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Validation of an ethnoscience-based inquiry learning instrument to measure engagement and readiness of pre-service elementary teachers: a Rasch analysis

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ABSTRACT
This study investigates the psychometric properties of a questionnaire designed to assess pre-service elementary school teachers' engagement and readiness within the context of ethnoscience-based inquiry learning. Ethnoscience integrates scientific knowledge with local cultural practices, aiming to enhance scientific literacy and critical thinking. The questionnaire was developed based on six key indicators Cultural Representation (CR), Connectivity with the Environment (CE), Student Engagement (SE), Integration with Other Lessons (IL), Representation of Values (RV), and the Reconstruction of Original Science into Scientific Science (ROSSS). Content validity was established through expert review, and a pilot study was conducted before full implementation. Using Rasch analysis, the instrument's validity and reliability were tested using data from 197 randomly selected pre-service teachers. Findings indicate that female participants showed significantly higher engagement, especially in SE (M = 4.62 vs. 2.83, t = 2.73, p = 0.007) and ROSSS (t = 2.40, p = 0.019). Overall, the questionnaire revealed medium to high levels of readiness. While the instrument demonstrates promising psychometric quality, limitations related to self-report bias, sampling representativeness, and cultural specificity should be considered. This study provides an evidence-based tool to support more inclusive and culturally relevant science education practices.

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Introduction

The integration of ethnoscience into teacher education, particularly for elementary school teachers, is an emerging research area. It seeks to enhance pre-service teachers' readiness to implement inquiry-based learning (IBL) strategies (Adnan et al., 2021; Dewi et al., 2021; Wati et al., 2021).

Ethnoscience incorporates local cultural knowledge into science teaching, providing contexts that help students connect scientific concepts to their cultural backgrounds (Fasasi, 2017; Sotero et al., 2020; Zidny et al., 2021; Zidny & Eilks, 2018). In Indonesia, increased attention is being paid to ethnoscience teaching to enhance cultural relevance in science education.

However, pre-service teachers' readiness to adapt local knowledge into inquiry methods remains low. This readiness involves understanding ethnoscience concepts, implementing inquiry strategies, and developing culturally based pedagogical skills (Cammarata & Cavanagh, 2018; Dewi et al., 2021a; Ertikanto et al., 2017; Kerkhoff & Cloud, 2020; Parmin et al., 2017). A valid and reliable instrument must also be developed to assess this readiness. The Rasch model is suitable in this case, as it can assess instrument validity and reliability and evaluate item difficulty and participant abilities (W. J. Boone & Noltemeyer, 2017; Peeters & Augustine, 2023; Stemler & Naples, 2021; Van Zile-Tamsen, 2017).

This study involves pre-service elementary teachers at the Faculty of Teacher Training and Education (FKIP) of Cenderawasih University, Jayapura, Papua, Indonesia, 74% of whom come from underdeveloped, outermost, and remote areas with limited access to educational facilities. This condition creates a gap in effective learning engagement, particularly in collaboration and the adaptation of culture-based teaching methods. An initial survey revealed that 68% of students struggle with collaboration in multicultural classrooms. This challenge is a significant barrier to improving learning effectiveness in diverse environments.

To overcome this challenge, adaptive and contextual learning strategies are needed. A key factor that can significantly enhance interaction and learning in multicultural classrooms is a sense of belonging within a communal culture. Therefore, educators should develop learning strategies that align with local cultural characteristics to foster greater involvement and readiness among pre-service teachers in implementing ethnoscience-based learning.

Although previous studies have explored the integration of ethnoscience into science education and its impact on students' engagement and critical thinking, few have focused on pre-service elementary school teachers in multicultural contexts. Furthermore, limited research has employed Rasch analysis to validate instruments that measure both engagement and readiness within ethnoscience-based inquiry learning. This study seeks to fill this gap by developing and validating a culturally responsive instrument tailored to the Indonesian context, specifically for pre-service teachers in remote and underdeveloped regions.

Ethnoscience in Education

Ethnoscience, the study of local knowledge systems, is gaining recognition for its potential to make science education culturally relevant and engaging (Dewi et al., 2021a; Samsudin et al., 2021). Connecting students to their cultural heritage while teaching scientific concepts helps deepen their understanding of science. In Indonesia, where cultures and traditions are woven into daily life, integrating ethnoscience into science education is essential. An example of a local knowledge system to be incorporated into classroom learning is the traditional management of *Metroxylon sagu* (sago palm) by the Sentani community (Khusniati et al., 2023; Suprapto et al., 2024; Winarto et al., 2022). As such, pre-service teachers need to understand and integrate local wisdom into the curriculum to create contextually meaningful science lessons.

Past research has shown that combining inquiry-based learning (IBL) and ethnoscience can foster critical thinking, engagement, and cultural awareness among students (Prayogi et al., 2023; Samsudin et al., 2021). Hence, they can improve understanding and retention of scientific concepts. The integration of ethnoscience in physics education has also been shown to significantly enhance cognitive learning outcomes among pre-service teachers (Hikmawati et al., 2022; Wati et al., 2021). These findings underscore the importance of integrating ethnoscience into teacher training programs

in Indonesia, ensuring that pre-service teachers are well-prepared to apply this approach in their classrooms (Dewi et al., 2021a; Hartini et al., 2024; Soemardiawan et al., 2023).

IBL and the Readiness of Pre-Service Elementary School Teachers

IBL encourages students to engage in scientific inquiry by asking questions, conducting experiments, and reflecting on their findings. When paired with ethnoscience, IBL helps students link their cultural knowledge to scientific principles, fostering a deeper, more integrated understanding. Pre-service teachers who participated in an ethnoscience-based digital learning program showed significant improvements in critical thinking skills (Prayogi et al., 2023). Project-based learning models that incorporate ethnoscience have also been found to foster creativity, collaboration, and problem-solving skills in students (Rahayu et al., 2023) as they contextualize modern scientific inquiry, creating a more engaging and culturally relevant learning environment.

Preparing pre-service teachers to incorporate ethnoscience through IBL is essential for ensuring science education is both culturally relevant and pedagogically effective (Ardianti et al., 2023; Kusumastuti, 2024). Teacher readiness to implement ethnoscience has also been associated with their mastery of pedagogical frameworks such as Technological Pedagogical Content Knowledge (TPACK). In this study, however, TPACK is not used as a central analytical framework, but referenced to highlight the role of pedagogical and technological competencies in supporting culturally responsive teaching. Pre-service teachers who are experienced in using technology to enhance ethnoscience instruction are better prepared to design and deliver culturally responsive science lessons.

