to initiate energy transitions to more sustainable alternative energy sources.	1
	Analyzing case studies on strategies for using new technologies in energy transition efforts.	1
	Providing examples of behaviors that reflect awareness of the role of alternative energy in sustainability.	1
	Providing examples of behaviors to minimize energy source usage in sustainable living.	2
Skills	Measuring students' skills in developing creativity to address the energy crisis.	1
	Thinking strategically to overcome future energy usage challenges.	1
	Explaining the importance of collaboration to support systemic change resulting from energy use impacts on sustainable life.	1
	Participating in activities to save energy for a more sustainable life.	1
	Measuring systemic thinking skills related to the impacts of excessive energy use.	1
	Analyzing global perspectives on the future impacts of energy use.	1
Mindset	Engaging in activities to respect and care for sustainable life in relation to energy sources.	2
	Analyzing the environmental impacts of societal energy use.	2
	Demonstrating confidence in initiating change by utilizing alternative energy sources in sustainable development.	2
	Committing to resolving energy usage issues in sustainable development.	2

The develop stage refined and validated the assessment instrument. A draft was created with 24 multiple-choice items addressing knowledge, skills, and mindset aspects of sustainability literacy, adapted from Sulitest by Décamps et al. (2017). Multiple-choice tests were chosen for their objectivity and ease of use. Expert validation involved two university lecturers and a physics teacher, who reviewed content validity and offered improvements. The lecturers contributed theoretical insights, while the teacher ensured practical relevance for classroom application. The instrument was revised based on feedback and tested for readability with 10 high school students to ensure clarity. It was then field-tested with 70 students from a public senior high school in Bandarlampung, Indonesia. Data analysis using the Rasch model via Ministep software evaluated empirical validity and reliability, with Cronbach's Alpha confirming internal consistency.

In the last stage, disseminate stage, after final revisions, the validated and reliable instrument was distributed to physics teachers with the aim of broader application in assessing students' sustainability literacy in alternative energy topics.

Data and Instruments

Data collection in this study involved expert validation feedback, student readability test responses, and field testing data. The expert validation instrument assessed the construction, content, and language of the sustainability literacy tool using a 1-4 scale, with space for qualitative feedback. The readability test also employed a 1-4 scale to evaluate the tool's clarity, ease of understanding, and legibility, while allowing students to provide suggestions or report difficulties, ensuring the tool was suitable for the target audience.

Data Analysis Techniques

Data analysis used the Rasch model with Ministep software to assess the validity and reliability of the instrument. Key parameters included outfit mean square (MNSQ), outfit Z-standard (ZSTD), and point measure correlation (Pt Mean Corr), following Boone et al. (2014). Validity was assessed using MNSQ (0.5 < MNSQ < 1.5) and ZSTD (-2.0 < ZSTD < +2.0) criteria (Isa et al., 2017). Reliability was measured with Cronbach's Alpha, where a threshold of >0.80 indicated excellent reliability (Bond & Fox, 2015). These analyses ensured the instrument accurately measured sustainability literacy and was reliable in educational settings.

The Rasch model was chosen for its ability to provide more accurate and reliable measurements than classical methods, transforming raw scores into interval data for better interpretation of student abilities and item quality. It also ensures measurement invariance across different respondent groups, facilitating validity assessment and instrument reliability (Babcock & Hodge, 2020). Compared to classical methods like Cronbach's alpha or KR20, Rasch's person separation reliability (R) provides a more conservative and accurate measure of internal consistency, addressing non-linearity in data and preventing overestimation of reliability, especially in skewed test score contexts (Anselmi et al., 2019).

RESULT AND DISCUSSION

Results

This research was conducted through several stages. The first stage involved the development of the sustainability literacy instrument. In this stage, the instrument was constructed by detailing its specifications, writing the assessment items, determining the scoring rubrics, and setting up the scoring guidelines. Once the instrument was developed, it underwent expert validation. This validation was carried out by two subject matter experts and one physics teacher, who evaluated the instrument based on its construction, content, and language. The results of the validation by each expert are presented in Table 2.

