14 (3) (2025) 524-534

Unnes Science Education Journal
Accredited Sinta 2

https://journal.unnes.ac.id/journals/usej

Expert Review and Rasch Modelling of a Sustainability Awareness Instrument in the Context of Peatland Climate Realities under Global Warming Pressures

Lintang Auliya Kurdiati, Apit Fathurohman✉

DOI: http://dx.doi.org/10.15294/usej.v13i1.23264

Universitas Sriwijaya, Indonesia

Article Info

Submitted 2025-10-23
Revised 2025-11-08
Accepted 2025-12-15

Keywords

Peatland Ecosystems; Reliability; Sustainability Awareness; Validity

Abstract

Sustainability awareness among students is crucial for fostering environmentally responsible behaviors, particularly concerning peatlands' role in global warming. However, a valid and reliable measurement tool is needed to assess students' awareness effectively. This study aims to examine the validity and reliability of a questionnaire designed to measure secondary school students' sustainability awareness in this context. A descriptive survey design was employed, involving 40 participants eight expert validators and 32 students. Data were collected through expert validation and questionnaire distribution. Content validity was assessed by four content experts and four readability experts, while item validity and reliability were analyzed using the Rasch model. Results indicated a high content validity score (91%), confirming the questionnaire's effectiveness in measuring students' knowledge, attitudes, and behaviors. The item validity test showed all statement items were valid, and reliability analysis yielded strong internal consistency (Cronbach's Alpha: 0.84 for person reliability and 0.85 for item reliability). These findings suggest that the questionnaire is a reliable instrument for assessing sustainability awareness. The study contributes to environmental education by providing a scientifically validated tool for measuring students' understanding of sustainability, which can inform future curriculum development and policy-making efforts to enhance environmental awareness among students.

How to Cite

Kurdiati, L. A., & Fathurohman, A. (2025). Expert Review and Rasch Modelling of a Sustainability Awareness Instrument in the Context of Peatland Climate Realities under Global Warming Pressures. *Unnes Science Education Journal*, 14(3), 524-534.

✉ Correspondence Author:
E-mail: apit_fathurohman@fkip.unsri.ac.id

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

INTRODUCTION

Sustainability awareness among students is a critical area of research (Alsaati et al., 2020; Ekamilasari et al., 2021; Yani et al., 2023), particularly in the context of climate change and the role of unique ecosystems such as peatlands in mitigating global warming. Peatlands, which store vast amounts of carbon, are vital to the global carbon cycle (Kurdiati, Apriana, et al., 2024; Ribeiro et al., 2021; Zhong et al., 2020). Their degradation, however, contributes significantly to carbon emissions, exacerbating climate change (Antala et al., 2022; Escobar et al., 2022; Mander et al., 2024; Wilkinson et al., 2023). Despite their importance, awareness of peatlands' ecological role is often limited, especially among young individuals (Kurdiati, Fathurohman, et al., 2024). Developing valid and reliable tools to measure this awareness is essential for effective educational interventions aimed at fostering environmental stewardship among students (Amelia et al., 2020).

The use of measurement tools, such as questionnaires, requires rigorous evaluation to ensure validity and reliability (Carroll et al., 2017; Mellinger & Hanson, 2020). Validity, which refers to the instrument's ability to measure what it is intended to measure, is fundamental to research quality (Elangovan & Sundaravel, 2021; Fernández-Gómez et al., 2020). In the context of sustainability awareness, content validity ensures the instrument captures critical dimensions of environmental understanding, such as carbon sequestration, ecological balance, and human impacts (Olsson et al., 2020). Reliability, on the other hand, assesses the consistency of the instrument across different applications (Ahmad & Mir, 2021; Mat Nawi et al., 2020). Previous study by Izah et al. (2024) emphasize the importance of Cronbach's alpha in evaluating internal consistency.

Educational research highlights the role of contextual factors in shaping students' perceptions and attitudes towards sustainability (Du et al., 2022; Greenland et al., 2022; Romano et al., 2021). For instance, Kee & Zhang (2022) argue that experiential learning methods, which immerse students in local environmental contexts, enhance understanding and engagement. Peatlands provide a unique case for integrating local ecological knowledge into sustainability education (Hariyadi et al., 2021; Hekmah et al., 2019). Moreover, Rustamova (2023) suggest that emphasizing local ecosystems can deepen students' appreciation of global environmental challenges. Thus, developing a robust measurement tool tailored to this context is not only academically relevant but also socially impactful.

Several prior studies have explored the design and validation of instruments for measuring environmental and sustainability awareness, providing relevant insights for this research. Reis Neto et al. (2021) developed the New Ecological Paradigm (NEP) Scale, which has become a widely recognized tool for gauging environmental attitudes globally. However, while the NEP scale measures general environmental awareness, it lacks a focus on specific ecological systems, such as peatlands, which are vital in mitigating global warming through their significant carbon storage capacity. In another relevant study, Dawson & Carson (2020) introduced a framework for assessing students' conceptions of climate change, which emphasized anthropogenic factors but did not address localized ecological contexts such as peatland degradation. These studies highlight the importance of measuring sustainability awareness but underscore the lack of tools tailored to specific ecosystems.