Using the Rasch Model in Assessing Pre-Service Teachers' Readiness

The Rasch model, developed by Georg Rasch in the 1960s as part of Item Response Theory (IRT) (Azizan et al., 2020; Hairida et al., 2023; Linacre, 2022; Sukarelawan et al., 2021), has become a fundamental tool in psychometric analysis to evaluate the properties of assessment instruments. The one-parameter logistic (1PL) model focuses on the relationship between individual ability and item difficulty, offering a robust framework for assessing the validity and reliability of an instrument. It is based on the principle that individuals with higher ability are more likely to respond correctly, regardless of the item. This allows researchers to measure underlying constructs precisely, such as teacher readiness (Abdul et al., 2022; Fitria et al., 2024; Ismail et al., 2024; Oktaviyanthi et al., 2024; Sumintono & Widhiarso, 2015; Zafrullah et al., 2023). The model provides a probabilistic analysis of an individual's likelihood of responding correctly to an item based on their ability and the item's difficulty (Azizan et al., 2020; Bond et al., 2020; Fisher, 2007; Omarov et al., 2023; Taber, 2018). As a unidimensional model, it asserts that easier questions are more likely to be answered correctly, and individuals with higher abilities are more likely to outperform those with lower abilities on the same questions (Al Ali & Shehab, 2020; Ismail et al., 2025). This approach enables educational researchers to measure readiness, competence, or skill level with greater precision (Browne & Cano, 2019; Khine, 2020). In this study, the Rasch model was used to assess pre-service teachers' readiness to integrate ethnoscience and IBL into science education. By analyzing item difficulty and individual ability, this method provides insights into the competencies and attitudes of future educators.

The six indicators, Cultural Representation (CR), Connectivity with the Environment (CE), Student Engagement (SE), Integration with Other Lessons (IL), Representation of Values (RV), and Reconstruction of Original Science into Scientific Science (ROSSS), were developed through a hybrid approach combining deductive review of prior literature and expert consultation. Foundational works

on culturally responsive teaching, ethnoscience, and inquiry-based learning (Parmin et al., 2017; Zidny & Eilks, 2018) were used to construct these dimensions, which were then refined through expert validation and pilot testing

Previous research has shown the effectiveness of the Rasch model in validating instruments related to teacher readiness and learning outcomes (Prayogi et al., 2023). However, this study offers a novel application by focusing on the underexplored area of teacher readiness to incorporate ethnoscience into science education in culturally diverse classrooms. Furthermore, while ethnoscience and IBL have been widely studied, research on pre-service teachers' readiness to implement these approaches is limited. By applying the Rasch analysis, this study contributes to a deeper understanding of culturally responsive teaching and offers insights into how teacher education programs can better equip educators to integrate indigenous knowledge into their curricula (Bond & Fox, 2015; Fisher Jr, 1991; Hrnjicic & Alihodžic, 2024).

Research Questions

Using the Rasch model, this study aims to assess the readiness of pre-service teachers to integrate ethnoscience through IBL, addressing the following :

1. What is the evidence of the questionnaire's reliability and validity to assess the engagement and readiness of pre-service teachers to integrate ethnoscience and IBL in science education?
2. How engaged and ready are the pre-service teachers in integrating ethnoscience and IBL in science education?
3. What are the results of the scale functioning assessment of the questionnaire developed in this study?
4. Is there evidence of gender-related differential item functioning (DIF) between female and male pre-service elementary school teachers?

Methods

Participants

This study adopts a quantitative approach using a survey instrument designed to assess teacher readiness of pre-service teachers in integrating ethnoscience and IBL. The instrument includes items that measure key competencies, such as pre-service teachers' understanding of ethnoscience concepts, their ability to apply inquiry-based methods, and their readiness to incorporate local knowledge into science teaching. A total of 197 pre-service elementary school teachers from the Faculty of Education at Cenderawasih University in Papua Province, Indonesia, were selected via a simple random sampling technique to ensure equal probability of participation among the target population. Before completing the questionnaire, respondents provided their consent to ensure voluntary participation, and their anonymity was guaranteed to protect their privacy. Data collection was conducted through an online survey via Google Forms, which streamlined the process of distributing and collecting responses efficiently. The demographic profile of the participants is provided in Table 1.

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Table 1

Demographic profiles of participants (N = 197)

Variable	Frequency	%
Male	42	21.32%
Female	155	78.68%
Total	197	100%

Table 1 shows that out of the total participants, 42 (21.32%) were male, and 155 (78.68%) were female. The mean value for gender distribution was 1.99, with a standard deviation of 2.23. Since there were more female than male participants, gender bias analysis was performed using the Rasch model.
Instruments and scoring

The questionnaire focuses on the engagement and readiness of pre-service elementary school teachers in integrating ethnoscience-based inquiry learning into science education. It includes six indicators: (i) Cultural Representation (CR), (ii) Connectivity with the Environment (CE), (iii) Student Engagement (SE), (iv) Integration with Other Lessons (IL), (v) Representation of Values (RV), and (vi) the Reconstruction of Original Science into Scientific Science (ROSSS). These indicators were developed specifically for this study, grounded in the theoretical framework of ethnoscience-based inquiry learning and aligned with prior literature on culturally responsive pedagogy and inquiry-based education. The operational definitions were refined through expert judgment and pilot testing before distribution. Two ethnoscience learning experts confirmed the content validity of the test, while construct validity was verified through Rasch analysis. Gender-related data was also collected for the bias analysis. The questionnaire used a five-point rating scale: 1 for Strongly Disagree (SD), 2 for Disagree (D), 3 for Neutral (N), 4 for Agree (A), and 5 for Strongly Agree (SA). Respondents were assigned a score based on their selected answer

Data Analysis

To enhance the interpretability and clarity of the Rasch model findings, key fit statistics are summarized in Table 2. These indicators include reliability coefficients, separation indices, and item fit measures (Infit and Outfit Mean Squares), all of which are critical for evaluating the psychometric properties of the instrument. The summary highlights the extent to which the instrument demonstrates consistency, discrimination, and fairness across participants and items.