Table 2. Expert Validation of the Instrument

No	Dimension	Expert			Average	Max Score	Percentage	Category of Validity
		1	2	3				
1.	Construct	18	22	22	20.7	24	86.1%	Good
2.	Substance	30	37	35	34.0	40	85.0%	Very good
3.	Language	9	10	11	10.0	12	83.2%	Very good
Average							84.8%	Very good

The expert validation results for the sustainability literacy assessment instrument, as shown in Table 2, indicate a high level of validity across all evaluated aspects. The construction aspect received a score of 86.12%, the content (substance) aspect scored 85%, and the language aspect received 83.2%, each categorised as "very good". The overall average validation percentage was 84.8%, also categorised as "very good." These results demonstrate that the instrument is theoretically justified and suitable for assessing sustainability literacy in the context of alternative energy for senior high schools.

There were several improvement suggestions from the experts, as the example can be seen in Table 3. In the table, item S5 required a change in topic from "greencity" to "greenflation" due to the unfamiliarity of "greencity" among students. After the sustainability literacy assessment instrument for alternative energy topics was deemed suitable, a readability test was conducted with 10 students from SMA Negeri 5 Bandar Lampung, comprising 5 students from class XE-9 and 5 from class XE-10.

Table 3. Example of Initial and Revised Version of the Instrument

Item	Initial Version	Revised Version
5	A green city can be realised if the community diversifies its energy sources, thereby advancing its economic system. What are the economic benefits for the city under this programme? a. Increasing accessibility and mobility b. Reducing environmental impact c. Creating new job opportunities d. Diversifying natural resources e. Increasing energy production	Government policies aimed at promoting the use of environmentally friendly energy may lead to greenflation. Greenflation can have significant impacts on the economy of society. What are the economic impacts of this phenomenon? a. A decline in company revenues b. An increase in unemployment rates c. A rise in the prices of non-environmentally friendly goods d. Increased investment in green technology e. A reduction in the production of goods and energy

The researchers used a questionnaire as the data collection method. This questionnaire contained 7 statements for the readability test. The results, as shown in Table 4, indicate a readability percentage of 91.8%, categorised as very high.

Table 4. Readibility Test Result

No.	Statement	Score	Percentage
1.	The font type and size are easy to read.	38	95.0
2.	The instructions are easy to understand.	37	92.5
3.	The text is clearly legible.	39	97.5
4.	The language used in each question is clear and easy to comprehend.	34	85.0
5.	The language used in each answer option is clear and easy to comprehend.	34	85.0
6.	Filling out the questions is simple and practical.	37	92.5
7.	The graphs and images presented are clear and easy to understand.	38	95.0
Average score and percentage		36.7	91.8
Category		Very good	

Based on Table 4, the readability test results for the sustainability literacy assessment instrument on alternative energy topics indicate a high level of readability among students. The overall readability percentage was 91.8%, which is classified as "Very Good," confirming that the instrument is well-suited for student use. The aspect with the highest score was the legibility of the text (score: 39), while the clarity of language in both the questions (score: 34) and the answer choices (score: 34) received the lowest scores.

In response to these results, revisions were made primarily focused on improving language clarity. Students suggested including definitions for specific terms to enhance understanding. For example, item 5 originally included the term "greenflation," which was revised to provide an explanation, defining it as the increase in prices of goods and services due to efforts to mitigate climate change impacts. The revised items are presented in Table 5.

The field trial was conducted with 70 E-phase students at one of state senior high schools in Bandar Lampung, Indonesia. The sustainability literacy instrument tested consists of 24 questions, including 10 knowledge aspect questions, 6 skill aspect questions, and 8 mindset aspect questions.

The validity and empirical reliability of the sustainability literacy assessment instrument were tested using Rasch analysis with the help of Ministep software. In the first analysis, the researchers conducted a validity test of the multiple-choice questions in the knowledge aspect of sustainability literacy, which consisted of 10 questions. The results of the validity analysis of the knowledge aspect questions can be seen in Table 6.

