

Applying Winsteps-Rasch Analysis to Evaluate the Psychometric Soundness of an Ecopedagogy-Based Ecological Intelligence Test for Technical Students

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Abstract—Ecological intelligence is important to prepare technical students to comprehend the relationship between human activities and environmental sustainability. This study assessed the psychometric soundness of an ecological intelligence test based on ecopedagogy through the Rasch measurement model using Winsteps. It consisted of 32 items that measured ecological knowledge, ecological awareness, ecological sensitivity, and ecological behavior. Item fit, reliability, separation, item difficulty, person-item targeting, and dimensionality were analyzed in 113 technical students. Overall, results indicated acceptable quality of measurement, although some items and aspects of the instrument require further refinement. The findings support the use of Rasch analysis in improving ecological intelligence assessment in technical education and call for further validation using larger samples of technical students.

Keywords—ecological intelligence, ecopedagogy, psychometric evaluation, Rasch model, technical students, winsteps.

I. INTRODUCTION

Environmental problems have become increasingly complex due to their close interrelations with human activities, social development, economic systems, and spatial processes. Ecological problems such as environmental degradation, loss of biodiversity, climate change, land-use change, waste generation, and disaster vulnerability indicate that these problems cannot be understood in terms of the natural environment alone. Instead, they are the result of complex interactions between human decisions and ecological systems (Alcántara-Ayala, 2025; Hariram et al., 2023; Fang et al., 2016). Education, therefore, is important in preparing learners to comprehend the relations and to develop responsible responses to environmental issues.

One educational competence that is particularly relevant to this challenge is ecological intelligence. Ecological intelligence is the ability to understand natural systems, to be aware of the ecological consequences of human actions, and to understand the interdependence of humans and their environments. The construct goes beyond factual ecological knowledge by including environmental attitudes, ecological sensitivity, competencies, and environmentally responsible

behavior (Güven & Uyulgan, 2021; Morrone et al., 2001; Roczen et al., 2014). Therefore, ecological intelligence cannot be adequately measured by a limited assessment of students' environmental knowledge. We need an instrument that can capture the multidimensional nature of students' relationships with environmental issues to measure it.

Ecological intelligence is especially important in technical education because technical students are being prepared for professional and social activities in which technological, economic, and environmental issues are increasingly coming together. Thus, contemporary technical education needs not only occupational readiness, but also sustainability-oriented competencies and responsible decision-making (Fiandini et al., 2025). Students need opportunities to not only learn about the environment, but also how human activities, economic practices, communities, and ecological systems interact. Contextual learning that connects environmental concepts with real social and geographical situations can provide an appropriate foundation for developing these competencies, particularly when learning activities explicitly address sustainability awareness and ecological issues.

Social Studies learning provides the immediate instructional context for this study because it integrates social, spatial, economic, cultural, and environmental perspectives. Within a technical-school setting, these interdisciplinary perspectives can support technical students in understanding the broader social and ecological consequences of human and technological activities (Syaharuddin et al., 2020; Mariati et al., 2021). Environmental issues can therefore be examined through the relationships between communities and natural resources, spatial connectivity, economic activities, social interaction, disaster potential, and environmental change. This approach enables students to go beyond abstract descriptions of environmental problems to a more contextual understanding of the reciprocal relations between society and ecological systems (Fitrianto & Farisi, 2025; Purwasih et al., 2026).

Ecopedagogy provides a crucial pedagogical framework for building this understanding. Rooted in critical educational thought, ecopedagogy emphasizes ecological

awareness, critical consciousness, and responsibility toward the planet. Rather than treating environmental problems merely as scientific phenomena, ecopedagogy encourages learners to critically examine the social structures, economic activities, and human practices associated with ecological crises (Misiaszek, 2020). Through this perspective, environmental learning can support the development of students who are able to recognize ecological problems, reflect critically on their causes, and consider responsible actions.