Table 2

Summary of Rasch model fit statistics

Parameter	Value/Range	Interpretation
Person Reliability	0.86	High consistency of participant response
Item Reliability	0.89	High reliability across items
Person Separation Index	2.43	Good ability stratification
Item Separation Index	2.65	Items well-distributed by difficulty
Infit MNSQ (acceptable range)	0.74 – 1.26	Within acceptable range (0.5 – 1.5)
Outfit MNSQ (acceptable range)	0.71 – 1.32	Within acceptable range
DIF (Gender)	No significant DIF	Items are not biased across gender

Table 2 presents the summary of Rasch model fit statistics. All values fall within acceptable ranges, indicating that the instrument has strong psychometric properties, including internal consistency, item functioning, and lack of gender-based item bias.

To confirm the statistical validity of the data analysis, several thresholds must be considered in interpreting the results. Reliability criteria are assessed using various indicators, including the Rasch model parameters for individual ability and item reliability (Fisher, 2007; Linacre, 2021; Linacre, 2000) and Cronbach's alpha (α) (Taber, 2018). For reliability to be considered acceptable, the values for individual reliability, item reliability, and Cronbach's alpha (α) must all exceed 0.67 (Fisher, 2007; Linacre, 2021; Taber, 2018).

The instrument's fit was evaluated using item and person fit statistics from Rasch analysis, particularly focusing on Infit and Outfit mean square (MNSQ) values. Validity is considered acceptable when MNSQ values range between 0.5 and 1.5, with values up to 1.6 still considered tolerable (Andrich, 2018; W. Boone et al., 2014; W. J. Boone, 2016). The optimal fit criterion is ideally close to 1.00 logit. In this study, Z-standardized (ZSTD) values were not reported, as the sample size (N = 197) was below the recommended threshold where such values become more stable and interpretable. Instead, interpretation focused on MNSQ values for assessing item fit quality.

Meanwhile, the item separation analyses show that the inductive reasoning tests include a range of items with varying levels of difficulty (Boone et al., 2014). The separation values should exceed 2 logits, as higher separation indices are associated with improved test quality (Boone et al., 2014; Fischl & Fisher, 2007; Planinic et al., 2019). Lastly, Differential Item Functionality (DIF) analyses were employed to assess participants' responses by subgroup for each test item (Bond & Fox, 2015), evaluated through probability of significance ($p < 0.05$) and DIF contrast. DIF contrast was categorized into three levels: negligible, slight to moderate ($|DIF| \geq 0.43$ logits), and moderate to large ($|DIF| \geq 0.64$ logits) (Zwick et al., 1999).

Findings

Evidence of the Questionnaire's reliability and validity (RQ1)

Table 3 summarizes the Rasch parameters, offering a comprehensive analysis of the psychometric properties of the questionnaire on the engagement and readiness of the pre-service teachers in integrating ethnoscience and IBL into science education. The analysis is disaggregated into six indicators: CR, CE, SE, IL, RV, and ROSSS. Each indicator contains five items, bringing the total number of items in the questionnaire to 30. The distribution of items across indicators is crucial, as it influences the reliability and precision of measurements within each indicator, ultimately affecting the overall effectiveness of the test.

Table 3

Rasch parameters for the questionnaire on pre-service elementary school teachers' engagement and readiness in integrating ethnoscience and ibl into science education

Psychometric attribute	Indicator						All Indicators
	CR	CE	SE	IL	RV	ROSSS	
Number of items	5	5	5	5	5	5	30
Item reliability	0.93	0.73	0.68	0.91	0.29	0.82	0.94
Person reliability	0.80	0.78	0.82	0.85	0.84	0.88	0.92
Cronbach's alpha (α)	0.90	0.85	0.94	0.89	0.93	0.94	0.98
Mean							
Item outfit MNSQ	0.99	1.05	0.79	0.93	0.95	0.86	1.07
Item infit MNSQ	1.02	1.00	1.01	0.99	0.99	0.98	1.01
Person outfit MNSQ	0.99	1.05	0.74	0.93	0.92	0.86	1.08
Person infit MNSQ	1.00	1.05	0.75	0.93	0.92	0.86	1.10
Item separation	3.67	1.66	1.45	3.20	0.65	2.16	3.91
Person separation	1.99	1.87	2.14	2.35	2.30	2.71	3.29

Unidimensionality						
Raw variance by measure	61.6%	50.1%	66.4%	59.4%	66.3%	68.9%
Unexplained variance first contrast	1.54	1.49	1.62	1.42	1.40	1.53

Based on the table analyzing the Rasch validity and reliability parameters, and in relation to the article's focus on the impact of IBL and ethnoscience on engagement and readiness, several key factors need to be considered. The reliability values of the six main indicators: Cultural Representation (CR), Connectivity with the Environment (CE), Student Engagement (SE), Integration with Other Lessons (IL), Representation of Values (RV), and Reconstruction of Original Science into Scientific Science (ROSSS) are all above the threshold of 0.67, indicating that the instrument is reliable. The highest values were observed in the IL indicator (0.91) and ROSSS (0.82).