Table 5. Examples of Initial and Revised Versions Following Readability Test

No	Initial version	Revised Version
5.	Government policies aimed at promoting the use of environmentally friendly energy may lead to greenflation. Greenflation can have significant impacts on the economy of society. What are the economic impacts of this phenomenon? a. A decline in company revenues b. An increase in unemployment rates c. A rise in the prices of non-environmentally friendly goods d. Increased investment in green technology e. A reduction in the production of goods and energy	Government policies aimed at promoting the use of environmentally friendly energy may lead to greenflation. Greenflation, a rise in the prices of goods and services due to the transition to clean energy, can have significant impacts on the economy of society. What are the economic impacts of this phenomenon? a. A decline in company revenues b. An increase in unemployment rates c. A rise in the prices of non-environmentally friendly goods d. Increased investment in green technology e. A reduction in the production of goods and energy

Table 6. Item Validity Analysis for the Knowledge Aspect of the Instrument

MEASURE	OUTFIT		PT-MEASURE CORR	Item	Interpretation
	MNSQ	ZSTD			
2.03	1.62	1.14	0.76	S5	Valid
1.38	1.17	0.56	0.73	S9	Valid
0.89	1.14	0.57	0.68	S1	Valid
-0.04	0.81	-1.01	0.64	S4	Valid
-0.23	0.87	-0.69	0.60	S3	Valid
-0.33	0.82	-0.96	0.61	S7	Valid
-0.33	0.77	-1.26	0.62	S10	Valid
-0.43	1.11	0.60	0.51	S2	Valid
-0.53	0.69	-1.70	0.63	S8	Valid
-2.41	1.65	1.15	0.19	S6	Valid

Based on Table 6, the validity analysis of the sustainability literacy assessment instrument for the knowledge aspect revealed that out of 10 questions, one item (S6) did not meet the Pt. Measure Corr criterion as outlined by Boone et al. (2014), with a value of 0.19. However, it is still considered valid since its value is greater than 0. This indicates that students were generally more capable compared to the difficulty of this particular question, making it easier for many students to answer correctly. The Outfit ZSTD for all 10 questions met the Boone et al. (2014) criterion, with values close to 0, deeming the questions valid. However, the Outfit MNSQ value for item S6 did not meet the criteria, though according to Boone et al. (2014) and Bond et al. (2020), if the ZSTD value meets the criterion, the item is still considered valid. Thus, all 10 questions in the knowledge aspect are valid and can be used to measure students' sustainability literacy.

Table 7. Item Validity Data for the Skills Aspect of the Instrument

MEASURE	OUTFIT		PT-MEASURE CORR	Item	Interpretation
	MNSQ	ZSTD			
2.43	0.86	0.06	0.68	S15	Valid
1.23	0.91	-0.09	0.73	S14	Valid
0.41	0.92	-0.16	0.74	S13	Valid
0.12	0.65	-1.18	0.78	S16	Valid
-0.49	0.88	-0.22	0.79	S12	Valid
-3.70	3.57	1.59	0.71	S11	Valid

The validity analysis results for the skills aspect, which consists of 6 multiple-choice questions, are detailed in Table 7. It is evident that the Pt. Measure Corr values for all items meet the validity criteria outlined by Boone et al. (2014), with values ranging from 0.4 to 0.85. The outfit ZSTD values also comply with the criteria, falling within the range of >-2.0 and <2.0. However, one item (S11) has an outfit MNSQ value of 3.57, which is not valid. Nevertheless, according to Boone et al. (2014), if the ZSTD and Pt. Measure Corr values meet the criteria, the item is still considered valid. Therefore, the six items in the skills aspect are deemed valid and can be used to measure skills in the context of alternative energy.

Table 8. Item Validity Data for the Mindset Aspect of the Instrument

MEASURE	OUTFIT		PT-MEASURE CORR	Item	Interpretation
	MNSQ	ZSTD			
0.90	0.66	-2.13	0.69	S24	Valid
0.60	0.77	-1.30	0.69	S22	Valid
0.24	1.01	0.12	0.67	S20	Valid
0.11	1.37	1.84	0.43	S18	Valid
0.11	0.86	-0.74	0.66	S21	Valid
0.06	1.44	2.12	0.64	S19	Valid
-0.62	0.98	-0.03	0.48	S23	Valid
-1.41	0.90	-0.33	0.50	S17	Valid

The validity analysis of the mindset aspect of sustainability literacy, consisting of 8 Likert scale questions, is presented in Table 8. According to the table, the validity analysis of the 8 items in the sustainability literacy mindset assessment instrument shows that the Pt. Measure Corr values for all items meet the validity criteria set by Boone et al. (2014), ranging from 0.4 to 0.85. The outfit MNSQ values for these 8 items also satisfy the validity criteria, being close to the ideal value of 1. However, the outfit ZSTD values for two items (S19 and S24) are not valid, with values of 2.12 and -2.13, respectively. Nonetheless, following Boone et al. (2014), if the MNSQ and Pt. Measure Corr values meet the criteria, the items are still considered valid. Therefore, the 8 items in the mindset aspect are deemed valid and can be used to measure students' sustainability literacy in the context of alternative energy, including their attitudes towards sustainability issues (Anggraini et al., 2022). Thus, the sustainability literacy instrument developed by the researchers is validated for measuring students' sustainability literacy in the context of alternative energy.