Although sustainability awareness has been widely studied, instruments that specifically assess awareness related to peatland ecosystems are still unavailable. Most environmental scales, including the NEP and ACiSD-Q, were designed for general environmental contexts and therefore do not capture the unique ecological functions, risks, and management challenges of peatlands. This limitation is even more apparent in Indonesia, where peatlands represent one of the most critical carbon-storing ecosystems and are increasingly threatened by land conversion, fires, and other human activities. Studies validating sustainability awareness instruments in the Indonesian setting are also limited, and those that exist seldom apply robust psychometric approaches such as the Rasch model. As a result, educators lack assessment tools that reflect both the local ecological realities and the learning needs of students. Considering that degraded peatlands are major contributors to carbon emissions, as shown by Zulkarnaini et al. (2020), developing an instrument aligned with the peatland context becomes increasingly urgent. This study responds to that need by examining the validity and reliability of a sustainability awareness questionnaire that incorporates knowledge of peatlands and their connection to global warming. Through this approach, the research contributes to strengthening environmental literacy and supporting the alignment between global sustainability objectives and Indonesia's local environmental challenges.

The novelty of this study emerges from its development of a sustainability awareness instrument that is explicitly grounded in the peatland ecosystem context, allowing the measurement of students' awareness to reflect the ecological functions, vulnerabilities, and climate relevance of peatlands that are absent from existing environmental scales. The validation process applies the Rasch model with a full set of analyses, including item fit evaluation, person and item reliability coefficients, separation values, and rating scale diagnostics, ensuring that the instrument demonstrates strong internal structure and precise measurement capabilities. The instrument is also designed to capture sustainability awareness across three interconnected dimensions, namely sustainability practices, attitudes and behaviors, and emotional engagement, which together offer a holistic and context-specific understanding of how students perceive and respond to sustainability issues related to peatland-driven global warming pressures.

The purpose of this research is to examine the validity and reliability of a measurement tool designed to assess secondary school students' sustainability awareness, particularly in the context of peatlands' role in global warming. This study aims to ensure that the questionnaire accurately and consistently captures students' sustainability awareness in the context of peatlands' role in the global warming phenomenon. By focusing on the testing of this instrument, the research contributes to the methodological rigor needed for studies in environmental education and sustainability. The study addresses the following key questions:

1. Are the questionnaire's content and structure valid for assessing students' sustainability awareness in the context of peatlands?
2. Do the individual statement items in the questionnaire exhibit sufficient validity to measure students' sustainability awareness?
3. Is the questionnaire reliable in providing consistent results when used to assess students' sustainability awareness?

METHOD

General Background

This study employed an instrument-development–oriented descriptive survey design that explicitly adopts the instrument development framework proposed by DeVellis (2016), which outlines a systematic sequence consisting of item generation, expert review, pilot testing, and psychometric evaluation. In line with this model, the development process began with constructing items based on established theoretical constructs of sustainability awareness, followed by evaluation from expert validators to ensure content accuracy and readability. After incorporating expert feedback, the refined instrument was administered to student participants to obtain empirical response data. These two complementary data sources expert judgment and student responses allowed for a robust psychometric examination through Rasch modelling, including analyses of item validity, person–item interactions, and reliability indices. The adoption of the DeVellis instrument-development model ensured that the questionnaire was developed through a rigorous, standardized, and theoretically grounded process. To provide a clearer overview of the methodological sequence, the flowchart of research activities is presented in Figure 1.

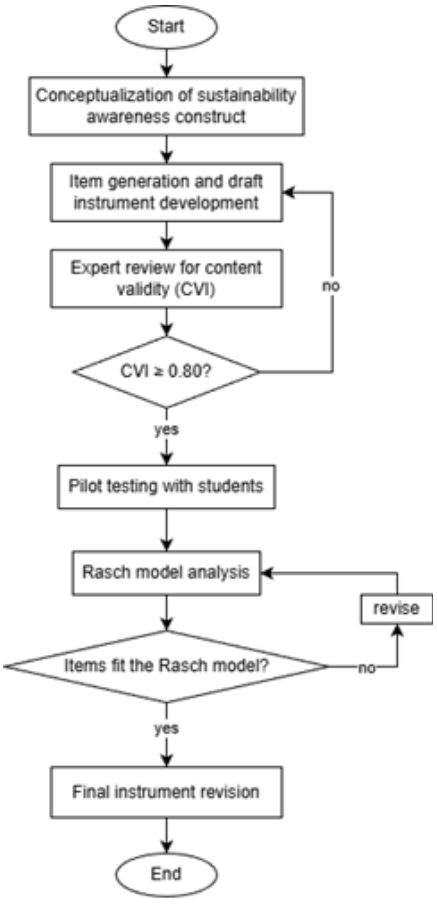

Figure 1. Flowchart of Instrument Development and Validation Procedures

Participants

The participants involved in this study consisted of 40 individuals who took part in the expert validation process as well as item validity and reliability testing, including several experts and

students. The selection of validators was based on their academic qualifications and professional expertise in education and sustainability-related fields. Their insights were crucial in refining the assessment instrument to accurately measure students' sustainability awareness, particularly in the context of peatlands' role in global warming. The demographic distribution of these expert validators is presented in Table 1.

