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Developing and validating Technology and Engineering Literacy Instrument (TELI) for pre-service science teachers

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Abstract. Technology and engineering literacy (TEL) is an essential competency for pre-service science teachers in meeting the demands of the modern workforce. However, existing TEL assessment instruments are often insufficiently aligned with developing country contexts. This study aimed to develop and validate a contextual Technology and Engineering Literacy Instrument (TELI) for pre-service science teachers. The instrument was developed based on the National Assessment of Educational Progress (NAEP) TEL framework and incorporated scenario-based assessments reflecting real-world problems. A psychometric instrument development and validation design was employed. Content validity was evaluated by five experts, and field testing involved 132 pre-service science teachers in Riau Province, Indonesia. Rasch model analysis was used to examine construct validity, item fit, and reliability. The results demonstrated high content validity and acceptable construct validity, item fit, and reliability. These findings indicate that TELI is a valid, reliable, and contextually relevant instrument for assessing TEL competencies. The study concludes that TELI can support authentic assessment in science teacher education and provide a practical tool for evaluating and improving technology and engineering literacy in developing country contexts.

Introduction

The rapid development of science, innovation, and technology in the 21st century has significantly transformed the educational landscape. Higher education institutions are expected not only to develop students' conceptual understanding but also to foster essential 21st-century skills, such as problem-solving, creativity, collaboration, and innovation. These competencies are increasingly important for preparing graduates to adapt to technology-driven workplaces (Maries & Singh, 2023; Tee et al., 2024). However, current learning and assessment practices still tend to emphasize low-level cognitive skills and have not fully supported the development of these competencies. Therefore, educational systems need assessment approaches that can more effectively measure students' higher-order thinking and technology-related competencies.

In this context, technology and engineering literacy (TEL) has emerged as an important competency for students and educators, particularly pre-service science teachers. Technology and engineering literacy (TEL) refers to the ability to use, understand, evaluate, and apply technology and engineering concepts to solve real-world problems ethically and responsibly (ITEEA, 2020; National Assessment Governing Board, 2018). In the context of science education, TEL is particularly important for pre-service science teachers because it supports the integration of technological knowledge, engineering reasoning, and problem-solving skills in classroom learning (Hamka et al., 2024; Mitchell, 2018). In addition, TEL integrates theoretical understanding with practical application, making it highly relevant to science education in technology-oriented societies (Brändle et al., 2024; Caratozzolo et al., 2021).

Several international organizations have developed frameworks for assessing TEL, including the National Assessment of Educational Progress (NAEP) and the International Technology and Engineering Educators Association (ITEEA). Both frameworks emphasize the application of engineering principles to solve real-world problems ethically and responsibly. However, NAEP focuses more on technology application and performance-based assessment, whereas ITEEA places greater emphasis on engineering design processes and technological practices (ITEEA, 2020; National Assessment Governing Board, 2018). Despite these differences, both frameworks provide a strong theoretical foundation for TEL assessment development.

Although international TEL frameworks are widely recognized, most existing assessment instruments have been developed within Western educational contexts. Consequently, they may not adequately reflect technological infrastructure, sociocultural conditions, and educational realities in developing countries (Silva et al., 2020; Choon-Sig, 2021; Jantassova et al., 2024; Love et al., 2023). Similar challenges have been identified in Indonesia, where science education assessment still tends to emphasize conceptual understanding rather than contextual problem-solving, creative thinking, collaboration, and authentic technology application (Hamka et al., 2024; Masfuah et al., 2024; Nasrudin, 2020). This condition occurs because science education assessments in Indonesia tend to emphasize conceptual understanding, lacking opportunities for students to participate in contextual problem-solving, creative, collaborative thinking, and the application of real technology (Aslam et al., 2023; Jackson et al., 2021; Nadifa & Zulvani, 2024). Comparable issues have also been reported in several Southeast Asian countries, highlighting the broader regional need for contextually relevant TEL assessment approaches (Techakosit & Nilsook, 2018).