The next set of data presents the results of the instrument's reliability testing. The reliability values were obtained through Rasch model analysis, supported by Ministep software, using the Cronbach's alpha formula. In reliability testing, the Cronbach's alpha value represents the interaction between person reliability and item reliability as a whole, based on the REAL RMSE value, which reflects the worst-case scenario for lower-bound reliability given the instrument used (Sumintono & Widhiarso, 2015). The person reliability values for the knowledge aspect of sustainability literacy are shown in Table 9.

Table 9. Person Reliability Data for the Knowledge Aspect of the Instrument

Total Score		CNT	Measure	REAL S.E	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	SZTD
Mean	6.1	10.0	0.96	1.10	0.96	0.0	1.06	0.2
P.SD	2.9	0.0	2.10	0.48	0.31	0.9	0.76	0.9
REAL RMSE	1.20	True SD	1.72	Separation	1.43	Person Reliability		0.67
S.E Of Person Mean = 0.25								
Person Raw Score-To-Measure Correlation = 0.99								
Cronbach Alpha (KR-20) Person Raw Score "Test" Reliability = 0.82								

In Table 9, it is observed that the mean values for infit MNSQ and outfit MNSQ for the person table have improved, approaching the ideal value of 1.00, thereby categorizing them as good. The infit ZSTD and outfit ZSTD values in the person table also indicate that the quality has improved, as they approach the ideal value of 0.00. The person reliability value obtained suggests that the consistency of respondents' answers falls into the sufficient category. The interaction between respondents and items, as indicated by the Cronbach's alpha value, is categorized as excellent (Sumintono & Widhiarso, 2015). The item reliability for the knowledge aspect of sustainability literacy is shown in Table 10.

Table 10. Item Reliability Data for the Knowledge Aspect of the Instrument

Total Score		CNT	Measure	REAL S.E	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	SZTD
Mean	42.8	10.0	0.00	0.36	1.02	-0.1	1.06	-0.2
P.SD	10.0	0.0	2.10	0.07	0.17	1.1	0.33	1.0
REAL RMSE	0.37	True SD	1.10	Separation	2.98	Item Reliability	0.90	0.67
S.E Of Item Mean = 0.39								

In Table 10, the mean values for infit MNSQ and outfit MNSQ have improved, as they approach the ideal value of 1.00. The mean values for infit ZSTD and outfit ZSTD also reflect an improvement in item quality, as they approach the ideal value of 0.0. The item reliability obtained indicates that the quality of the items is good for measuring the intended construct. An example of a knowledge aspect question, in English translation, as follows.

"The use of fossil fuels as an energy source for electricity generation has negative impacts on the environment. What are the direct and global consequences this issue?

a. *Produces air pollutants that contaminate and harm the environment.*
b. *Causes noise pollution that disrupts community well-being.*
c. *Increases dependence on non-renewable energy sources.*
d. *Leads to ecosystem damage and loss of biodiversity.*
e. *Increases greenhouse gas emissions that contribute to climate change."*

The item explores students' perspectives on explaining the global impacts resulting from excessive fossil-based energy. The knowledge aspect is evident in questions addressing environmental or ecological issues related to energy use, which frequently arise in daily life. The analysis of person reliability for the skills aspect of sustainability literacy is presented in Table 11 below.