The development of WEGAL (Web Gamified Collaborative Learning) was situated within this ecopedagogical perspective. WEGAL was designed as a web-based learning medium that integrates contextual environmental learning, collaborative activities, and gamification. Digital learning environments can provide additional opportunities to connect sustainability-oriented content with engagement and environmental awareness (Kelana et al., 2025). The learning content uses local social-ecological issues related to Curiak Island in Barito Kuala Regency, South Kalimantan. The context enables students in a technical-school setting to examine environmental conservation, river-based spatial connectivity, economic activities, social interaction, disaster potential, and multi-stakeholder environmental collaboration.

The development and implementation of WEGAL required an instrument to assess students' ecological intelligence. The ecological intelligence test used in the study consisted of 32 items distributed across four dimensions: ecological knowledge, ecological awareness, ecological sensitivity, and ecological behavior. These dimensions were intended to represent complementary cognitive, affective, skill-based, and behavioral aspects of ecological competence and environmental responsibility (Morrone et al., 2001; Roczen et al., 2014; Rusmaniah et al., 2026). However, the use of an instrument in educational research requires evidence that the items function appropriately as measurement indicators. This requirement is particularly important in technical and vocational education, where assessment instruments should provide interpersss evidence of the competencies they are intended to measure (Fiandini et al., 2024). Conventional score-based analysis provides limited information regarding how individual items function across technical students with different levels of the measured construct, making item-level psychometric evaluation important for educational assessment (Fiandini et al., 2024; Schumacker & Smith, 2007; Van Zile-Tamsen, 2017). An instrument may produce numerical scores while still containing items that do not adequately contribute to the measurement of the intended construct. Therefore, psychometric evaluation is necessary to examine whether the relationship between respondents and items supports meaningful measurement.

The Rasch measurement model provides an approach for evaluating instrument quality at both the item and person levels (Van Zile-Tamsen, 2017; Schumacker & Smith, 2007). Rasch analysis transforms ordinal response data into interval-level logit measures and provides information

regarding item fit, respondent ability, item difficulty, reliability, separation, and dimensionality. Unlike conventional score-based analysis, the Rasch model enables researchers to investigate whether individual items function consistently with the underlying measurement model and whether the instrument can differentiate respondents with different levels of the measured construct.

The use of Winsteps-Rasch analysis is particularly relevant for evaluating an ecological intelligence instrument because the construct is represented through multiple dimensions and diverse indicators (Gaborieau & Pronello, 2021; Supriatno et al., 2025). Psychometric analysis can identify items that function appropriately, items requiring revision, the relative difficulty of items, and the extent to which the instrument provides reliable measurement (Tavakol & Dennick, 2013). Such evidence is important before ecological intelligence scores are used as a basis for evaluating learning outcomes or the effectiveness of educational interventions. Although the study focused on the development, feasibility, practicality, and effectiveness of WEGAL, the availability of ecological intelligence response data provides an opportunity for a complementary psychometric investigation. The present study therefore shifts the analytical focus from evaluating the effectiveness of the learning medium to evaluating the quality of the instrument used to measure ecological intelligence.

Based on our previous study (Mutiani et al., 2025), this study aimed to evaluate the psychometric soundness of an ecopedagogy-based ecological intelligence test for technical students using Winsteps-Rasch analysis. Specifically, the study examined: (1) item fit and item polarity; (2) person and item reliability; (3) person and item separation; (4) the distribution of item difficulty and student ability; (5) the person-item relationship through a Wright map; and (6) evidence regarding the dimensionality of the instrument. The findings are expected to contribute to the establishment of more rigorous measurement practices in environmental and Social Studies education and provide evidence regarding the suitability of the ecological intelligence test for use in ecopedagogy-based educational research.

II. METHODOLOGY

A. Research Design

This study employed a quantitative psychometric evaluation design using the Rasch measurement model. The study was based on the ecological intelligence assessment data collected during the implementation of an ecopedagogy-based learning program supported by WEGAL (Web Gamified Collaborative Learning). The research focused on the development and implementation of the web-based learning medium; the present analysis focused specifically on evaluating the psychometric quality of the ecological intelligence test. The Rasch measurement model was selected because it enables the evaluation of measurement quality at both item and person levels. The analysis provides information concerning the extent to which individual items conform to the measurement model, the reliability of the instrument, the separation of respondents

and items, the relative difficulty of each item, and the relationship between student ability and item difficulty.