To address these challenges, a contextual and comprehensive TEL assessment instrument is needed, particularly for pre-service science teachers in developing countries. In this study, the NAEP framework was selected because of its emphasis on authentic assessment and real-world problem-solving, which aligns with the professional competencies required of pre-service science teachers (Bybee, 2020; Krupczak et al., 2021). NAEP conceptualizes TEL through three major domains: design and systems, technology and society, and information and communication technology. These domains collectively assess learners' understanding of technology concepts, their ability to design and evaluate solutions, and their communication and collaboration skills in technology-related contexts. In this study, these domains were operationalized as TELI indicators and scenario-based assessment items designed to measure pre-service science teachers' abilities to understand technology concepts, solve contextual problems, evaluate technological impacts, and apply engineering-related reasoning in authentic situations.

In addition to the assessment framework, scenario-based assessment (SBA) was adopted as an appropriate assessment approach for measuring TEL. SBA enables learners to apply knowledge and skills in realistic situations, thereby providing a more authentic representation of analytical thinking, decision-making, and problem-solving abilities (Daniel & Mazzurco, 2020; Norris et al., 2022; Rediani, 2024). Although SBA has been widely implemented in medical and engineering education, its application in science education assessment remains relatively limited (Joshi & Davis, 2024). As a result, science education assessments often focus primarily on conceptual and procedural knowledge and have not optimally measured higher-order reasoning and applied technology skills (Johnson et al., 2024; Oola & Iqbal, 2024).

From a methodological perspective, most TEL assessment studies still rely on conventional psychometric validation approaches. The use of more advanced measurement models, such as Rasch analysis, remains relatively limited, despite their advantages in evaluating item functioning, construct validity, and measurement reliability (Bond et al., 2020; Chan & Subramaniam, 2020). Recent studies have also shown that modern psychometric models are still underutilized in science and technology education instrument development (Arjana et al., 2025; Stolt et al., 2022). Therefore, there is a need to develop TEL instruments that are not only contextually relevant but also supported by rigorous psychometric evidence.

Based on the literature, three major gaps remain in TEL assessment research. First, contextual TEL instruments for developing countries are still limited. Second, rigorous psychometric validation methods, such as Rasch analysis, are rarely applied in TEL instrument development. Third, studies focusing on pre-service science teachers remain limited. Therefore, this study aimed to develop and validate the Technology and Engineering Literacy Instrument (TELI) based on the NAEP framework for pre-service science teachers in Indonesia. The research questions guiding this study were as follows: (1) RQ1. What are the essential components of technology and engineering literacy as outlined in TELI, and how is the validity of items assessed by expert evaluation? (2) RQ2. What is the construct validity of TELI in assessing the technology and engineering literacy of pre-service science teachers? (3) RQ3. What is the reliability of TELI in assessing the technology and engineering literacy of pre-service science teachers?

Method

Research design

This study uses an instrument development design and psychometric validation with a pilot study approach (DeVellis & Thorpe, 2021), in line with the procedures recommended in the educational measurement literature and instrument development. According to previous studies, the pilot study approach is crucial to the instrument's development since it enables researchers to evaluate the item's clarity, the construct's applicability, and the psychometric integrity before implementing it on a larger scale (Pleasants, 2021; Vargas et al., 2024). Therefore, this design is used to be relevant to the research objectives and to ensure that TELI has an adequate level of validity and reliability before it is used more widely.

Development Instruments Procedures

The design of the development and validation of psychometrics-based instruments with a pilot study approach is carried out through systematic stages in the development process. The TEL framework developed by the National Assessment of Educational Progress (NAEP) was chosen as the basis for the development of the instrument, as it emphasizes performance-based assessment and real-world problem-solving, making it relevant to the characteristics of the TEL required by pre-tenured science teachers. Furthermore, the three core domains of the NAEP framework, namely design and systems, technology and society, and information and communication technology (ICT) are used in the design of the technology and engineering literacy instrument (TELI). This domain represents an important competency of technology and engineering literacy, encompassing how to understand the principles of technology, the ability to design and develop solutions, and awareness of the social impacts of the use of technology in the context of science education.