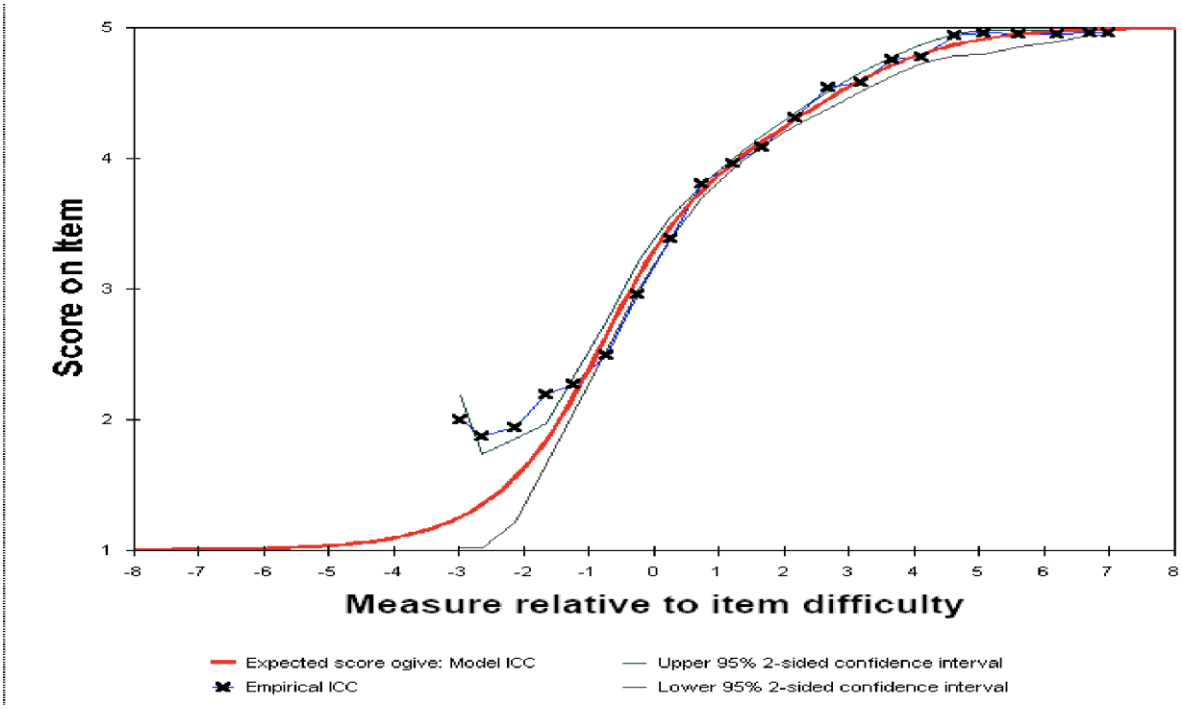
Meanwhile, the MNSQ item-fit and MNSQ infit on all indicators show values close to the ideal number of 1.0, which indicates the suitability of the items to the Rasch model. The individual and item separation values exceed the threshold of 2 for several indicators, particularly ROSSS (person separation: 3.29; item separation: 3.91), demonstrating the instrument's ability to distinguish between participants with varying ability levels. Overall, this instrument is reliable for evaluating the impact of ethnoscience and IBL on the engagement and readiness of pre-service elementary school teachers. Construct validity is further supported by unidimensionality, as the raw variance explained by the measure exceeds 40% across all indicators.

To verify that the data in this study aligns with the Rasch model probability, an Item Characteristic Curve (ICC) analysis was conducted, as shown in Figure 1. The figure illustrates the alignment between the empirical data points (marked with stars) and the expected score curve (red line). The close alignment of the empirical data points with the theoretical red curve indicates a good fit for the Rasch model, confirming the consistency of item performance across different ability levels. The blue line, representing the 95% confidence interval, further confirms the reliability of the results, showing that the observed scores fall within the expected range of variability. This alignment validates the effectiveness of the items in measuring the abilities within the Rasch framework.

The ICC graph (Figure 1) and item discrimination estimation using the Rasch model confirm that the instrument for ethnoscience-based inquiry learning is valid and reliable in measuring the engagement and readiness of pre-service elementary school teachers. The alignment between the model prediction curve (red line) and empirical data (black crosses) indicates that the items accurately map difficulty levels and effectively differentiate students based on their abilities. This study confirms that ethnoscience-based inquiry learning positively impacts engagement and readiness. The Rasch analysis further supports the instrument's effectiveness in evaluating the influence of this learning approach.

Figure 1

ICC Plot



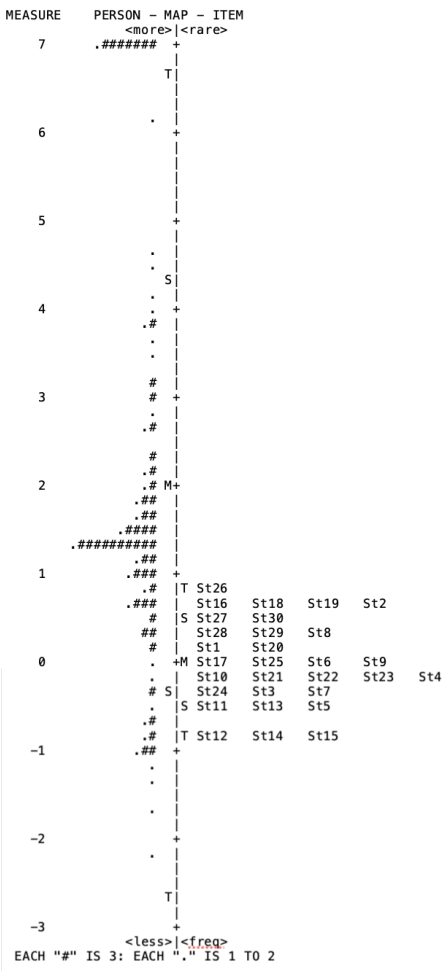
Engagement and Readiness of the Pre-Service Teachers to Integrate Ethnoscience and IBL in Science Education (RQ2)

The Wright Map (Figure 2) visualizes the alignment between participant ability and item difficulty. Most participants are clustered at higher ability logits (approximately 4–7), indicating strong engagement and readiness to integrate ethnoscience-based IBL in science education. This pattern also suggests a potential *ceiling effect*, meaning the current item set may be less sensitive in differentiating respondents with very high engagement/readiness. Overall, the map indicates that items of medium to great difficulty were answered well by most participants, reflecting preparedness to integrate ethnoscience-based IBL and to address more complex academic challenges. Future iterations should expand the difficulty range by adding more challenging items to better discriminate among top performers and improve measurement precision at the upper end of the construct.

Items of medium to great difficulty are answered well by the participants, suggesting that they are prepared to tackle more complex academic challenges when applying ethnoscience in the science curriculum. High engagement and readiness of pre-service teachers are crucial for the successful integration of ethnoscience into science learning. In this study, the Wright Map demonstrates that ethnoscience-based inquiry learning can boost the engagement and readiness of pre-service elementary school teachers to implement this approach in science education.

Figure 2

The wright map



Rating Scale Category Functioning (RQ3)

The 5-point rating scale in the questionnaire is designed to assess how well respondents understand the scale. The category probability curve in Figure 3 illustrates the performance of this 5-point scale within the questionnaire.

The rating scale graph in Figure 3 displays the probability distribution of participants' responses based on their ability and the difficulty level of the items. The response categories range from 1 (strongly disagree) to 5 (strongly agree). On the left side of the graph, students with lower abilities are more likely to select Category 1, suggesting they are less engaged or less prepared for ethnoscience-based inquiry learning. Around logit 0, where students' abilities align with the difficulty level of the items, Category 3 (neutral) has the highest probability, indicating that students with intermediate engagement and readiness tend to provide neutral responses. On the right side of the graph, students with higher ability are more likely to choose Category 5, reflecting greater engagement and readiness for ethnoscience-based inquiry learning.