Table 1. Demographic Distribution of the Validator Participants (n=8)

	Frequency	Percentage (%)
Gender		
Male	4	50
Female	4	50
Education Background		
Master	4	50
Doctor	4	50
Profession		
Lecturer	6	75
Teacher	2	25
Age		
40-50 years	3	37.5
51-60 years	3	37.5
61-70 years	2	25

To evaluate the item validity and reliability of the measurement tool, student participants were involved in the validation process using the Rasch model. These students, selected from a secondary school setting, provided responses that were analyzed to determine how effectively the instrument measured their sustainability awareness. The student sample consisted of 32 respondents, which aligns with widely accepted guidelines for pilot testing in Rasch measurement. Previous Rasch methodological guidelines, particularly those published on official Rasch website, state that a sample of 30–50 participants is sufficient to achieve stable item calibrations and dependable person–item estimates in early-stage instrument development. These guidelines indicate that, for most measurement purposes, a minimum of 30 respondents is adequate, and that stability improves progressively as sample size approaches 50. The sample size used in this study therefore meets recommended standard and is fully aligned with range endorsed by the Rasch Measurement framework for exploratory or developmental phases of instrument construction.Their demographic distribution is detailed in Table 2.

Table 2. Demographic Distribution of the Student Participants (n=32)

	Frequency	Percentage (%)
Gender		
Male	24	75
Female	8	25
Age		
15 years	15	46.9
16 years	16	50
17 years	1	3.1

Research Instruments

To ensure the research instrument effectively measures students' sustainability awareness in the context of peatlands' role in global warming, validation was conducted by experts in two key areas: content validity and clarity/readability. The content validation process involved subject-matter experts evaluating whether each item appropriately assessed students' environmental knowledge, attitudes, and awareness. This step ensured that the instrument aligned with the intended constructs and provided an accurate measurement of sustainability awareness. Table 3 outlines the distribution of items assessed by content experts.

Table 3. Content Expert Validation Grid

No	Indicators	Number of Item	Item Number
1	Environmental knowledge	3	1, 2, 3
2	Attitudes and behavior towards the environment	3	4, 5, 6
3	Awareness of importance of environmental protection	2	7, 8
Total		8	

In addition to content validation, the research instrument was evaluated for clarity and readability. This process aimed to ensure that the items were easily comprehensible, linguistically accurate, and free from ambiguity. Experts assessed whether the wording of each item was clear, relevant, and unbiased to ensure that students could interpret and respond accurately. Table 4 presents the clarity and readability validation grid used in this study.

Table 4. Clarity and Readability Expert Validation Grid

No	Indicators	Number of Item	Item Number
1	Clarity	3	1, 2, 3
2	Content accuracy	2	4, 5
3	Relevance	2	6, 7
4	Content validity	1	8
5	No bias	2	9, 10
6	Language accuracy	4	11, 12, 13, 14
Total		14	

Data Analysis

Validity Analysis

The assessment of validation values by expert validators utilizes a Likert scale with five response options. The validation results are subsequently presented in a tabular format, followed by the calculation of the average statement scores. The overall percentage obtained from the validators is then classified into specific categories, as outlined in Table 5.

Table 5. Categories of Expert Validation Results

Average	Category
$86 \leq EVR \leq 100$	Highly Valid
$70 \leq EVR < 86$	Valid
$56 \leq EVR < 70$	Less Valid
$0 < EVR < 56$	Invalid

The validity test of the questionnaire items in the study was carried out using the Rasch modeling approach with the help of Winsteps software. The validity testing criteria based on Rasch modeling are based on Sumintono & Widhiarso (2014) which are described in Table 6.

Table 6. Instrument Item Validity Test Criteria

Indicator	Inclusion Criteria
Outfit Mean Square (MNSQ)	$0.5 < MNSQ < 1.5$
Outfit Z-Standard (ZSTD)	$-2.0 < ZSTD < +2.0$
Point Measure Correlation (Pt Measure Corr)	0.4 < Pt Measure Corr < 0.85

Reliability Analysis

Reliability testing was conducted using the Rasch model based on the criteria outlined by Sumintono & Widhiarso (2014) as follows.

1. Person measure and item measure assess the tendency of students' abilities in comparison to the difficulty level of the questionnaire. A mean value greater than logit 0.0 indicates that students' abilities exceed the questionnaire's difficulty level, suggesting that respondents are generally able to answer the statements provided in the questionnaire.
2. Cronbach's Alpha measures the extent to which the items in the questionnaire are interrelated or consistent, providing an indication of the reliability of the instrument. The criteria for Cronbach's Alpha in Rasch modeling are detailed in Table 7.
3. Person reliability evaluates the consistency of students' scores in responding to the questionnaire items, reflecting the stability and trustworthiness of responses if the questionnaire were administered multiple times. Item reliability measures the consistency of items in distinguishing between students with varying levels of ability, indicating the extent to which the items effectively separate high-ability students from low-ability students. The criteria for person and item reliability in the Rasch model are presented in Table 8.

Table 7. Cronbach Alpha Reliability Value Criteria

Score	Cronbach Alpha Criteria
>0.8	Very good
0.7 – 0.8	Good
0.6 – 0.7	Quite
0.5 – 0.6	Bad
<0.5	Poor

Table 8. Person and Item Reliability Value Criteria

Score	Person and Item Reliability Criteria
>0.94	Excellent
0.91 – 0.94	Very Good
0.81 – 0.90	Good
0.67 – 0.80	Quite
<0.67	Weak

A questionnaire item is considered valid if it meets at least two criteria; it is revised if it meets only one of the three criteria, and it is discarded if it does not meet any of the criteria (Siswanti et al., 2023).