The stages of development and validation of TELI are carried out in a structured manner. The process begins with the determination of constructs and indicators based on the NAEP framework, then proceeds to the preparation of instrument items, followed by expert assessment for content validation to appraise the suitability of the items with the measured construct, editorial clarity, and the educational context of pre-service science teacher education. After revision based on expert input, a pilot study of the instrument was conducted with the respondent group to assess the clarity of the items, the suitability of the construct, and the instrument's initial psychometric quality before use on a wider scale. The test results were then analyzed to evaluate the construct's validity and the instrument's reliability. The results of this analysis are used as a basis for refining the instrument and ensuring that each TELI item has an adequate measurement function. The flow of TELI development and validation is presented in **Image 1**.

Image 1. TELI development and validation process

Participant
Participants in this study consisted of two groups, namely expert validators and student respondents. Both groups were selected using non-probability purposive sampling techniques, in accordance with the research objectives of instrument development and validation. The expert validator group consists of experts who have more than five years of experience and hold doctoral degrees in science education, educational technology, educational assessment, and STEM teaching. These experts help validate the instrument's content to ensure the suitability, clarity, and consistency of the items with the TEL framework used.

The student respondent group consisted of 132 pre-service science teachers who were pursuing undergraduate education in the Science Education study program at a university in Riau Province. Of these, 44% are second-year students and 56% are third-year students. All respondents have completed basic courses related to science content and pedagogy. A sample size of n = 132 is considered adequate for the early stages of validation of Rasch model-based instruments, in line with general recommendations in the development of early-stage scales. The literature suggests a sample size of more than 100 people to obtain valid and reliable results and improve the stability of instrument parameter estimation (Linacre, 1994; Memon et al., 2020). The students participated in field trials (*Field trial*), which aimed to test the instrument's empirical validity and reliability, the clarity of instructions, and the practicality of implementing TELI in real learning contexts. This study obtained informed consent before implementation, and all participant identities and responses are kept confidential for data analysis.

Data Collection

The data sources in this study were obtained from two main stages: the results of content validation by experts and the results of field trials, which served as the basis for testing construct validity using Rasch analysis. The content validation process is carried out by five expert validators who assess each instrument item using a structured assessment sheet. The validation instrument contains binary scales (i.e., "does not meet indicators =0" and "meets indicators = 1") and comment fields for qualitative feedback. Each item is quantitatively assessed by experts based on aspects of conformity with the TEL construct, clarity of statements, and alignment with the NAEP framework. Furthermore, the suggestions and inputs of expert validators in the comment column are used as qualitative data to revise TELI.

Furthermore, testing on student respondents was carried out after the instrument was revised and validated from the content aspect. The data from the field trial were analyzed using Rasch analysis to assess construct validity and instrument reliability. This process aims to ensure that TELI meets the requirements for content and construct validity, and to empirically demonstrate the quality of the instrument's grains, including the suitability of the items, their reliability, and their functionality in measuring the technology and engineering literacy of pre-service science teachers.

Data Analysis

The analysis of content validity and construct validity in this study employs both quantitative and qualitative approaches. The validity of the TELI content, assessed through expert judgment, is analyzed using the Content Validity Index (CVI) at the item level (I-CVI) and scale level (S-CVI). Based on the established methodological recommendations, items with an I-CVI of ≥ 0.78 are considered relevant, and an S-CVI of ≥ 0.90 indicates strong overall content validity (Polit et al., 2007).