The graph offers valuable insights into how the questionnaire effectively maps the engagement and readiness of pre-service elementary school teachers. Those with lower engagement provided lower scores, while those who were more prepared and engaged tended to give higher scores. This distribution of responses shows that the instrument successfully differentiates participants based on their engagement levels, from the least engaged to the most prepared. This

confirms the instrument's effectiveness in measuring the impact of ethnoscience-based inquiry learning.

Figure 3

Probability distribution

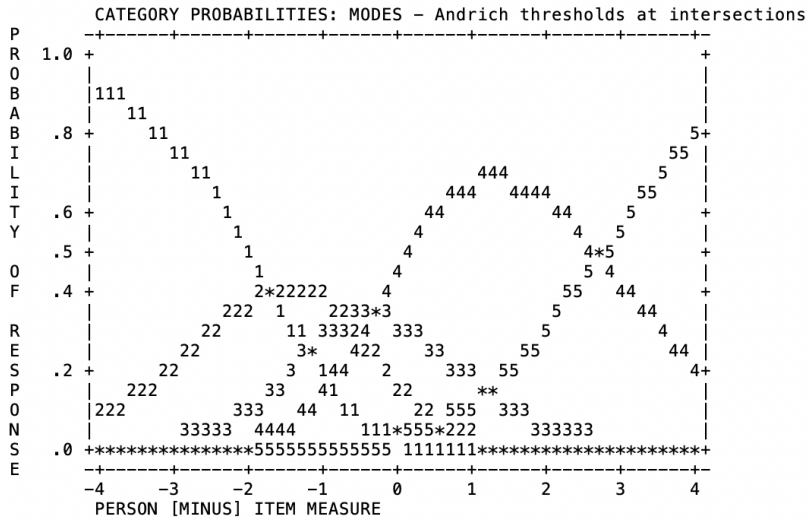


Table 3 presents the analysis of the rating scale functioning based on the five response categories used in the questionnaire. It shows the number of respondents who selected each category, along with the average observation value, Infit MNSQ, Outfit MNSQ, and Andrich Threshold. These metrics are crucial for evaluating the effectiveness of the instrument in differentiating the levels of student engagement and readiness.

Table 3

Rating scale category functioning

Category label	Observed		Observed	INFIT	OUTFIT	Andrich
	Count	%	average	MNSQ	MNSQ	Threshold
1	170	3	-0.36	2.08	3.56	NONE
2	391	7	-0.75*	0.66	0.64	−1.68
3	767	13	0.29	0.91	0.95	−0.70
4	2658	45	1.35	0.66	0.66	-0.34
5	1868	32	2.76	1.10	0.99	2.72

Based on the rating scale analysis in Table 3, the assessment of the scale functioning for measuring engagement and readiness reveals notable variations across response categories. Category 1, chosen by only 3% of respondents, had an Infit MNSQ value of 2.08 and an Outfit MNSQ value of 3.56, suggesting a mismatch with the Rasch model. The high MNSQ values suggest that responses in this category were erratic or inconsistent with the model's expectations, indicating that this category does not function optimally in the instrument. In contrast, Categories 2, 3, and 4, selected by the majority of respondents (7%, 13%, and 45%, respectively), displayed consistent and favorable Infit and Outfit MNSQ values, demonstrating the instrument's effectiveness in accurately measuring the pre-service teachers' engagement in these categories. Category 5, while still within the acceptable range

with an Infit MNSQ value of 1.10, showed a slight deviation from the other categories, suggesting some variability in how the most engaged participants were assessed.

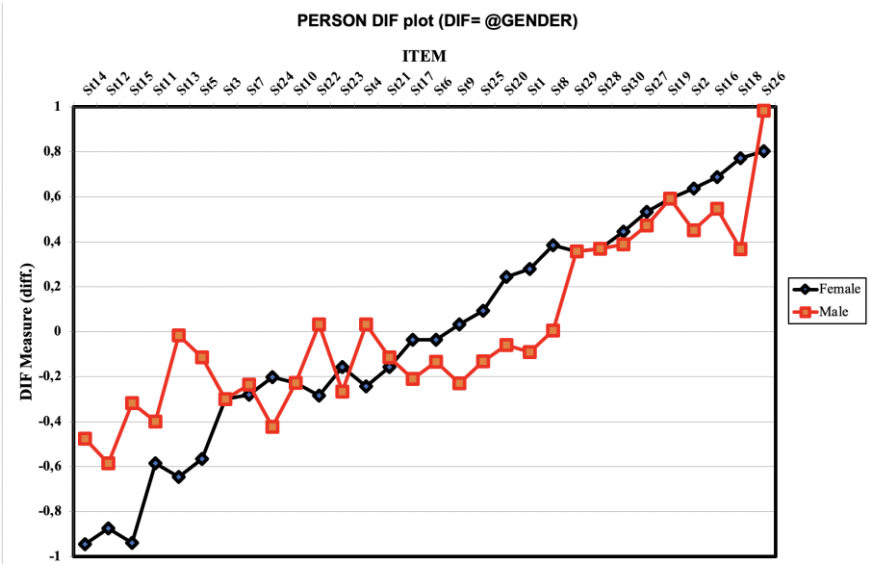
Meanwhile, the Andrich Threshold values show a fairly large difference between Categories 1 and 2 (-1.68 logit) and between Categories 4 and 5 (2.72 logit), indicating a clear distinction between low and high levels of engagement. The difference between categories 3 and 4 (-0.34 logit) is smaller, indicating that the pre-service teachers may have little difficulty in distinguishing between medium and high levels of engagement. This suggests that the instrument has successfully measured engagement and readiness well, although further review is needed to improve Categories 1 and 5 to better fit the desired measurement model.

Gender-based DIF analysis (RQ4)

DIF analysis was conducted to assess whether the items showed gender bias (female vs. male) that could affect the participants' engagement and readiness. This analysis identifies item-level bias based on participant subgroups or background variables Ismail et al., 2024; Soeharto, 2021; Soeharto et al., 2024; Soeharto & Csapó, 2022; Testa et al., 2020). The DIF results in this study were calculated using two criteria: significant probability ($p < 0.05$) and DIF contrast. Three DIF contrast classifications were used (Zwick et al., 1999): negligible ($|DIF| < 0.43$ logits), mild to moderate ($|DIF| \geq 0.43$ logits), and moderate to large ($|DIF| \geq 0.64$ logits). Figure 4 shows the DIF measures based on the significant probabilities of some items in this study.