RESULT AND DISCUSSION

Questionnaire Content Validity Test Results

Content validity testing is a crucial step in ensuring that an instrument accurately measures the intended constructs. In this study, expert validators assessed the validity of the questionnaire in two key aspects: content material and clarity/ readability. The evaluation process involved four expert validators who provided ratings based on predetermined indicators. Their assessments were then averaged to determine the overall validity percentage for each aspect. The results of this validation process are presented in Table 9 and Table 10.

Table 9 shows that the average validity score across all categories in content material aspect was 4.54, corresponding to a high validity percentage of 90.83%. Among the assessed aspects, "awareness of the importance of environmental protection" received the highest score (4.63 or 92.50%), indicating strong content relevance. Table 10 presents the results of the clarity and readability validation, assessing aspects such as clarity, content accuracy, relevance, content validity, bias, and language accuracy. Table 10 shows that the overall average score of clarity and readability aspects was 4.56, with a validity percentage of 91.25%. "No bias" received the highest score (4.38 or 97.5%), indicating that the questionnaire is largely unbiased and fair. Additionally, clarity and relevance both scored 95%. If the total average validation scores from both aspects are averaged to obtain the final result of the questionnaire testing, a score of 4.55 or 91% is obtained, which falls into the "highly valid" category.

Questionnaire Statement Item Validity Test Results

The validity test of questionnaire statement items was conducted using the Rasch model to ensure that each item accurately measures students' sustainability awareness in the context of peatlands' role in the global warming phenomenon. This analysis examines the outfit mean square (MNSQ), standardized Z-score (ZSTD), and point measure correlation (Pt Measure Corr) to determine the appropriateness of each statement. Items are considered valid if they meet the accepted statistical criteria, ensuring the instrument's reliability in assessing students' understanding and awareness. The results of the validity test for each questionnaire statement item, can be seen in Figure 2.

The results presented in Figure 1, indicate that all statement items meet the validity criteria.

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	JMLE MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	ITEM
5	85	32	1.47	.33	.86	-.51	.86	-.50	.70	.62	62.5	65.6	Q5
2	86	32	1.37	.33	.58	-1.89	.57	-1.87	.71	.62	75.0	65.7	Q2
6	88	32	1.15	.33	1.21	.88	1.20	.84	.73	.61	56.3	65.3	Q6
7	89	32	1.05	.33	1.08	.39	1.09	.43	.59	.61	65.6	65.3	Q7
3	101	32	-.26	.34	.81	-.79	.82	-.79	.78	.60	68.8	63.3	Q3
10	101	32	-.26	.34	1.07	.36	1.08	.42	.41	.60	53.1	63.3	Q10
8	103	32	-.49	.34	1.07	.38	1.08	.41	.57	.60	56.3	64.8	Q8
1	104	32	-.61	.34	.98	-.02	.94	-.17	.48	.60	75.0	65.4	Q1
9	104	32	-.61	.34	.84	-.66	.84	-.67	.64	.60	62.5	65.4	Q9
4	106	32	-.85	.35	1.45	1.76	1.42	1.64	.26	.60	62.5	66.1	Q4
12	106	32	-.85	.35	.80	-.82	.78	-.91	.78	.60	68.8	66.1	Q12
11	108	32	-1.10	.36	1.23	.99	1.17	.74	.54	.60	56.3	67.6	Q11
MEAN	98.4	32.0	.00	.34	1.00	.01	.99	-.03			63.5	65.3	
P.SD	8.3	.0	.92	.01	.23	.95	.22	.92			7.0	1.1	

Figure 2. Validity Result Test of Questionnaire Statement Items with Rasch Model

The outfit MNSQ values range between 0.57 and 1.42, remaining within the acceptable range of 0.5 to 1.5, which signifies a good fit. Additionally, the Pt Measure Corr values are consistently above 0.60, confirming that each item is positively correlated with the overall measurement. The findings suggest that the questionnaire items effectively capture the intended constructs and can be used to assess students' sustainability awareness with high confidence.

Questionnaire Reliability Test Results

Reliability testing in this study was conducted using the Rasch model to assess the consistency and accuracy of the questionnaire in measuring students' sustainability awareness. The

analysis focused on three key aspects: person measure, item measure, and Cronbach's Alpha. The person measure evaluates the students' ability in comparison to the difficulty level of the questionnaire, while the item measure determines how well the questionnaire items differentiate between students of varying abilities. Cronbach's Alpha assesses the internal consistency of the questionnaire items, providing an indication of the overall reliability of the instrument. The results of the reliability test are presented in Figure 3.

The results show that the person measure value is 1.93, indicating that students' abilities tend to exceed the difficulty level of the questionnaire. The person reliability value of 0.82 falls into the "Good" category, meaning that students' responses are stable and consistent. Meanwhile, the item reliability value of 0.85 is also categorized as "Good," signifying that the questionnaire items effectively distinguish between different levels of student understanding. Furthermore, the Cronbach's Alpha value of 0.84 is classified as "Very Good," indicating a strong internal consistency among the questionnaire items. These results confirm that the questionnaire is reliable and suitable for assessing students' sustainability awareness in the context of peatlands and global warming.

After conducting validity and reliability tests, the finalized questionnaire consists of statement items categorized into three key indicators: sustainability practice awareness, behavior and attitude awareness, and emotional awareness. Each category includes multiple items that comprehensively assess students' understanding, actions, and emotional engagement in sustainability, particularly in the context of peatlands and global warming. The distribution of the questionnaire items after these tests is presented in Table 11.