B. Research Context and Participants

The study was conducted at technical school SMKN 1 Telagasari in Banjarmasin, Indonesia, in July 2026. The participants were technical students enrolled at a vocational secondary school and organized into naturally occurring classes. The ecological intelligence assessment data were obtained from students who participated in the implementation and evaluation of WEGAL. The study involved classroom groups that were assigned to experimental and control conditions using intact-group procedures because individual random assignment was not feasible within the school context. The ecological intelligence test was administered as a posttest to the participating students after the learning implementation. For the present study, the unit of psychometric analysis was not the experimental treatment condition but the pattern of student responses to the ecological intelligence items. Therefore, the Rasch analysis focused on the response data generated by the participating technical students across the 32-item ecological intelligence test. Because responses from the experimental and control groups were analyzed together, future studies should also examine differential item functioning across treatment conditions.

C. Ecopedagogy-Based Learning Context

The ecological intelligence test was developed and administered within an ecopedagogy-based learning context. The learning environment was supported by WEGAL, a web-based learning medium integrating contextual environmental learning, collaborative learning, and gamification (Alsawaier, 2018; Kelana et al., 2025; Syaharuddin et al., 2025). The learning content was developed based on social-ecological issues around Curiak Island, Barito Kuala Regency, South Kalimantan. Students learned about the environmental issues of ecological conservation, river-based spatial connectivity, social interaction, economic activities, disaster potential, and environmental responsibility. The learning context was oriented toward ecopedagogy, to invite students to investigate the relations between human activities and ecological systems. Students were thus expected to deal both with factual information about the environment and with questions about ecological awareness, environmental sensitivity, and environmentally responsible behavior.

D. Ecological Intelligence Test

The main tool used in this study was the ecological intelligence test. The instrument consisted of 32 items distributed across four dimensions, with eight items representing each dimension. The four dimensions were:

- (i) Ecological Knowledge;
 1. Ecological Awareness;
 2. Ecological Sensitivity; and
 3. Ecological Behavior.

These dimensions were intended to operationalize ecological intelligence as a multidimensional educational construct. Ecological knowledge represented students' understanding of environmental and social-ecological relationships. Ecological awareness represented students' recognition of environmental issues and the consequences of human activities. Ecological sensitivity represented students' affective orientation and concern toward ecological conditions and problems. Ecological behavior represented students' tendencies toward responsible environmental action. The 32-item instrument was developed to assess these dimensions within the contextual framework of ecopedagogy and local environmental issues. The present study evaluated the functioning of the items using the Rasch measurement model. As illustrated in Figure 1, ecopedagogy can serve as a pedagogical approach for developing ecological intelligence by providing learning experiences that encourage students to critically examine human-environment relationships and the ecological consequences of human actions. In turn, ecological intelligence guides learners in making informed decisions and engaging in environmentally responsible actions. This relationship is represented as a cyclical process in which ecopedagogical learning develops ecological understanding and critical awareness, while the resulting ecological intelligence informs students' attitudes, decisions, and actions toward environmental issues. Ultimately, the integration of ecopedagogy and ecological intelligence seeks to foster learners who possess an informed awareness, a critical mind, and a willingness to act responsibly to sustain ecological systems. Ecological intelligence includes both cognitive and affective dimensions (Abdelraheem et al., 2025; Güven & Uyulgan, 2021). From a cognitive perspective, students need to understand ecological concepts, biodiversity, environmental changes, climate change, natural disasters, and relationships between humans and their environment. However, knowledge alone does not necessarily result in environmentally responsible behavior. Students also need to develop empathy, concern, and positive attitudes toward environmental sustainability.