Figure 4

Gender-based DIF graph from indicated biased items



The DIF graph (Figure 4) based on gender shows no significant differences between male and female responses to most of the items in the questionnaire, indicating that the instrument measures engagement and readiness fairly for both groups. However, a few items, such as St16, St18, and particularly St26, show notable differences, with male participants tending to provide higher responses than their female counterparts. This suggests that the male pre-service teachers might feel more engaged or prepared in certain aspects of ethnoscience-based inquiry learning. These results highlight the effectiveness of ethnoscience-based inquiry learning while also emphasizing the importance of addressing gender differences to ensure equitable impact for all participants.

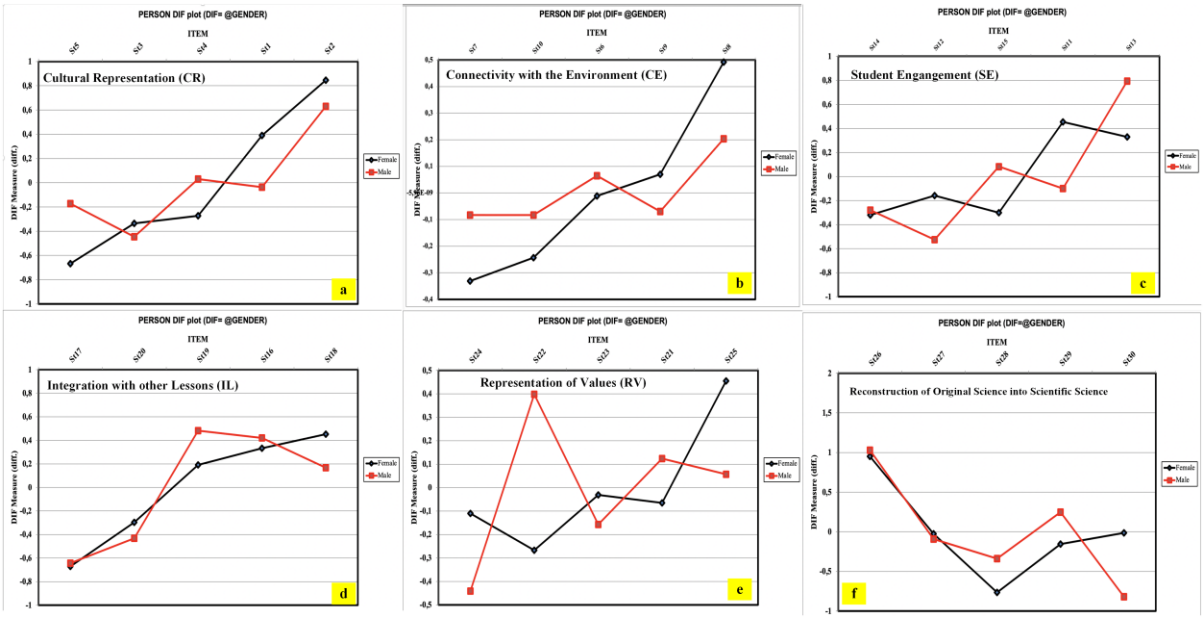
Figure 5 presents a continuation of the DIF analysis based on gender in Figure 4. While the previous graph highlighted overall gender differences in responses, this one breaks down the analysis

into six key indicators: Cultural Representation (CR), Connectivity with the Environment (CE), Student Engagement (SE), Integration with Other Lessons (IL), Representation of Values (RV), and Reconstruction of Original Science into Scientific Science (ROSSS). This detailed analysis provides deeper insight into how gender differences manifest across each aspect of engagement and readiness, helping to understand variations in responses based on specific questionnaire items.

In some indicators, such as CR and CE, male participants gave higher responses, indicating greater engagement with materials related to the environment and cultural representations. In contrast, female participants showed higher responses in the RV and ROSS indicators, suggesting a stronger focus on values and the integration of science. Overall, these findings highlight significant gender differences in how male and female pre-service teachers respond to materials in ethnoscience-based inquiry learning. To enhance engagement, a more inclusive and gender-sensitive approach is necessary. Adjustments in how the materials are presented and the use of diverse learning methods can help ensure that both genders are equally engaged and benefit from the learning process.

Figure 5

Gender-based DIF graph per indicator



These findings are important for curriculum developers and educators in designing more effective and equitable learning strategies for all students. Table 4 presents a comparative analysis of the average responses between males and females across six key indicators of ethnoscience inquiry-based learning: Cultural Representation (CR), Connectivity with the Environment (CE), Student Engagement (SE), Integration with Other Lessons (IL), Representation of Values (RV), and Reconstruction of Original Science into Scientific Science (ROSSS). This analysis evaluates potential significant differences between male and female pre-service teachers' engagement and readiness for ethnoscience-based inquiry learning using t-tests and probability as indicators of statistical significance.

Table 4

T-tests of the indicators of the questionnaire on the engagement and readiness of pre-service elementary school teachers in implementing ethnoscience-based inquiry learning

Indicator	Male	Female	t	Prob.
	Mean (SD)	Mean (SD)		
All	1.34 (2.17)	2.16 (2.21)	2.05	0.044
CR	1.70 (2.31)	2.42 (2.01)	1.66	0.103
CE	1.54 (2.21)	2.22 (1.91)	1.63	0.109
SE	2.83 (3.45)	4.62 (2.81)	2.79	0.007
IL	1.41 (2.55)	2.15 (2.37)	1.56	0.123
RV	2.41 (2.95)	3.48 (2.62)	1.96	0.055
ROSSS	1.32 (2.88)	2.65 (3.13)	2.40	0.019

Based on Table 4, the analysis of the average differences between male and female pre-service teachers across the six main indicators reveals significant differences. In the Student Engagement (SE) indicator, female pre-service teachers are significantly more engaged than men, with an average value of 4.62 for women and 2.83 for men, a t-value of 2.79, and a probability of 0.007. Additionally, the Reconstruction of Original Science into Scientific Science (ROSSS) indicator shows a significant difference, with female pre-service teachers being more prepared to reconstruct original science into formal science, reflected by a t-value of 2.40 and a probability of 0.019. This suggests that women tend to be more prepared and engaged in key aspects of inquiry-based learning.