As shown in Table 11, the questionnaire comprises 12 validated items distributed across

SUMMARY OF 12 MEASURED ITEM

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	98.4	32.0	.00	.34	1.00	.01	.99	-.03
SEM	2.5	.0	.28	.00	.07	.29	.07	.28
P.SD	8.3	.0	.92	.01	.23	.95	.22	.92
S.SD	8.7	.0	.96	.01	.24	.99	.23	.96
MAX.	108.0	32.0	1.47	.36	1.45	1.76	1.42	1.64
MIN.	85.0	32.0	-1.10	.33	.58	-1.89	.57	-1.87

REAL RMSE .35 TRUE SD .85 SEPARATION 2.40 ITEM RELIABILITY .85
MODEL RMSE .34 TRUE SD .86 SEPARATION 2.54 ITEM RELIABILITY .87
S.E. OF ITEM MEAN = .28

SUMMARY OF 32 MEASURED PERSON

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	36.9	12.0	1.93	.56	.99	-.02	.99	-.02
SEM	.9	.0	.25	.01	.08	.20	.08	.20
P.SD	4.8	.0	1.41	.03	.43	1.09	.43	1.09
S.SD	4.8	.0	1.44	.03	.44	1.11	.44	1.11
MAX.	44.0	12.0	4.22	.65	1.89	2.11	1.88	2.08
MIN.	26.0	12.0	-1.15	.51	.36	-2.02	.32	-1.92

REAL RMSE .60 TRUE SD 1.28 SEPARATION 2.13 PERSON RELIABILITY .82
MODEL RMSE .56 TRUE SD 1.30 SEPARATION 2.34 PERSON RELIABILITY .85
S.E. OF PERSON MEAN = .25

PERSON RAW SCORE-TO-MEASURE CORRELATION = 1.00
CRONBACH ALPHA (KR-20) PERSON RAW SCORE "TEST" RELIABILITY = .84 SEM = 1.89
STANDARDIZED (50 ITEM) RELIABILITY = .96

Figure 3. Reliability Result Test of Questionnaire Statement Items with Rasch Model

Table 11. Distribution of Sustainability Awareness Questionnaire Statements (After Feasibility Test)

No	Indicator	Number of Item	Item Number
1	Sustainability Practice Awareness	4	1,2,3,4
2	Behavior and Attitude Awareness	4	5,6,7,8
3	Emotional Awareness	4	9,10,11,12
Total		12	

three main indicators. Sustainability practice awareness consists of four items (1-4), evaluating students' understanding and application of sustainable practices. Behavior and attitude awareness is measured through four items (5-8), assessing students' environmentally responsible actions and ethical considerations. Lastly, emotional awareness includes four items (9-12), focusing on students' emotional connections and concerns regarding sustainability issues. This structured distribution ensures that the questionnaire effectively captures different aspects of sustainability awareness among students.

The results of the content validity test indicate that the developed questionnaire is highly valid, with an overall validity percentage of 91%. This suggests that the instrument effectively captures essential aspects of sustainability awareness, including environmental knowledge, attitudes, and behavior toward the environment, as well as awareness of environmental protection. These findings are consistent with the study conducted by Fernández-Gómez et al. (2020), which highlights the crucial role of expert validation in the development of assessment instruments to ensure content accuracy and alignment with the intended constructs. Similar results were reported by Fadara et al. (2023), who found that expert-validated sustainability assessment tools significantly enhanced the reliability of environmental education research. These findings further reinforce the necessity of rigorous content validation in constructing scientifically robust instruments.

The item validity test results also demonstrate that all questionnaire items meet the criteria for validity based on the Rasch model analysis. Each item in the questionnaire falls within the acceptable range of outfit MNSQ values, ZSTD values, and Pt-Measure Corr values, indicating that the statements are well-targeted and effectively measure sustainability awareness among students. The high validity of the questionnaire items is in line with previous research by Shafie et al. (2021), which emphasized the importance of Rasch model analysis in ensuring the construct validity of assessment instruments. Furthermore, the item validity findings corroborate studies by Agus & Oktaviyanthi (2024), which highlighted that well-calibrated items in a Rasch-based instrument contribute to increased measurement precision and improved differentiation among respondents. The validity of each item further supports the notion that sustainability awareness can be effectively measured through structured and psychometrically sound instruments (Sass et al., 2021).

The reliability test results further reinforce the robustness of the developed questionnaire, with Cronbach's Alpha values of 0.84 for person reliability and 0.85 for item reliability, indicating that the instrument is highly reliable. These findings are consistent with Raof & Musta'amal (2021), who stated that a Cronbach's Alpha above 0.8 reflects very good reliability in Rasch model-based instruments. Similarly, studies by Cui et al. (2021) and Cerri et al. (2023) emphasize that reliability coefficients in this range ensure measurement consistency and reproducibility across different populations. The high reliability scores suggest that the questionnaire can be consistently used in various educational settings to assess students' sustainability awareness, providing valuable insights for curriculum development and environmental education initiatives. These findings also align with the work of Leonidou et al. (2022), who found that high reliability in environmental awareness instruments enhances their applicability in longitudinal studies and cross-cultural research contexts.