Furthermore, Rasch's analysis was used to check the validity of the construct based on field trial data from student respondents. Prior to the Rasch analysis, a descriptive examination of the distribution of the data, including normality and outliers, was performed to ensure suitability for psychometric analysis, as recommended in the Rasch measurement theory (Engelhard, Jr. & Wang, 2024). The Rasch analysis focused on key indicators, including unidimensionality, item suitability, item and person reliability, and internal consistency. The acceptance criteria for each indicator are summarized in **Table 1**.

Table 1. Acceptance Criteria for Rasch Analysis for Instrument Construct Validation

Analysis Component	Purpose/Function	Criteria
Item Fit (Infit/Outfit MNSQ)	Examines whether each item fits the Rasch model expectations and contributes meaningfully to the construct.	0.5 – 1.5
Item Fit (Infit/Outfit ZSTD)	Identifies misfitting items that deviate significantly from model expectations. Requires careful interpretation alongside MNSQ values.	-2.0 to +2.0
PT-Measure Corr	Indicates the correlation between item scores and person ability estimates, confirming item alignment with the construct.	PT Corr > 0.30

Analysis Component	Purpose/Function	Criteria
Unidimensionality (PCA Residual)	Verifies that the instrument measures a single dominant construct rather than multiple unrelated dimensions.	Eigenvalue < 2.0 or residual variance < 20%
Item Reliability	Assesses internal consistency among items and the stability of the item difficulty hierarchy.	≥ 0.80
Person Reliability	Evaluates consistency of respondents' performance patterns, reflecting the homogeneity of person ability estimates.	≥ 0.70

Results and Discussion

Development and Structure of TELI Instruments

The technology and engineering literacy instrument (TELI) was developed based on the Technology and Engineering Literacy (TEL) framework of the National Assessment of Educational Progress (NAEP), which conceptualizes technology and engineering literacy in three domains: design and systems, technology and society, and information and communication technology (ICT) and three practices: understanding the principles of technology, developing solutions and achieving goals, and communicating and collaborating. Each domain is combined with all three practices, which are then derived into the TELI indicator. This indicator is operationalized through contextual, scenario-based performance tasks and translated into nine question items representing each indicator.

The selection of context in the instrument considers aspects of relevance to local and global challenges in the field of food security sustainability, namely the problem of agricultural irrigation with limited resources. Thus, TELI can measure conceptual mastery (cognitive), procedural in designing solutions, and socio-contextual through communication and collaboration in decision-making on the impact of technology use. Integration between content, practice, and context, in accordance with the characteristics of the TEL assessment emphasized in the NAEP framework. Table 2 presents in detail the structure of the development of TELI.

Table 2. Structure of the TELI

Domain	Practice	Indicator of TELI	Task Type	Scenario
Design and Systems	Understanding technological principles	Analyzing needs	Analyze news/article	Farmer with limited water resources
	Developing solutions and achieving goals	Determining how to meet needs	Choose irrigation technology	Hydram vs. Submersible vs. Diesel pump
	Communicating and collaborating	Representing data	Graph water efficiency	Comparing two farming groups
Technology and Society	Understanding technological principles	Comparing the impacts of technologies	Compare irrigation methods	Drip vs. sprinkler efficiency
	Developing solutions and achieving goals	Choosing appropriate technology	Select tech for the community	Solar vs. diesel pump in a village

Domain	Practice	Indicator of TELI	Task Type	Scenario
	Communicating and collaborating	Creating multimedia presentations	Present digital solution	Student project presentation
Information and Communication Technology (ICT)	Understanding technological principles	Justifying tool choice	Select media/tools	Choose app/article/video
	Developing solutions and achieving goals	Finding digital resources	Search and evaluate info	Farmer seeks irrigation knowledge
	Communicating and collaborating	Explaining how something works	Explain with visual/media	Group explains drip irrigation

Based on **Table 2**, each TEL domain is systematically operationalized into specific practices, indicators, task types, and contextual scenarios. This structured mapping ensures that TELI assesses not only conceptual understanding but also applied reasoning, decision-making, and communication skills within technology-related contexts. The use of authentic task formats, such as technology selection, data representation, and evaluation of digital resources, supports alignment with higher-order thinking and problem-solving competencies.