On the other hand, indicators such as Cultural Representation (CR), Connectivity with the Environment (CE), Integration with Other Lessons (IL), and Representation of Values (RV) showed differences in the averages between male and female pre-service teachers, but these differences were not statistically significant. This means that although the female participants tend to give higher responses in these indicators, the differences are not large enough to be considered significant. These results suggest that ethnoscience-based inquiry learning is effective overall, but there are differences in engagement and readiness between male and female pre-service teachers, particularly in student engagement and the reconstruction of science. A more inclusive approach may be necessary to ensure that both genders benefit equally from this learning.

Discussion

The results of the Rasch model analysis of the questionnaire assessing the involvement and readiness of pre-service elementary school teachers in ethnoscience-based inquiry learning showed excellent reliability and validity. The item reliability scores exceeded the threshold of 0.67, with the Other Lessons (IL) and Reconstruction of Original Science into Scientific Science (ROSSS) instruments demonstrating the highest reliability (Muliani et al., 2022). The separation of items and individuals also showed that this instrument could differentiate respondents based on their engagement and readiness, with the ROSSS having the highest separation value (Elfrida et al., 2023). These findings are supported by other studies showing that integrating ethnoscience and IBL can significantly increase scientific engagement and understanding (Prayogi et al., 2023; Wati et al., 2021). This approach has also been shown to strengthen critical and creative thinking skills (Rahayu et al., 2023). Furthermore, this study highlights the importance of using valid and reliable measuring instruments to assess engagement in ethnoscience (Murwitaningsih & Maesaroh, 2023). Overall, this evidence supports the effectiveness of the instruments in assessing the impact of ethnoscience on education.

The engagement and readiness of pre-service elementary school teachers indicate that integrating ethnoscience can enhance critical thinking skills and scientific literacy. The high engagement also reflects the participants' readiness to connect scientific concepts with local cultural contexts ((Soemardiawan et al., 2023). This finding aligns with previous studies suggesting that

ethnoscience teaching materials encourage students to participate more actively in scientific activities, which in turn enhances understanding and retention of concepts (Wati et al., 2021). In addition, Prayogi et al., (2023) found that the integration of ethnoscience with inquiry learning on a digital platform improves the critical thinking skills of pre-service teachers. This readiness is crucial to incorporating local and cultural knowledge into the curriculum to foster a more inclusive and culturally relevant learning environment (Rahayu et al., 2023).

The Rating Scale Category Functioning analysis of the 5-point Likert scale used to assess teacher engagement and preparedness showed that the scale worked well overall. However, there were challenges with the low engagement category. The Rasch analysis revealed that Category 1 had a high Outfit MNSQ (3.56), indicating inconsistencies in responses from participants with low engagement. On the other hand, the other categories functioned well. There was a large logit gap between Categories 1 and 2 (−1.68 logit), but the gap between Categories 3 and 4 was smaller (−0.34 logit), suggesting that respondents could more easily distinguish higher levels of readiness (Budiarti et al., 2022). This is in line with research showing that ethnoscience-based teaching, by connecting science material to local cultural contexts, increases engagement and understanding (Rahayu et al., 2023; Wati et al., 2021). However, refinement of the scale is still needed for the extreme categories.

This study has shown that the integration of ethnoscience into inquiry-based learning significantly enhances the readiness and engagement of pre-service elementary school teachers, with gender differences playing an important role. The Differential Item Functioning (DIF) analysis revealed that male and female participants responded differently to certain aspects of ethnoscience-based inquiry learning. For example, female pre-service teachers generally demonstrated higher engagement. This aligns with previous studies' findings that women often exhibit greater motivation and engagement in inquiry-based environments (Adams et al., 2022; Adams & August, 2010; Adams et al., 2020; Sharoni et al., 2022). Past studies have also shown that ethnoscience-based inquiry learning allows students to connect scientific concepts with their cultural backgrounds, thereby enriching the learning experience (Pamudiah & Setiawan, 2023; Prayogi et al., 2023).

Regarding gender, DIF analysis also identified items such as St16, St18, and especially St26, which indicated that male pre-service teachers tended to give higher responses compared to female students. This suggests that male pre-service teachers may feel more prepared in some aspects of ethnoscience-based inquiry learning, which suggests the need for a more inclusive approach in designing ethnoscience-based inquiry learning by considering gender differences (Fahrudin et al., 2023; Manishimwe et al., 2022). Overall, the Rasch analysis of this study revealed that the integration of ethnoscience in inquiry-based learning had a significant positive impact on engagement and readiness. The instrument used was found to be valid and reliable in measuring the readiness of pre-service teachers, with an effective 5-point Likert scale. However, improvements are needed in the low-engagement category (Budiarti et al., 2022). This study also found that ethnoscience integration can improve the understanding and critical thinking skills of pre-service teachers by connecting scientific concepts with local culture (Soemardiawan et al., 2023). Finally, the DIF analysis revealed gender differences in engagement and readiness. Female pre-service teachers showed higher engagement, while male students tended to be more prepared in certain aspects (Adams et al., 2022; Prayogi et al., 2023).

Conclusion and Implications

Conclusion

This study emphasizes the importance of integrating ethnoscience into inquiry-based learning (IBL) for pre-service elementary school teachers, aligning with the research objective to evaluate their engagement and readiness using a validated instrument. The Rasch model analysis confirms the instrument's validity and reliability in measuring both constructs. Among the six indicators, Integration with Other Lessons (IL) and Reconstruction of Original Science into Scientific Science

(ROSSS) yielded the highest item reliability, supporting the instrument's capacity to distinguish different engagement levels. This finding addresses the research question concerning the effectiveness of an ethnoscience-based IBL model in fostering engagement and readiness. Furthermore, the alignment with previous studies reinforces that this pedagogical approach enhances scientific reasoning and cultural contextualization. The five-point rating scale was deemed effective, though improvements are needed in the lower engagement category. Gender-based DIF analysis revealed differences in engagement and readiness, but overall, the ethnoscience-IBL model proved beneficial across genders, contributing to inclusive science teacher preparation.