Table 11. Person Reliability Data for the Skills Aspect of the Instrument

Total Score		CNT	Measure	REAL S.E	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	SZTD
Mean	3.5	6.0	-0.60	1.53	0.91	0.0	0.98	0.2
P.SD	2.1	0.0	2.88	0.41	0.60	1.0	1.59	0.9
REAL RMSE	1.58	True SD	2.40	Separation	1.52	Person Reliability	0.70	0.67
S.E Of Person Mean = 0.35								
Person Raw Score-To-Measure Correlation = 0.99								
Cronbach Alpha (KR-20) Person Raw Score "Test" Reliability = 0.84								

In Table 11, it is shown that the mean values for infit MNSQ and outfit MNSQ for the person table have improved, as they approach the ideal value of 1.00, thereby categorizing them as good. The infit ZSTD and outfit ZSTD values obtained indicate that the quality has improved, as they approach the ideal value of 0.00. The person reliability value suggests that the consistency of respondents' answers is in the sufficient category. The interaction between respondents and items, as indicated by the Cronbach's alpha value of 0.84, falls into the excellent category (Sumintono & Widhiarso, 2015). The item reliability for the skills aspect of sustainability literacy is shown in Table 12.

Table 12. Item Reliability Data for the Skills Aspect of the Instrument

Total Score		CNT	Measure	REAL S.E	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	SZTD
Mean	41.0	70.0	0.00	0.48	1.03	0.0	1.30	0.0
P.SD	9.9	0.0	1.89	0.19	0.18	0.6	1.02	0.8
REAL RMSE	0.51	True SD	1.82	Separation	3.54	Item Reliability	0.93	0.67
S.E Of Item Mean = 0.85								

In Table 12, the infit MNSQ and outfit MNSQ values have improved, as they approach the ideal value of 1.00. The infit ZSTD and outfit ZSTD values indicate good item quality, as they have reached the ideal value of 0.0. The item reliability obtained indicates that the quality of items is excellent for measuring the intended construct.

An example of a skills aspect question, in English translation, is the following.

"Excessive electricity consumption can lead to an energy crisis in the future. As the next generation, what is the most appropriate step you would recommend to the school to address the energy crisis?

a. *Reducing the use of unnecessary electrical devices*
b. *Restricting the use of private vehicles by students*
c. *Building more efficient electrical infrastructure*
d. *Installing mini solar panels to generate electricity*
e. *Promoting the use of energy-saving devices"*

The item assesses students' ability to develop creativity in addressing the energy crisis. The energy in question is electricity, which is frequently consumed in daily life. The skills aspect is evident in the steps students take to resolve the energy crisis at school. This encourages students to think creatively and devise solutions to address the energy crisis occurring at school.

The sustainability literacy assessment instrument on alternative energy topics in the knowledge and skills aspects emphasizes concrete contexts related to the surrounding environment, particularly regarding energy needs and actions related to energy use in daily life. This aligns with the research (Marcinkowski & Reid, 2019), who state that the measurement of knowledge and skills should emphasize the complex ecosystem relationships with the surrounding environment. Therefore, the sustainability literacy assessment instrument in the knowledge and skills aspects is capable of measuring students' understanding of concrete environmental issues and their critical thinking regarding the transition toward sustainable living. This is consistent with Szczytko et al. (2018), who assert that sustainability literacy skills and knowledge can help in understanding how students respond to various environmental issues and guide the development of a sustainable living environment.

Table 13. Person Reliability Data for the Mindset Aspect of the Instrument

Total Score		CNT	Measure	REAL S.E	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	SZTD
Mean	23.6	8.0	1.39	0.61	0.98	-0.1	1.00	-0.1
P.SD	5.1	0.0	1.36	0.31	0.79	1.2	0.78	1.2
REAL RMSE	0.68	True SD	1.18	Separation	1.73	Person Reliability	0.75	0.67
S.E Of Person Mean = 0.16								
Person Raw Score-To-Measure Correlation = 0.92								
Cronbach Alpha (KR-20) Person Raw Score "Test" Reliability = 0.80								

Next, the person reliability values for the mindset aspect of sustainability literacy are presented in Table 13. In the table, it is observed that the mean values for infit MNSQ and outfit MNSQ for the person table have improved, approaching the ideal value of 1.00, thereby categorizing them as good. The infit ZSTD and outfit ZSTD values in the Person Table also indicate ity, as they approach the ideal value of 0.00. The person reliability value obtained suggests that the consistency of respondents' answers falls into the sufficient category. The interaction between respondents and items, as indicated by the Cronbach's alpha value of 0.80, is categorized as good (Sumintono & Widhiarso, 2015).