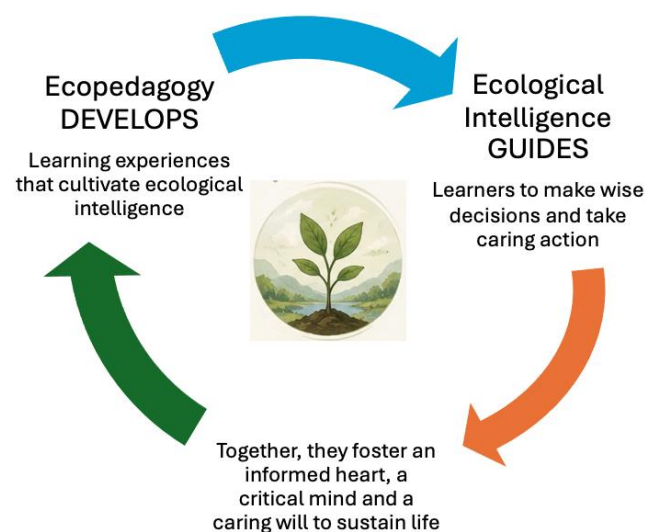


Fig. 1. Relationship between ecopedagogy and ecological intelligence.

E. Data Collection

The ecological intelligence response data were collected following the implementation of the learning activities in the study. Students completed the 32-item ecological intelligence test as a post-learning assessment. For the present psychometric study, the students' item-level responses were prepared for analysis using Winsteps software. The analysis examined the response patterns across all items and respondents rather than relying exclusively on students' total scores.

F. Rasch Data Analysis

The data were analyzed using the Rasch measurement model through Winsteps software. The psychometric evaluation included several complementary indicators.

- (i) **Item Fit and Item Polarity.** Item fit analysis was conducted to determine whether individual items functioned consistently with the Rasch measurement model. The primary indicators included Outfit Mean Square (MNSQ), Outfit Z-Standard (ZSTD), and Point-Measure Correlation. Items were evaluated according to commonly used Rasch criteria. Outfit MNSQ values approximately within the range of 0.50 to 1.50 were considered productive for measurement. Outfit ZSTD values approximately between -2.00 and +2.00 were considered acceptable. Positive Point-Measure Correlation values were used as evidence that the item contributed in the expected direction to the measured construct. Items that did not meet one or more criteria were identified for further examination and potential revision.
- (ii) **Person and Item Reliability.** Person reliability was examined to determine the consistency of respondents' response patterns across the instrument. Item reliability was examined to determine the stability of the item hierarchy based on the available sample. Cronbach's alpha was also considered as supplementary evidence of overall internal consistency. Higher reliability values indicate more consistent measurement, whereas lower person reliability may indicate limited variation in respondent ability or inconsistent response patterns.
- (iii) **Person and Item Separation.** Person separation was examined to determine the extent to which the instrument could differentiate students into distinct levels of ecological intelligence. Item separation was examined to determine whether the sample was sufficient to establish a stable hierarchy of item difficulty. Higher separation values indicate greater differentiation among persons or items.
- (iv) **Item Difficulty.** Item difficulty was evaluated using Rasch logit measures. Items with higher positive logit values were interpreted as relatively more difficult to endorse or answer, whereas items with lower or negative logit values were interpreted as relatively easier. The distribution of item difficulty was examined to determine whether the instrument

provided an appropriate range of items for students with different levels of ecological intelligence.

- (v) **Person-Item Map.** A Wright map was used to examine the relationship between student ecological intelligence measures and item difficulty measures. The map provides a visual representation of whether the difficulty of the items is appropriately targeted to the ability distribution of the participating students. The person-item relationship was interpreted to identify possible gaps in item targeting, including the possibility that items were too easy or too difficult for the sample.
- (vi) **Dimensionality.** Dimensionality was examined using Principal Component Analysis of Residuals. The analysis was used to investigate whether the instrument demonstrated sufficient evidence of a dominant measurement dimension. Because ecological intelligence was operationalized through four theoretically defined dimensions, the present overall Rasch calibration was treated as an initial psychometric evaluation rather than definitive evidence that the instrument represents a single latent construct. The dimensionality analysis was therefore interpreted cautiously, with further dimension-level Rasch analyses recommended to examine the psychometric functioning of ecological knowledge, ecological awareness, ecological sensitivity, and ecological behavior separately.