Implication

This study provides several important theoretical, methodological, practical, and policy implications. Theoretically, the findings strengthen the conceptual foundation of ethnoscience-based inquiry learning by empirically validating six core dimensions: Cultural Representation, Connectivity with the Environment, Student Engagement, Integration with Other Lessons, Representation of Values, and Reconstruction of Original Science into Scientific Science as coherent components of teacher engagement and readiness. The strong Rasch model fit, high reliability indices, and evidence of unidimensionality confirm that readiness to integrate ethnoscience within inquiry-based learning can be measured as a stable latent construct. Notably, the high reliability and separation values in the ROSSS and IL indicators highlight the central role of epistemological transformation, particularly the ability to reconstruct indigenous knowledge into formal scientific understanding, in shaping teacher preparedness. This suggests that culturally responsive science education requires more than contextual adaptation; it requires the systematic bridging of knowledge systems.

Methodologically, this study demonstrates the robustness of the Rasch model for validating culturally grounded educational instruments. The acceptable item and person reliability values, appropriate MNSQ fit statistics, and absence of substantial gender-based DIF indicate that the instrument functions consistently and fairly across groups. However, the clustering of participants at higher logit levels suggests a potential ceiling effect, indicating the need to develop more challenging items to improve discrimination among highly engaged respondents. Additionally, the misfit observed in the lowest response category of the rating scale implies that refinement of extreme categories may enhance measurement precision. These findings guide future instrument development in culturally responsive education research.

Practically, the results have direct implications for pre-service teacher education programs, particularly in multicultural and remote contexts. The high levels of engagement and readiness observed suggest that integrating ethnoscience within inquiry-based frameworks can effectively prepare future teachers to design culturally relevant science instruction. Teacher education curricula should therefore systematically embed ethnoscience principles into pedagogical training, emphasizing cross-disciplinary integration, inquiry facilitation, and the reconstruction of local knowledge into scientific explanations. The observed gender differences particularly the higher engagement and readiness among female pre-service teachers in Student Engagement and ROSSS also indicate the importance of adopting inclusive and gender-sensitive instructional approaches to ensure equitable development of competencies.

From a policy perspective, the validated instrument offers an evidence-based tool that can support institutional and national efforts to promote culturally responsive science education. Policymakers may utilize this instrument to monitor teacher readiness, evaluate professional development initiatives, and strengthen curriculum reforms that integrate indigenous knowledge into formal science education. In contexts such as Papua and other remote regions, where cultural

diversity is rich but educational access is uneven, structured support systems and targeted training programs are essential to translate readiness into effective classroom practice.

Overall, this study implies that ethnoscience-based inquiry learning is both pedagogically meaningful and psychometrically measurable. By providing a validated instrument and empirical evidence of engagement and readiness, this research contributes to the advancement of inclusive, culturally sustainable, and scientifically rigorous teacher education.

Limitation

This study has several limitations. First, the relatively small sample size may limit the generalizability of the findings to a broader population of pre-service elementary school teachers. Second, participants' cultural backgrounds and prior experiences may have influenced their responses, suggesting the need for further research using more diverse samples and settings. Third, although the Rasch-based instrument demonstrated acceptable reliability and validity, refinements may still be needed, particularly for the lowest response category, to improve measurement consistency. In addition, the Wright Map results show that many respondents were clustered at the upper end of the logit scale (approximately 4–7), indicating a potential *ceiling effect*. This suggests that the current item set may be less sensitive in differentiating respondents with very high engagement/readiness. Future iterations should consider adding more challenging items to expand the difficulty range and improve discrimination among highly engaged respondents.

Suggestion

1. Enhancing Ethnoscience Integration in IBL: The integration of ethnoscience into Inquiry-Based Learning (IBL) should be further developed in pre-service elementary teacher education.
2. Targeted Training for Lecturers and Students. Specialized training is necessary for both lecturers and students to develop effective strategies for integrating ethnoscience into IBL.
3. Refinement of Engagement Measurement: The low engagement category in the rating scale should be refined to improve the accuracy of engagement measurement.
4. Optimization through Digital Media and Technology. The incorporation of digital media and technology can further support the exploration of ethnoscience concepts within an inquiry-based learning framework.

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Declaration of Interest

The author(s) declare that there is no conflict of interest regarding the research, authorship, and/or publication of this article.

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Appendix

Full Instrument: Ethnoscience-Based Inquiry Learning Questionnaire

Respondents answered using a 5-point Likert scale: SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree

Cultural Representation (CR)

Code	Item
CR1	The subject matter I design always takes into account the local culture of the students.
CR2	I am able to identify elements of local culture that could be integrated into teaching.
CR3	My teaching materials describe cultural values relevant to students' daily lives.
CR4	I feel it is important to include local wisdom in every subject matter.
CR5	I can design learning activities that help students understand their own culture.

Connectivity with the Environment (CE)

Code	Item
CE1	I can relate subject matter to the conditions of the student's environment.
CE2	The material I design pays attention to environmental conservation.
CE3	I am able to relate science lessons to ecological problems in society.
CE4	My learning emphasizes the importance of maintaining environmental balance.
CE5	I often use examples from the surrounding environment to explain scientific concepts.

Student Engagement (SE)

Code	Item
SE1	I always try to involve students in every stage of learning.
SE2	I use methods that encourage students to actively participate in class.
SE3	Students are often invited to discuss and share their views during lessons.
SE4	I design activities that encourage students to collaborate in completing assignments.
SE5	I organize classroom tasks that enhance peer-to-peer engagement.

Integration with Other Lessons (IL)

Code	Item
IL1	I am able to relate my subject matter to other relevant lessons.
IL2	I design lessons that integrate multiple disciplines.
IL3	The material I teach is often connected with concepts from other subjects.
IL4	I structure learning that links science to other fields.
IL5	I believe it is important to integrate cross-disciplinary content in science teaching.

Representation of Values (RV)

Code	Item
RV1	My teaching materials reflect local values important to students.
RV2	I insert local wisdom values into every material I teach.
RV3	I understand which local values should be instilled through teaching.
RV4	I use materials that highlight the importance of local cultural values.
RV5	I ensure that local values are consistently embedded in the topics I teach.

Reconstruction of Original Science into Scientific Science (ROSSS)

Code	Item
ROSSS1	I am able to translate local scientific concepts into formal scientific learning.
ROSSS 2	I feel prepared to teach traditional science in a modern scientific context.
ROSSS 3	I can relate traditional knowledge to principles of modern science.
ROSSS 4	I try to explain local science concepts using appropriate scientific approaches.
ROSSS 5	I often adapt traditional scientific ideas into formal educational contexts.