Furthermore, the integration of scenario-based assessment (SBA) was intentionally designed to reflect locally relevant technological challenges, particularly those associated with sustainable irrigation and rural infrastructure constraints in Indonesia. This contextual adaptation represents a deliberate extension of the NAEP TEL framework to enhance its relevance and applicability within non-Western educational settings.

By embedding assessment tasks within realistic technological problem situations, TELI aligns with constructivist perspectives that emphasize learning and assessment through engagement with authentic real-world challenges (Ajjawi et al., 2024). Previous studies have highlighted the effectiveness of scenario-based assessment in promoting authentic problem-solving and higher-order thinking within STEM education (Gedera, 2023; Evi Yupani & Widana, 2023). The present study extends this line of research by demonstrating that SBA can also be effectively integrated into technology and engineering literacy assessment for pre-service science teachers. Whereas previous applications of SBA have predominantly been situated in medical and engineering education, the current study expands its implementation to science teacher education within a developing-country context. This extension strengthens the relevance of SBA as an approach for assessing technological reasoning, decision-making, and solution-oriented thinking in authentic educational settings.

Overall, the development structure of TELI demonstrates how integrating TEL domains, literacy practices, and contextualized scenarios can produce an assessment framework that captures technology and engineering literacy as a multidimensional yet coherent construct. By combining authentic technological contexts with scenario-based tasks, TELI provides a foundation for assessing not only what pre-service teachers know about technology, but also how they apply, evaluate, and communicate technological solutions in addressing real-world problems.

Content Validity: Confirmation of Instrument Development Standards

The content validity of TELI was evaluated through expert judgment using both quantitative and qualitative approaches. Quantitatively, content validity was examined using the Content Validity Index (CVI) at both the item level (I-CVI) and scale level (S-CVI). A summary of the results is presented in **Table 3**.

Table 3. Summarizes the results of the CVI and S-CVI analysis of the content

Item Validity Summary	Min	Max	Red	Items with I-CVI = 1.0	S-CVI
I-CVI values	0.80	1.00	0.93	5 of 9 items	0.93

Note: All items exceeded the minimum threshold of 0.78, with five items achieving perfect agreement.

Based on **Table 3**, all TELI items exceeded the recommended minimum I-CVI threshold of 0.78, with values ranging from 0.80 to 1.00. The average I-CVI was 0.93, while the overall S-CVI reached 0.93. Five of the nine items achieved perfect expert agreement (I-CVI = 1.00), indicating a high level of consensus regarding their relevance and representativeness. These findings suggest that the instrument adequately captures the intended dimensions of technology and engineering literacy and that the developed items are strongly aligned with the underlying theoretical framework. To complement the quantitative evidence, qualitative feedback from experts was analyzed to identify areas for improvement. The results are summarized in **Table 4**.

Table 4. Results of Expert Input Analysis on the Instrument

Main Themes	Examples of expert input	Researcher Revision Actions
Suitability to Constructs and Indicators	The indicators developed are relevant, but ensure the TEL indicators align with the question indicators	Review the relationship between the TEL indicators and the question indicators to ensure they align with the constructs being measured
Clarity of Language and Instrument Display	The text in the journal article is too small or unclear; it can be rewritten to be clearly legible by students.	Adjust the display format and font size for easy reading by readers and reviewers.
Accuracy of Writing	Correct any spelling errors.	Conduct thorough editing of spelling, punctuation, and sentence structure to correct any errors.
Relevance of Context and Material	The questions and statements developed are relevant, but some require adjustment to the course material	Align all questions with the topic and course learning outcomes to maintain content relevance

The qualitative findings in **Table 4** show that TELI items are assessed clearly and in accordance with the construct indicators measured by experts. However, minor revisions were made to rectify language clarity, indicator suitability, and instrument display. This indicates that content validity is determined not only by the suitability of the concept but also by the correctness of the construct representation in the form of a question. These results are in line with the view that content validity depends not only on expert agreement but also on the conceptual coherence and relevance of the instrument's context (Tawfik et al., 2024). Overall, the expert validation results indicate that TELI possesses strong content relevance and conceptual alignment with the intended TEL constructs. These findings support the appropriateness of TELI for measuring technology and engineering literacy among pre-service science teachers.