G. Ethical and Analytical Considerations

The present study analyzed educational assessment data collected from students participating in the classroom-based research. The analysis focused on aggregate psychometric characteristics and did not report personally identifiable student information. The interpretation of Rasch results was limited to the evidence generated by the participating sample. In addition, because responses from the experimental and control groups were calibrated together, future studies should examine whether item functioning remains invariant across treatment conditions. Therefore, the findings should be interpreted as evidence regarding the functioning of the ecological intelligence test within the present technical and vocational school context. Further studies with larger and more diverse samples are recommended to evaluate the stability and generalizability of the instrument across educational contexts.

III. RESULTS AND DISCUSSION

A. Overall Measurement Quality of the Ecological Intelligence Test

The psychometric quality of the Ecological Intelligence Test was evaluated using the Rasch measurement model. Table I. The study focused on the operation of the 32 items and the response styles of 113 technical students, with 47 students in the control group and 66 students in the experimental group. The overall measurement evaluation consisted of person reliability, item reliability, person separation, item separation, and internal consistency. These

indicators provide additional information about the extent to which the instrument can reliably differentiate respondents and establish a stable hierarchy of item difficulty.

TABLE I
OVERALL MEASUREMENT QUALITY OF THE ECOLOGICAL INTELLIGENCE TEST.

Measurement Indicator	Value	Interpretation
Number of respondents	113	Adequate for the present psychometric evaluation
Number of items	32	Four dimensions with eight items each
Response scale	1–5	Polytomous rating scale
Cronbach's Alpha	0.812	Good internal consistency
Person Reliability	0.833	Good consistency of person measures
Person Separation	2.237	Able to distinguish respondents into different levels
Item Reliability	0.777	Acceptable stability of item hierarchy
Item Separation	1.864	Moderate-to-good separation of item difficulty

The analysis revealed a person reliability value of 0.833, indicating good consistency of students' response patterns. This result means that the ecological intelligence test was able to distinguish technical students according to their ecological intelligence level in a reasonable manner. The value of item reliability was 0.777, indicating that the stability of the item difficulty hierarchy was acceptable. This value provides encouraging information about the functioning of the items, but the stability of the item hierarchy might be improved by further testing on larger and more heterogeneous samples.

The person separation index was 2.237, and the item separation index was 1.864. The tool was able to distinguish pupils into different levels of ecological intelligence, according to the person separation value. The item separation value, on the other hand, indicates that the sample offered moderate evidence for determining the relative hierarchy of item difficulty. The 32-item test had strong general internal consistency, as seen by its Cronbach's alpha of 0.812. For technical students, the ecological intelligence exam shows encouraging measurement quality.

These results are significant from a psychometric standpoint since ecological intelligence is meant to reflect differences in students' comprehension, attitudes, abilities, and behavioral orientation about environmental issues (El Rizaq et al., 2025; Güven & Uyulgan, 2021; Roczen et al., 2014). An instrument with adequate reliability and separation can provide more meaningful distinctions between students than an assessment based solely on raw total scores.

B. Item Fit and Item Polarity

Item fit analysis was conducted to determine whether the 32 ecological intelligence items functioned consistently with the Rasch measurement model. The preliminary evaluation considered Infit Mean Square (MNSQ), Outfit Mean Square (MNSQ), and Point-Measure Correlation.

The analysis showed that 31 of the 32 items were within the commonly accepted productive Outfit MNSQ range of approximately 0.50 to 1.50. Only one item, EB6, showed an Outfit MNSQ slightly above this range. Importantly, all 32

items showed positive Point-Measure Correlation values, indicating that all items contributed in the expected direction toward the measurement of ecological intelligence.