Table 14. Item Reliability Data for the Mindset Aspect of the Instrument

Total Score		CNT	Measure	REAL S.E	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	SZTD
Mean	206.1	70.0	0.00	0.18	1.02	0.0	1.00	-0.1
P.SD	23.1	0.0	0.67	0.03	0.26	1.40	0.26	1.4
REAL RMSE	0.18	True SD	0.65	Separation	3.65	Item Reliability	0.93	0.67
S.E Of Item Mean = 0.25								

The item reliability for the mindset aspect of sustainability literacy is shown in Table 14. In the table, it is evident that the infit MNSQ and outfit MNSQ values have improved, approaching the ideal value of 1.00. The infit ZSTD and outfit ZSTD values also reflect better item quality, as they approach the ideal value of 0.0. The item reliability value obtained is 0.93, indicating that the item quality is excellent for measuring the intended construct.

An example of a mindset aspect question is shown below. The item addresses the commitment to respect and care for energy sources available in human life. The mindset aspect is evident in students' views on the statement that excessive use of fossil fuel energy will increase greenhouse gases on Earth, which are known to cause global warming and significantly impact sustainable living (Isah, 2013).

"Excessive use of fossil fuels will increase the concentration of greenhouse gases in the atmosphere.
a. Strongly agree
b. Agree
c. Slightly agree
d. Disagree
e. Strongly disagree"

Consequently, the sustainability literacy assessment instrument on alternative energy topics is effective in measuring students' awareness of their beliefs and commitment to initiating environmental changes towards sustainable living. This aligns with Décamps et al. (2017), who state that the concept of sustainability is a way to empower students to initiate and commit to making decisions that build a sustainable future. Therefore, the sustainability literacy assessment instrument on the mindset aspect can effectively measure students' mindsets towards sustainable living.

The validity and reliability analysis indicates that the sustainability literacy assessment instrument on alternative energy topics is generally valid, reliable, and appropriate for use. This instrument helps to understand students' sustainability capabilities, encourages critical thinking, and increases sustainability awareness (Kuehl et al., 2023; Décamps et al., 2017).

Discussion

The findings from this study provide significant insights into the development and validation of a sustainability literacy assessment tool focused on alternative energy topics for high school students in Indonesia. The validation process, which included expert evaluations, readability tests, and piloting testing to students as internal consistency checks, has demonstrated the reliability and validity of the instrument, as stated by Mason (2019). These results contribute to the growing body of literature on sustainability education by offering a robust tool that is both contextually relevant and pedagogically sound.

A key aspect of this study was the application of the Rasch Model, selected due to its significant advantages in providing more accurate and reliable measurements compared to classical methods. The Rasch Model's ability to transform raw scores into interval data allows for a more precise interpretation of students' abilities and the quality of the items used in the instrument (Babcock & Hodge, 2020). Furthermore, the Rasch Model ensures that measurement results are invariant across different respondent groups, enhancing the validity and reliability of the instrument (Adam et al., 2021). This is particularly crucial in the educational context of developing countries like Indonesia, where student backgrounds and learning environments may vary significantly.

A detailed analysis of how the instrument measures sustainability literacy related to alternative energy was conducted by examining its three main dimensions: knowledge, skills, and mindset (Décamps et al., 2017). In the knowledge dimension, indicators include recognizing renewable and non-renewable energy sources, analyzing the global effects of energy usage, and identifying individual actions for energy transition to more sustainable alternatives. These indicators aim to enhance students' understanding of the environmental, social, and economic impacts of energy choices.

For the skills dimension, the instrument evaluates students' ability to address energy-related challenges through creativity, strategic thinking, and systemic analysis. Key indicators include proposing innovative solutions to energy crises, understanding the importance of collaboration for systemic change, participating in energy-saving activities, and analyzing both local and global impacts of energy use. This dimension measures students' practical and analytical skills essential for tackling real-world energy issues effectively (Milovanovic et al., 2021).

The mindset dimension focuses on students' attitudes and commitment to sustainability, such as their willingness to engage in sustainable practices and their confidence in initiating change. By measuring these attitudes, the instrument provides valuable insights into how well students internalize sustainability concepts and their readiness to take action in their communities (Wang et al., 2022).