Descriptive Analysis

Before the Rasch analysis, the field trial results were analyzed descriptively to provide initial insights for data preparation and to determine whether the instrument was appropriate for measuring the desired dimension concept, so that better results could be produced by the Rasch model. The results of statistical descriptive analysis are presented in **Table 5**.

Table 5. Descriptive Statistics

Descriptive Statistics									
	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Kurtosis
Score	132	10	13	23	18.17	2.385	5.687	.085	-.430
Valid N (listwise)	132								

Table 5 shows that the participants' scores ranged from 13–23 with an average score of 18.17 (SD = 2.385). The distribution of scores was relatively normal with low values of skewness and kurtosis, indicating the absence of extreme deviations. The moderate variation in scores indicates that TELI is able to adequately distinguish participants' levels of technology and engineering literacy, as well as meet the prerequisites for advanced psychometric analysis (Engelhard, Jr. & Wang, 2024). These findings suggest that the response data are suitable for further Rasch-based psychometric analysis.

Construct Validity-Based Rasch Analysis

The validity of the TELI construct was tested using Rasch analysis, starting with unidimensionality testing through residual Principal Component Analysis (PCA). A summary of the analysis results is presented in **Table 6**.

Table 6. Summary of PCA of Rasch Residuals

Component	Eigenvalue	Variance Explained (Empirical)	Variance Explained (Modeled)
Total raw variance in observations	20.7	100%	100%
Raw variance explained by measures	11.7	56.6%	50.0%
Raw variance explained by persons	6.0	28.8%	25.5%
Raw variance explained by items	5.8	27.8%	25.9%
Raw unexplained variance (total)	9.0	43.4%	24.5%
Unexplained variance in the 1st contrast	1.6	7.9%	18.2%
Unexplained variance in the 2nd contrast	1.5	7.2%	16.7%

The PCA results indicate that more than 50% of the variance was explained by the Rasch model, while the first and second contrast eigenvalues remained below 2.0, supporting the unidimensionality of TELI. These findings confirm that TELI consistently measures a single latent construct, namely technology and engineering literacy. This result is consistent with previous Rasch-based validation studies in STEM and literacy assessment, which also reported strong evidence of construct validity and dimensional coherence (Avinç & Doğan, 2024; Chiu & Wang, 2024), as well as similar research in the Indonesian context (Qudratuddarsi & Hidayat, 2022). However, unlike previous studies that mainly focused on general STEM literacy or Western educational settings, the present study extends the application of Rasch-based validation to a contextual TEL instrument specifically designed for pre-service science teachers in Indonesia. This finding suggests that the NAEP-based TEL framework can be adapted effectively to non-Western educational contexts while maintaining strong psychometric quality.

Item Fit Based on Rasch Analysis

Item fit was examined using Rasch fit statistics, including Infit and Outfit Mean Square (MNSQ), standardized fit statistics (ZSTD), and Point-Measure Correlation (PTMEA Corr). As shown in Table X, all TELI items met the recommended Rasch criteria, with Infit and Outfit MNSQ values ranging from 0.73 to 1.24, ZSTD values within the acceptable interval of −2.0 to +2.0, and PTMEA Corr values exceeding 0.30. These results indicate that all items functioned consistently with model expectations and contributed meaningfully to the measurement of technology and engineering literacy.