As shown in Table II, the item requiring the greatest attention was EB6, which had an Outfit MNSQ value of 1.527. This value is only slightly above the commonly used upper threshold of 1.50. Therefore, EB6 should not automatically be removed from the instrument. Instead, its wording and theoretical relevance should be reviewed to determine whether the relatively unexpected response patterns resulted from ambiguous wording, contextual complexity, or differences in how technical students interpreted the ecological behavior represented by the item. Clear and systematically structured terminology can support students' interpretation of assessment items requiring precise conceptual understanding (Nandiyanto & Yulistiani, 2024).

TABLE II
ITEMS WITH THE HIGHEST OUTFIT MNSQ VALUES.

Item	Infit MNSQ	Outfit MNSQ	Point-Measure Correlation	Preliminary Interpretation
EB6	1.362	1.527	0.328	Requires review
ES2	1.270	1.271	0.283	Acceptable
EB8	1.194	1.223	0.313	Acceptable
EA7	1.251	1.219	0.309	Acceptable
EK4	1.204	1.219	0.321	Acceptable
EK1	1.213	1.160	0.476	Acceptable

Most items demonstrated acceptable response patterns and contributed positively to the measurement of ecological intelligence. The Point-Measure Correlation results were generally positive. The highest correlations were observed for items such as ES5, EK1, EA1, EK7, and ES6, indicating that these items demonstrated relatively strong positive relationships with the overall ecological intelligence measure.

The fact that no item showed a negative Point-Measure Correlation is an important positive finding. It indicates that none of the items functioned in a direction opposite to the construct being measured. Therefore, the item-fit analysis provides evidence that the ecological intelligence test generally demonstrates acceptable item functioning. Nevertheless, EB6 should be reviewed in subsequent instrument development before any decision regarding item revision or removal is made.

C. Distribution of Item Difficulty

The Rasch item measures were used to examine the relative difficulty of the ecological intelligence items. Items with higher positive logit values were relatively more difficult for students, whereas items with negative logit values were relatively easier.

Table III results showed that ES2 was the most difficult item, with a measure of approximately 0.503 logits, whereas EB6 was the easiest item, with a measure of approximately -0.630 logits. The item difficulty hierarchy provides meaningful information regarding the ecological intelligence construct. The relatively difficult items included indicators from ecological sensitivity, ecological awareness, and ecological knowledge. This suggests that some aspects

of ecological intelligence require students to demonstrate more complex understanding, reflection, or reasoning than others.

TABLE III
MOST DIFFICULT AND EASIEST ITEMS.

Rank	Item	Preliminary Measure (Logit)
Most Difficult Items		
1	ES2	0.503
2	EA8	0.327
3	EK6	0.314
4	EK7	0.207
5	ES4	0.193
Easiest Items		
1	EB6	-0.630
2	EB4	-0.610
3	EB7	-0.455
4	EB2	-0.437
5	EB1	-0.419

An interesting pattern can also be observed among the relatively easiest items. Several of these items belonged to the Ecological Behavior dimension, including EB6, EB4, EB7, EB2, and EB1. This finding should be interpreted cautiously. Easier ecological behavior items do not necessarily indicate that students consistently demonstrate strong ecological behavior in real-life situations. Instead, the findings suggest that the statements represented by these items were relatively easier for students to endorse or receive higher scores compared with other indicators in the instrument.

The hierarchy of item difficulty can therefore help researchers identify which aspects of ecological intelligence may require greater attention in learning. In particular, the difficulty of ES2 suggests that the ecological sensitivity represented by this item may require more complex reflection or judgment than other ecological intelligence indicators.

D. Person-Item Distribution and Wright Map

The Wright map was used to examine the relationship between student ecological intelligence measures and the difficulty distribution of the 32 items. The preliminary analysis showed that the item difficulty measures covered a range from approximately -0.630 to 0.503 logits. In contrast, the distribution of student measures covered a broader range. This pattern suggests that the participating students demonstrated a wider range of ecological intelligence than the range represented by the item difficulties. In particular, some students were located above the difficulty level of the most difficult items.