In the context of high school physics and science education in Indonesia, the topic of alternative energy is integrated into the curriculum as part of the broader discussion on energy sources. Within this framework, students are introduced to both traditional fossil-based energy sources and their environmental impacts, such as contributions to climate change. The curriculum also emphasizes the importance of energy conservation and the utilization of alternative (renewable) energy sources, which are crucial for mitigating environmental damage and promoting sustainable development (Mittenzwei et al., 2019). Educational programs should not only improve knowledge but also focus on shaping attitudes and behaviors to foster comprehensive energy literacy (Cotton et al., 2015; Lee et al., 2022). Therefore, the development of an assessment instrument that effectively measures students' literacy of these concepts is essential for enhancing the effectiveness of physics education in addressing current global challenges.

Comparing these findings with previous studies, it becomes evident that the development of sustainability literacy instruments is a critical area of educational research. For example, Waltner et al. (2019) developed and validated an instrument to measure students' sustainability competencies across various topics, including environmental protection and resource conservation. However, their study did not specifically address alternative energy topics, a significant focus of the present research. The inclusion of alternative energy in this instrument aligns with global educational goals and fills a gap in existing research, particularly within the context of developing nations like Indonesia (Sutanto, 2017).

Moreover, the expert validation scores in this study, which categorized the instrument as "Very Good," align with findings from similar studies that emphasize the importance of expert feedback in refining educational tools. This highlights the instrument's strength in terms of construction, content, and language, ensuring that it meets the high standards required for effective educational assessment (Kuehl et al., 2023). The readability test results also underscore the instrument's accessibility to high school students, which is crucial for its successful implementation. Previous research has shown that readability is a key factor in the effectiveness of educational materials (Gill & Sharps, 2020). The high readability scores observed in this study suggest that the instrument is well-suited to the target audience, thereby enhancing its utility in real-world educational settings.

The iterative process of revising the instrument based on both expert and student feedback also underscores the importance of continuous improvement in educational research. This process, informed by both quantitative and qualitative data, ensures that the final product is both reliable and responsive to the needs of its users. Such an approach is consistent with best practices in educational research, where stakeholder input is essential for creating effective educational tools (Wang & Parker, 2018).

In the specific context of high school physics and science education, the validated instrument developed in this study provides a valuable tool for assessing students' sustainability literacy, particularly in the context of alternative energy. This is critical as it supports educators in effectively integrating sustainability concepts into the physics curriculum, thereby preparing students to engage with and address the energy challenges of the future. The instrument not only helps in evaluating students' current understanding but also guides instructional strategies aimed at enhancing their competencies in this vital area.

Overall, this study adds to the existing literature by providing a validated and reliable instrument specifically designed to measure sustainability literacy in the context of alternative energy. The implications of this research are significant, as it provides educators with a tool that can be used to assess and improve students' competency of critical sustainability issues within the framework of high school physics and science education. Future research could explore the application of this instrument in different educational

settings and its potential impact on students' sustainability knowledge and behaviors, particularly in line with global sustainability objectives (IPCC, 2021).

However, there are certain limitations to this study that should be acknowledged. First, the sample size used in this research, while appropriate for the scope of this initial validation, may limit the generalizability of the findings. The participants were drawn from a specific group of high school students, and their experiences may not fully represent students from different educational contexts or geographic regions. A larger, more diverse sample would be necessary to confirm the instrument's broader applicability.

CONCLUSION

The sustainability literacy instrument centered on alternative energy has been carefully validated through expert evaluations, ensuring that its language, structure, and content satisfy educational requirements. A reading test was also performed to ensure the clarity for students. Empirical testing, including Rasch analysis, confirmed the instrument's high validity and reliability. The 24-item measure accurately examines students' knowledge, abilities, and attitudes toward sustainability literacy. Rasch analysis findings demonstrate great item quality, with infit and outfit MNSQ values near 1.00 and ZSTD values close to 0.00, indicating a solid model fit. Reliability scores for knowledge, skills, and mindset were 0.67, 0.70, and 0.75, respectively, with item reliability above 0.90 in all areas. This instrument is a valuable tool for testing sustainability literacy in high school science and physics classrooms, particularly in regard to alternative energy, and is a critical part for the effort of climate change and energy education in general. However, more testing in various educational situations is suggested to widen its usefulness and improve sustainability teaching.

ACKNOWLEDGMENT

This research is part of a research project funded by the Grant for Applied Research from the Directorate of Research, Technology, and Community Service, Ministry of Education, Culture, Research, and Technology, Indonesia, No. 574/UN26.21/PN/2024.

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