Table 7. Item Fit Statistics for TELI

Item	Total Score	Measure (Logit)	S.E.	Infit MNSQ	Outfit MNSQ	Infit ZSTD	Outfit ZSTD	PT-Measure Corr	Observed %	Expected %
I1	316	–2.97	0.39	1.14	1.24	1.00	1.10	0.69	88.6	81.4
I2	292	–1.57	0.41	1.00	0.98	0.10	0.00	0.62	85.6	83.0
I3	292	–1.57	0.43	0.88	0.99	-0.80	0.00	0.56	93.2	83.0
I6	251	1.00	0.40	0.76	0.95	-1.60	-0.10	0.31	93.9	83.3
I8	236	1.89	0.38	0.77	0.88	-1.80	-0.50	0.68	89.4	81.5
I9	213	3.12	0.43	0.88	0.69	-1.00	-1.40	0.69	90.9	79.0
I4	276	0.58	0.41	0.82	0.67	-1.20	-1.30	0.62	90.9	83.5
I7	253	0.88	0.43	0.80	0.73	-1.30	-1.10	0.46	87.9	83.7
I5	270	0.20	0.40	0.73	0.77	-1.90	-0.49	0.54	92.4	83.9
Red	266.6	0.00	0.24	0.86	0.88	-1.0	-0.50		90.3	82.5
S.D.	29.9	1.80	0.01	0.13	0.17	0.90	0.70		2.50	1.50

The distribution of item difficulty estimates also demonstrated an appropriate range of challenge levels, spanning from −2.97 logits (Item 1) to 3.12 logits (Item 9). This variation suggests that the instrument captures different levels of respondent ability while maintaining coherence with the underlying construct. The absence of misfitting items supports the construct representation of TELI and indicates that each item contributes to a valid measurement continuum of technology and engineering literacy. Similar findings have been reported in Rasch-based instrument validation studies, where acceptable fit statistics provide evidence that items operate consistently across varying respondent ability levels (Kean & Ray, 2017; Mutakin et al., 2022).

Measurement Reliability and Accuracy

The results of Rasch's reliability analysis are presented in **Table 8**.

Table 8. Summary of Rasch Model Person and Item Reliability

Parameters	Value	Decision
Item Reliability	0.98	Acceptable, the instrument is reliable for distinguishing between different respondent abilities, suitable for decisions.
Person Reliability	0.74	Acceptable, the items are highly stable, and the instrument is reliable across different samples. Retain items.
Person Separation	1.69	Fair, the instrument distinguishes respondents into several ability levels but may need improvement for more precision.

Parameters	Value	Decision
Item Separation	7.25	Very Good, items are well distributed across difficulty levels. No changes needed, but it could benefit from more levels.
Cronbach Alpha (KR-20)	0.76	Acceptable to moderate-to-high consistency between items in the instrument.

TELI demonstrated strong measurement quality, with an item reliability of 0.98 and an item separation index of 7.25, indicating that the instrument can consistently differentiate item difficulty levels across the ability continuum. These findings suggest excellent item calibration and stability within the measurement model, supporting the precision of item difficulty estimation in Rasch measurement (Fitrah et al., 2024).

The person reliability coefficient (0.74) and Cronbach's alpha (0.76) indicate acceptable internal consistency and adequate measurement precision for assessing technology and engineering literacy among pre-service science teachers. These values are comparable to those reported in previous Rasch-based educational instrument studies, which found that moderate-to-high reliability is acceptable during the early stages of instrument development (Juandi et al., 2023; Zakariya, 2022). Although the person separation index (1.69) was moderate, it remains sufficient for an initial validation study and suggests that future versions of TELI may benefit from additional items or a broader range of item difficulties to improve discrimination among respondent ability levels (Karlin & Karlin, 2018). Overall, the reliability evidence supports the use of TELI as a stable and sufficiently precise instrument for measuring technology and engineering literacy in science teacher education contexts.

Person–Item Map (Wright Map)

The Person–Item Map (Wright Map) analysis presented in **Image 2** illustrates the relationship between participants' abilities and item difficulty levels on the same logit scale. Most participants were at the intermediate ability level, while the items spanned a range of difficulty levels. This finding indicates that TELI has adequate measurement coverage and can differentiate respondents with varying levels of technology and engineering literacy.