The person-item distribution therefore indicates that the instrument generally provides items across a moderate range of ecological intelligence. However, the relatively narrower distribution of item difficulty compared with person ability suggests that additional items may be needed at higher levels of difficulty. Such additional items may enhance measurement precision for students with relatively high levels of ecological intelligence. The Wright map is especially helpful for the present instrument since ecological intelligence involves ecological knowledge, ecological awareness, ecological sensitivity, and ecological behavior. Hence, an instrument that is well-targeted should provide

indicators across a sufficiently broad continuum rather than concentrating most items within a limited level of difficulty.

The first targeting results suggest that future development of the instrument should consider the addition of more challenging ecological intelligence items. This would enhance the instrument's ability to differentiate students with higher levels of ecological intelligence.

E. Dimensionality of the Ecological Intelligence Test

Dimensionality was assessed by Principal Component Analysis of standardized Rasch residuals. The first residual contrast had an eigenvalue of approximately 2.80 and explained 8.56% of the standardized residual variance.

These findings should be interpreted cautiously. Although the residual structure did not show a clearly dominant secondary pattern, an eigenvalue of 2.80 indicates that some residual structure may remain. Therefore, the results provide preliminary support for the overall measurement structure of the instrument but do not exclude the possibility of secondary dimensions. Further analysis of the four theoretical dimensions is recommended to clarify whether the observed residual structure reflects meaningful multidimensionality. However, the dimensionality results require particular attention because the ecological intelligence test was theoretically designed to represent four related dimensions:

1. Ecological Knowledge;
2. Ecological awareness;
3. Ecological sensitivity; and
4. Ecological Behavior.

Consequently, the Rasch residual analysis should not be interpreted as demonstrating that ecological intelligence is a strictly unidimensional construct. Rather, the findings suggest that the items share sufficient common measurement characteristics to support an overall ecological intelligence interpretation, while still representing theoretically distinguishable dimensions (Table IV). The first residual contrast provides preliminary support for an overall ecological intelligence interpretation, although possible secondary structure should not be disregarded. Nevertheless, because the instrument was intentionally developed with four theoretical dimensions, future research should also consider conducting separate Rasch analyses for:

- (i) Ecological Knowledge;
- (ii) Ecological awareness;
- (iii) Ecological sensitivity; and
- (iv) Ecological Behavior.

Such analyses could provide more detailed evidence regarding the psychometric functioning of each dimension.

TABLE IV
PRELIMINARY RESIDUAL DIMENSIONALITY RESULTS.

Indicator	Value
First contrast eigenvalue	2.80
First contrast residual variance	8.56%
Interpretation	No clearly dominant secondary pattern; further dimensional analysis recommended

F. Implications for Technical Education Assessment

The Rasch analysis provides a different type of evidence from the evaluation of WEGAL. The research focused primarily on the feasibility, practicality, and educational application of the ecopedagogy-based learning medium. The present analysis addresses a different but equally important question: whether the ecological intelligence instrument itself provides psychometrically sound measurement.

This distinction is important because the quality of a learning medium and the quality of an assessment instrument are related but conceptually different. A learning medium may be highly feasible and practical while the instrument used to evaluate its educational outcomes still requires rigorous psychometric investigation.

By examining item functioning, reliability, separation, item difficulty, and person-item targeting, the present study provides evidence that cannot be obtained from conventional validation percentages or group-level posttest comparisons alone. The findings indicate several important psychometric characteristics.

The instrument demonstrated good internal consistency, with a Cronbach's alpha of .812. Second, the person reliability of 0.833 and person separation of 2.237 showed the instrument was fairly effective in differentiating students with different levels of ecological intelligence. Third, the positive Point-Measure Correlations for all items show the items worked in the expected direction. Fourth, the item difficulty hierarchy was significantly different across the 32 items, with difficulties ranging from approximately -0.630 to 0.503 logits. Finally, residual dimensionality analysis did not reveal a dominant secondary dimension, though consideration of the theoretical multidimensionality of ecological intelligence is important for interpreting the instrument.