Moreover, the combination of strong content validity, item validity, and reliability results suggests that the questionnaire is a highly suitable tool for assessing sustainability awareness in the context of peatlands' role in global warming. Chen et al. (2022) demonstrated that the use of validated and reliable instruments in environmental education research enhances the accuracy of assessing students' knowledge, attitudes, and behaviors related to sustainability. The inclusion of diverse indicators, such as sustainability practice awareness, behavior and attitude awareness, and emotional awareness, aligns with the multidimensional approach to measuring environmental literacy, as suggested by Aikowe & Mazancova (2023). This comprehensive framework ensures that sustainability awareness is assessed holistically, capturing cognitive, behavioral, and affective dimensions that are critical for fostering long-term environmental responsibility.

This validated questionnaire demonstrates potential for implementation at the secondary and tertiary education levels, where students are expected to engage with complex environmental issues and develop critical thinking skills. Its content, which integrates sustainability awareness with the specific context of peatlands and global warming, aligns well with the demands of 21st century education in Indonesia, particularly in fostering ecological literacy, systems thinking, and local-global connections. Given Indonesia's vast peatland areas and their vulnerability to degradation, equipping students with contextually

relevant environmental knowledge is essential. The questionnaire supports this goal by serving as both an assessment and learning tool, encouraging students to reflect on their roles in sustainability challenges. In this way, it contributes to strengthening education for sustainable development (ESD) as outlined in the national curriculum and global frameworks such as the Sustainable Development Goals (SDGs).

CONCLUSION

The findings of this study demonstrate that the questionnaire developed to measure secondary school students' sustainability awareness, particularly in relation to peatlands' role in global warming, possesses strong psychometric properties. The high content validity score of 91 percent shows that the instrument successfully captures the essential dimensions of sustainability knowledge, attitudes, and behaviors. Analysis using the Rasch model further confirmed that all items performed effectively in distinguishing varying levels of student awareness, supported by consistent item and person measures. Reliability indices, indicated by Cronbach's Alpha values of 0.84 for persons and 0.85 for items, underscore the stability and internal consistency of the questionnaire. Taken together, these results affirm that the instrument is a scientifically robust tool for assessing sustainability awareness and provides clear answers to the study's research questions concerning content validity, item validity, and reliability.

The strength of this validated instrument carries meaningful implications for sustainability education and environmental policy development. By providing a standardized and reliable measure, the questionnaire enables educators to identify students' strengths and gaps more accurately and to design instructional strategies that align with their learning needs. This supports efforts to develop evidence-based curriculum enhancements, targeted interventions, and learning experiences that integrate local ecological issues, particularly peatland vulnerability under global warming pressures. Beyond instructional use, the instrument can assist policymakers and school leaders in evaluating the effectiveness of sustainability programs, monitoring progress, and guiding broader educational decisions related to environmental literacy. Its demonstrated consistency across respondents also makes it suitable for use in a range of school settings.

Building on these contributions, future research may expand the use of this instrument to broader and more diverse student populations to explore variations in sustainability awareness across educational levels, cultural backgrounds, and regional contexts. Comparative studies will help reveal differences in awareness shaped by environmental, social, or curricular factors. Longitudinal investigations may also provide insights into how sustainability awareness changes over time and how educational interventions influence students' understanding and behaviors. Such work will strengthen the generalizability of this instrument and deepen insights into the development of sustainability literacy within education systems.

REFERENCES

Agus, R. N., & Oktaviyanthi, R. (2024). Optimizing Students' Mathematical Visual Thinking Through Graphing Quadratic Worksheets: A Rasch Modeling Approach. In T. A. Aziz, I. Irwanto, & D. Safitri (Eds.), *Proceedings of the 4th Science and Mathematics International Conference (SMIC 2024)* (pp. 161–175). Atlantis Press International BV. https://doi.org/10.2991/978-94-6463-624-6

Ahmad, S., & Mir, A. H. (2021). Scalability, Consistency, Reliability and Security in SDN Controllers: A Survey of Diverse SDN Controllers. *Journal of Network and Systems Management*, 29(1), 9. https://doi.org/10.1007/s10922-020-09575-4

Aikowe, L. D., & Mazancova, J. (2023). Pro-environmental awareness of university students – assessment through sustainability literacy test. *International Journal of Sustainability in Higher Education*, 24(3), 719–741. https://doi.org/10.1108/IJSHE-06-2021-0219

Alsaati, T., El-nakla, S., & El-nakla, D. (2020). Level of Sustainability Awareness among University Students in the Eastern Province of Saudi Arabia. *Sustainability*, 12(8), 1–15.

Amelia, A., Muslim, M., & Chandra, A. F. (2020). Karakteristik Instrumen Non-Tes Sustainability Awareness Menggunakan Analisis Rasch Model Materi Pemanasan Global Untuk Siswa Sekolah Menengah. *WaPFi (Wahana Pendidikan Fisika),* 5(2), 49–56. https://doi.org/10.17509/wapfi.v5i2.27431

Antala, M., Juszczak, R., van der Tol, C., & Rastogi, A. (2022). Impact of climate change-induced alterations in peatland vegetation phenology and composition on carbon balance. *Science of the Total Environment*, 827, 154294. https://doi.org/10.1016/j.scitotenv.2022.154294

Carroll, H. A., Hook, K., Perez, O. F. R., Denckla, C., Vince, C. C., Ghebrehiwet, S., Ando, K., Touma, M., Borba, C. P. C., Fricchione, G. L., & Henderson, D. C. (2017). Establishing Reliability and Validity for Mental Health Screening Instruments in Resource-Con-

strained Settings: Systematic Review of the PHQ-9 and Key Recommendations. *Physiology & Behavior*, 176(1), 100–106. https://doi.org/10.1177/0022146515594631.Marriage