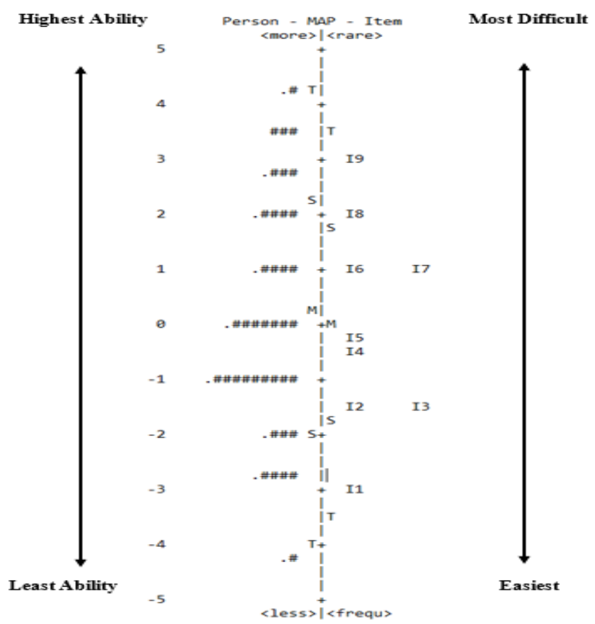

Image 2. Person-Item Map (Wright-Map) Representation

The Wright Map results demonstrate a strong alignment between item difficulty and respondents' ability, indicating that TELI is well calibrated and suitable for assessing technology and engineering literacy among pre-service science teachers. These findings support the validity and reliability of Rasch-based measurement, consistent with previous studies (Boone & Staver, 2020; Planinic et al., 2019).

Theoretical Implications

This study extends the applicability of the NAEP Technology and Engineering Literacy (TEL) framework to a non-Western educational context by demonstrating that technology and engineering literacy can be validly assessed through scenario-based tasks grounded in authentic local challenges. The findings contribute to the growing body of literature on contextual assessment in STEM education by providing empirical evidence that contextualized scenarios can represent TEL constructs while maintaining strong psychometric properties.

Practical Implications

The validated TELI instrument provides science teacher educators and researchers with a contextually relevant tool for assessing technology and engineering literacy among pre-service teachers. By incorporating authentic technological problems, TELI enables the assessment of not only conceptual understanding but also technological reasoning, decision-making, and communication skills, thereby supporting more authentic assessment practices in STEM teacher education (Widana et al., 2021).

Limitations and Future Directions

Several limitations should be acknowledged. First, the study involved pre-service science teachers from a specific educational context, which may limit the generalizability of the findings. Second, TELI consists of only nine scenario-based items, which may constrain measurement precision across a wider range of abilities. Future research should validate the instrument using larger, more diverse samples, expand the item pool to improve measurement coverage, and investigate its applicability across educational levels, disciplines, and cultural contexts.

Conclusion

This study aimed to develop and validate the Technology and Engineering Literacy Instrument (TELI) for pre-service science teachers in Indonesia. The findings indicate that TELI, which was developed based on the NAEP technology and engineering literacy framework and integrated with a scenario-based assessment approach, demonstrated strong content validity, construct validity, and acceptable reliability based on Rasch analysis. These results suggest that TELI is a feasible and psychometrically sound instrument for assessing technology and engineering literacy in contextual educational settings. The study also contributes to the TEL literature by extending the application of the NAEP framework and scenario-based assessment within science teacher education in a developing country context. Despite limitations related to the sample scope and number of items, TELI has the potential to support more authentic and contextual assessment practices in science teacher education. Future studies are recommended to validate TELI across different regions and educational levels, expand the number of scenario-based items to improve measurement precision, and investigate the effectiveness of TELI implementation in STEM learning programs and digital assessment environments.

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