These findings have important implications for assessment in technical education, particularly in the assessment of sustainability-related competencies within ecopedagogy-based learning contexts. Ecopedagogy aims to promote ecological knowledge, which goes beyond factual knowledge to include ecological awareness, sensitivity, and environmentally responsible behavior. Therefore, an assessment tool must be capable of capturing variation in these different aspects.

The ecological intelligence test may potentially support diagnostic interpretation in addition to its role as an outcome measure. Difficult items may identify ecological competencies requiring stronger instructional support, whereas misfitting items may identify conceptual or linguistic problems requiring revision.

G. Psychometric Evaluation and Limitations

The psychometric soundness of the ecological intelligence test should be interpreted based on the combined evidence generated by the Rasch analysis. The findings provide promising evidence for the psychometric quality of the instrument. The test demonstrated good internal consistency, acceptable person and item reliability, meaningful person separation, positive item polarity, and

generally acceptable item fit. Of the 32 items, 31 demonstrated Outfit MNSQ values within the commonly accepted productive range, while only EB6 showed a value slightly above the upper threshold. Importantly, EB6 still demonstrated a positive Point-Measure Correlation. Therefore, the item should be considered for review rather than immediately removed.

The person reliability value of 0.833 suggests good consistency in differentiating students, while the person separation value of 2.237 indicates that the instrument can distinguish students across different levels of ecological intelligence. The item reliability value of 0.777 and item separation of 1.864 provide acceptable but not optimal evidence regarding the stability of the item difficulty hierarchy. These findings suggest that future studies should examine the instrument using larger and more heterogeneous samples to strengthen the calibration of item difficulty.

The Wright map analysis also suggests a potential limitation in the range of item difficulty. Because student measures appear to cover a broader continuum than the items, additional difficult items may be useful for improving measurement precision among students with relatively high ecological intelligence.

The dimensionality findings provide preliminary evidence regarding the overall structure of the instrument, while further analysis of the four theoretical dimensions remains necessary. The first residual contrast had an eigenvalue of 2.80 and accounted for 8.56% of the residual variance, indicating that possible secondary structure should be interpreted cautiously and examined further in relation to the four theoretical dimensions. Nevertheless, ecological intelligence remains theoretically multidimensional. Therefore, the overall ecological intelligence score should be interpreted together with the conceptual distinctions among ecological knowledge, awareness, sensitivity, and behavior (Rusmaniah et al., 2026; Morrone et al., 2001).

The main contribution of the present study is therefore not limited to classifying the instrument as valid or invalid. Rather, the Rasch analysis provides detailed evidence regarding how individual items and respondents function within the measurement process.

The ecopedagogy-based ecological intelligence test demonstrates promising psychometric soundness for technical students, while also identifying several areas for further refinement, particularly the review of EB6, the expansion of item difficulty at higher levels, and further examination of the four theoretical dimensions.

CONCLUSION

Using the Rasch measurement model and Winsteps software, this study assessed the psychometric soundness of an ecopedagogy-based ecological intelligence exam for technical students. To ascertain whether the instrument offers meaningful and consistent measurement, the Rasch analysis looked at item fit, item polarity, person and item dependability, separation, item difficulty, person-item targeting, and dimensionality. The findings provide evidence for retaining well-functioning items while identifying items requiring revision, as well as evaluating the instrument's

ability to distinguish students with different levels of ecological intelligence. The study also emphasizes the necessity of evaluating the psychometric quality of an assessment instrument separately from the feasibility and practicality of the WEGAL learning medium. The use of Winsteps-Rasch analysis supports the improvement of the ecological intelligence test and offers a methodological basis for a more rigorous assessment of sustainability-related competences in technical education. Nevertheless, the results are limited to the present sample and educational context and, therefore, future research should involve larger and more heterogeneous samples, analyze each dimension separately, and explore possible item bias for different demographic and educational groups.

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