Cerri, L. Q., Justo, M. C., Clemente, V., Gomes, A. A., Pereira, A. S., & Marques, D. R. (2023). Insomnia Severity Index: A reliability generalisation meta-analysis. *Journal of Sleep Research*, 32(4), 1–12. https://doi.org/10.1111/jsr.13835

Chen, C., An, Q., Zheng, L., & Guan, C. (2022). Sustainability Literacy: Assessment of Knowingness, Attitude and Behavior Regarding Sustainable Development among Students in China. *Sustainability (Switzerland)*, 14(9). https://doi.org/10.3390/su14094886

Cui, Q., Xia, Y., Wu, Q., Chang, Q., Niu, K., & Zhao, Y. (2021). A meta-analysis of the reproducibility of food frequency questionnaires in nutritional epidemiological studies. *International Journal of Behavioral Nutrition and Physical Activity*, 18(1), 1–18. https://doi.org/10.1186/s12966-020-01078-4

Dawson, V., & Carson, K. (2020). Introducing Argumentation About Climate Change Socioscientific Issues in a Disadvantaged School. *Research in Science Education*, 50(3), 863–883. https://doi.org/10.1007/s11165-018-9715-x

DeVellis, R. F. (2016). *Scale Development: Theory and Applications*. SAGE Publications.

Du, X., Lundberg, A., Ayari, M. A., Naji, K. K., & Hawari, A. (2022). Examining engineering students' perceptions of learner agency enactment in problem- and project-based learning using Q methodology. *Journal of Engineering Education*, 111(1), 111–136. https://doi.org/10.1002/jee.20430

Ekamilasari, Permanasari, A., & Dwi Pursitasari, I. (2021). Students' Critical Thinking Skills and Sustainability Awareness in Science Learning for Implementation Education for Sustainable Development. *Indonesian Journal of Multidiciplinary Research*, 1(1), 121–124.

Elangovan, N., & Sundaravel, E. (2021). Method of preparing a document for survey instrument validation by experts. *MethodsX*, 8(March), 101326. https://doi.org/10.1016/j.mex.2021.101326

Escobar, D., Belyazid, S., & Manzoni, S. (2022). Back to the Future: Restoring Northern Drained Forested Peatlands for Climate Change Mitigation. *Frontiers in Environmental Science,* 10(March), 1–18. https://doi.org/10.3389/fenvs.2022.834371

Fadara, T. G., Wong, K. Y., & Maulana, M. I. (2023). Sustainability Assessment of Textile and Apparel Sector: A Review of Current Approaches and Tools. *Nigerian Journal of Technological Development*, 20(3), 1–20. https://doi.org/10.4314/njtd.v18i4.1255

Fernández-Gómez, E., Martín-Salvador, A., Luque-Vara, T., Sánchez-Ojeda, M. A., Navarro-Prado, S., & Enrique-Mirón, C. (2020). Content validation through expert judgement of an instrument on the nutritional knowledge, beliefs, and habits of pregnant women. *Nutrients*, 12(4). https://doi.org/10.3390/nu12041136

Greenland, S., Saleem, M., Misra, R., & Mason, J. (2022). Sustainable management education and an empirical five-pillar model of sustainability. *International Journal of Management Education*, 20(3), 100658. https://doi.org/10.1016/j.ijme.2022.100658

Hariyadi, B., Subagyo, A., & Kartika, W. D. (2021). Peat Ecosystem: Teachers' knowledge and perception, and its integration in learning biology. *Jurnal Bioedukatika*, 9(2), 102. https://doi.org/10.26555/bioedukatika.v9i2.19977

Hekmah, N., Wilujeng, I., & Suryadarma, I. G. P. (2019). Web-Lembar Kerja Siswa IPA terintegrasi lingkungan untuk meningkatkan literasi lingkungan siswa. *Jurnal Inovasi Pendidikan IPA,* 5(2), 129–138. https://doi.org/10.21831/jipi.v5i2.25402

Izah, S. C., Sylva, L., & Hait, M. (2024). Cronbach's Alpha: A Cornerstone in Ensuring Reliability and Validity in Environmental Health Assessment. *ES Energy and Environment*, 23, 1–14. https://doi.org/10.30919/esee1057

Kee, T., & Zhang, H. (2022). Digital Experiential Learning for Sustainable Horticulture and Landscape Management Education. *Sustainability (Switzerland),* 14(15), 1–18. https://doi.org/10.3390/su14159116

Kurdiati, L. A., Apriana, R., & Saparini. (2024). Transformation of Sustainability Science Education : PISA 2025 Science Framework and ESD on E-Worksheets Science in the Context of the Role of Peatland in Global Warming Phenomenon. *Kasuari : Physics Education Journal (KPEJ),* 7(2), 417–431.

Kurdiati, L. A., Fathurohman, A., & Susiloningsih, E. (2024). The Intersection of Education and Local Environmental Issues: Secondary Students' Views and Actions on Peatland Ecosystems in Global Warming Phenomenon. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, 14(2). https://doi.org/10.30998/formatif.v14i2.27851

Leonidou, C. N., Gruber, V., & Schlegelmilch, B. B. (2022). Consumers' Environmental Sustainability Beliefs and Activism: A Cross-Cultural Examination. *Journal of International Marketing*, 30(4), 78–104. https://doi.org/10.1177/1069031X221128786

Mander, Ü., Espenberg, M., Melling, L., & Kull, A. (2024). Peatland restoration pathways to mitigate greenhouse gas emissions and retain peat carbon. *Biogeochemistry*, 167(4), 523–543. https://doi.org/10.1007/s10533-023-01103-1

Mat Nawi, F. A., A.Tambi, A. M., Samat, M. F., & Mustapha, W. M. W. (2020). A Review on the Internal Consistency of a Scale: the Empirical Example of the Influence of Human Capital Investment on Malcom Baldridge Quality Principles in Tvet Institutions. *Asian People Journal*

(APJ), 3(1), 19–29. https://doi.org/10.37231/apj.2020.3.1.121

Mellinger, C. D., & Hanson, T. A. (2020). Methodological considerations for survey research: Validity, reliability, and quantitative analysis. *Linguistica Antverpiensia, New Series – Themes in Translation Studies,* 19, 172–190. https://doi.org/10.52034/lanstts.v19i0.549

Olsson, D., Gericke, N., Sass, W., & Boeve-de Pauw, J. (2020). Self-perceived action competence for sustainability: the theoretical grounding and empirical validation of a novel research instrument. *Environmental Education Research,* 26(5), 742–760. https://doi.org/10.1080/13504622.2020.1736991

Raof, S. A., & Musta'amal, A. H. (2021). Validity and Reliability of Instrument Competencies Framework of Agriculture Educators: The Rasch Measurement Model. *International Journal of Educational Methodology*, 7(3), 411–420. https://doi.org/10.12973/ijem.7.3.411

Reis Neto, J. F. dos, Souza, C. C. de, Bitencourt, T. D. A., Cupertino, C. M., Melo Neto, P. L. de, Soares, D. G., & Rodrigues, I. de O. (2021). Validating the Scale of the New Ecological Paradigm (NEP) in Brazilian University Students. *Research, Society and Development*, 10(4), e16410413947. https://doi.org/10.33448/rsd-v10i4.13947

Ribeiro, K., Pacheco, F. S., Ferreira, J. W., de Sousa-Neto, E. R., Hastie, A., Krieger Filho, G. C., Alvalá, P. C., Forti, M. C., & Ometto, J. P. (2021). Tropical peatlands and their contribution to the global carbon cycle and climate change. *Global Change Biology,* 27(3), 489–505. https://doi.org/10.1111/gcb.15408

Romano, L., Angelini, G., Consiglio, P., & Fiorilli, C. (2021). The effect of students' perception of teachers' emotional support on school burnout dimensions: Longitudinal findings. *International Journal of Environmental Research and Public Health,* 18(4), 1–7. https://doi.org/10.3390/ijerph18041922

Rustamova, R. P. (2023). Important features of the formation of ecological culture in students. *Journal of Economics and Business Management,* 6(4), 67–74. https://doi.org/https://doi.org/10.5281/zenodo.10116432

Sass, W., Pauw, J. B., Maeyer, S. De, & Petegem, P. Van. (2021). Development and validation of an instrument for measuring action competence in sustainable development within early adolescents: the action competence in sustainable development questionnaire (ACiSD-Q). *Environmental Education Research*, 27(9), 1284–1304. https://doi.org/10.1080/13504622.2021.1888887

Shafie, S., Abd Majid, F., Hoon, T. S., & Damio, S. M. (2021). Evaluating Construct Validity and Reliability of Intention to Transfer Training Conduct Instrument Using Rasch Model Analysis. *Pertanika Journal of Social Sciences and Humanities*, 29(2), 1055–1070. https://doi.org/10.47836/pjssh.29.2.17

Siswanti, Widyaningsih, S. W., & Sebayang, S. R. B. (2023). Analisis Kualitas Butir Soal Fisika Pada Penilaian Akhir Semester. *Al-Khazini : Jurnal Pendidikan Fisika: Jurnal Pendidikan Fisika*, 3(2), 130–139. https://doi.org/10.24252/al-khazini.v3i2.37721

Sumintono, B., & Widhiarso, W. (2014). *Aplikasi Model Rasch untuk Penelitian Ilmu-Ilmu Sosial (edisi revisi).* Trim Komunikata Publishing House.

Wilkinson, S. L., Andersen, R., Moore, P. A., Davidson, S. J., Granath, G., & Waddington, J. M. (2023). Wildfire and degradation accelerate northern peatland carbon release. *Nature Climate Change,* 13(5), 456–461. https://doi.org/10.1038/s41558-023-01657-w

Yani, M., Layyinah, S. Q., Zahra, I. R., Achwani, A. S., Riandi, R., Sholihat, R., & Amprasto, A. (2023). Student's interest in PENILIK as sustainable development extracurricular program to support agricultural awareness. *Jurnal Inovasi Pendidikan IPA,* 9(1), 107–117. https://doi.org/10.21831/jipi.v8i1.50393

Zhong, Y., Jiang, M., & Middleton, B. A. (2020). Effects of water level alteration on carbon cycling in peatlands. *Ecosystem Health and Sustainability,* 6(1). https://doi.org/10.1080/20964129.2020.1806113

Zulkarnaini, Meiwanda, G., Lubis, E. E., Nasution, M. S., & Habibie, D. K. (2020). Peatland Management Based on Education for Sustainable Development (ESD). *Journal of Physics: Conference Series,* 1655(1), 012142. https://doi.org/10.1088/1742-6596/1655/1/012142