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STEM Literacy Proficiency in Prospective Physics Educator: A Comprehensive Analysis Using Rasch Measurement Theory

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Abstract: This study aims to measure and analyze the level of STEM literacy among prospective physics educators using Rasch measurement theory. A quantitative approach with a descriptive design was employed. The research instrument consisted of a STEM literacy test comprising multiple-choice questions and essays, and the data were analyzed using Winstep software version 5.7.1 to assess the validity and reliability of the measurement instrument. The results reveal that only a small number of prospective physics educators exhibit very high STEM literacy, while the majority demonstrate moderate to low levels of competencies and attitudes toward STEM literacy. The measurement instrument was confirmed to be valid and reliable according to Rasch parameters. These findings highlight the need for targeted interventions to enhance digital literacy, multidisciplinary skills, technology integration, and scientific competence among aspiring educators. Educational institutions are thereby urged to better prepare future educators to teach and promote STEM literacy effectively among students.

Keywords: Physics Educators; Rasch Measurement Theory; STEM Literacy

Introduction

STEM (Science, Technology, Engineering, and Mathematics) literacy is one of the key competencies that prospective physics educators must possess to face the challenges of 21st century education. Effective STEM education can produce graduates who not only understand the basic concepts of science, technology, engineering, and mathematics, but are also able to apply them in real contexts to solve complex problems. An integrated STEM education model can increase student engagement and support sustainable science education (Ali, Bhadra, Siby, Ahmad, & Al-Thani, 2021; Gravel, Tucker-Raymond, Kohberger, & Browne, 2018; Ismail, Afriana, & Saputra, 2015; I Ismail, Permanasari, & Setiawan, 2016). The importance of STEM literacy in increasing positive attitudes towards science through involvement in citizen science projects (Bruckermann et al., 2021; Falloon, Hatzigianni, Bower, Forbes, & Stevenson, 2020; Ismail Ismail, Permanasari, & Setiawan, 2016; Sole, 2021; Wahyu, Edu, & Helmon, 2023).

In the context of physics education, STEM literacy includes not only theoretical understanding, but also practical and problem-solving skills required in learning and teaching (Gravel et al., 2018; Tenney, Stringer, LaTona-Tequida, & White, 2023; Wu, Huang, Liu, & Chiang, 2024). STEM literacy includes the ability to understand and integrate knowledge from various disciplines, as well as the critical thinking skills needed to apply that knowledge in real-life contexts (Agussuryani, Sudarmin, Sumarni, Cahyono, & Ellianawati, 2022; Ardianto, Firman, Permanasari, & Ramalis, 2019; Huang, Erduran, Luo, Zhang, & Zheng, 2023; Techakosit & Nilsook, 2018). Therefore, it is important to evaluate the extent to which prospective physics educators have adequate STEM literacy to

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ensure they are prepared to face challenges in science education and teaching (Braund, 2021; Falloon et al., 2020; Jackson et al., 2021; Tang & Williams, 2019).

This study aims to measure and analyze the level of STEM literacy among prospective physics educators using Rasch's measurement theory (Ginting, Mellyzar, & Lukman, 2023; Hariyadi, Rofi, Santosa, Taqiyuddin, & Sakti, 2023; Laksono, Rusilowati, & Widiyatmoko, 2023; Sole, 2021). By utilizing Rasch's measurement theory, this study will provide a comprehensive overview of the STEM literacy skills and understanding possessed by prospective physics educators, as well as identify the validity and reliability of the STEM literacy measurement instruments used (Ahmad Kamal, Subali, Astuti, Rusilowati, & Widiyatmoko, 2024; Ginting et al., 2023; Lestari, Rahmawati, Siskandar, & Dafenta, 2021; Putri & Ramli, 2023).

The scientific literature suggests that a design-based approach to educational research can provide deep insights into the effectiveness of learning methods. STEM literacy can be improved through an approach that pays attention to how students read and understand scientific texts (Hubbard, 2021; Karimah & Wulandari, 2023; Sujud, Rahmawati, & Utami, 2024; Supriyatman et al., 2024; Zarestky & Vilen, 2023), as well as how teaching methods can be adapted to support this understanding. The design-based approach applied in this study is expected to identify and overcome weaknesses in STEM literacy measurement instruments (Ali et al., 2021; Patricia Diane Mouboua, Fadeke Adeola Atobatele, & Olateju Temitope Akintayo, 2024; Widiyatmoko, Nugrahani, Yanitama, & Darmawan, 2023).

The use of technology, such as virtual reality game-based learning, can improve STEM literacy by providing interactive and immersive learning experiences (Junge, Bulc, Anseeuw, Yavuzcan Yildiz, & Milliken, 2019; Rasmussen et al., 2023; Widiyatmoko et al., 2023). The study also found that the integration of technology in STEM learning can help students connect abstract concepts with real applications, thereby improving STEM literacy understanding and skills. Therefore, this study will examine the effectiveness of STEM literacy measurement instruments using Rasch's measurement theory to ensure that the instruments are valid and reliable in measuring STEM literacy of prospective physics educators.

Previous research has extensively explored the importance of STEM literacy and methods to improve it. The use of aquaponics as an educational tool to improve STEM literacy through an interdisciplinary approach that combines science and engineering (Junge et al., 2019). A multilingual teaching approach in science education to bridge the gap between STEM literacy and Language. Both studies highlight the various approaches that can be used to improve STEM literacy, but there is still a gap in terms of comprehensive evaluation of STEM literacy among aspiring physics educators.

The adaptation and validation of the health literacy scale shows the importance of developing and validating reliable measurement instruments (Rasmussen et al., 2023). However, studies on the validity and reliability of STEM literacy measurement instruments, especially for prospective physics educators, are still limited. Therefore, this study will fill the gap by evaluating STEM literacy measurement instruments using Rasch's measurement theory, as well as identifying factors that affect the level of STEM literacy among prospective physics educators.

This study aims to measure and analyze the level of STEM literacy among prospective physics educators using Rasch's measurement theory (Aryadoust, Tan, & Ng, 2019; Browne & Cano, 2019; Chen & Oakley, 2020; Stemler & Naples, 2021). This research will also evaluate the validity and reliability of STEM literacy measurement instruments, as well as identify the difficulties or obstacles faced by prospective physics educators in achieving high STEM literacy. The novelty of this study lies in the comprehensive approach used to evaluate STEM literacy with Rasch's measurement theory (Blanchin, Guilleux, Hardouin, & Sébille, 2020; Kleppang, Steigen, & Finbråten, 2020; Moullin, Ehrhart, & Aarons, 2018), as well as focusing on aspiring physics educators as research subjects. The scope of the research includes analysis of STEM literacy data, the validity and reliability of measurement instruments, as well as recommendations for improving STEM literacy among prospective physics educators.

This study specifically targets prospective physics educators, who have a strategic role in conveying STEM concepts to the younger generation. Most previous studies have focused more on students or college students in general, so this study fills the literature gap related to STEM literacy evaluation in the context of prospective teacher education. This study also not only measures STEM literacy, but also comprehensively evaluates the measurement instruments, ensuring that the tools used have high validity and reliability. Rasch's measurement theory in evaluating the level of STEM literacy of prospective physics educators is an approach that has rarely been done before. This approach provides an in-depth analysis of the validity, reliability, and difficulty level of the measurement instrument, resulting in a more accurate and reliable measurement tool.

This research is important because it can prepare prospective physics educators to face the challenges of 21st-century education, where STEM literacy is one of the main competencies. With strong STEM literacy, prospective educators can teach science, technology, engineering, and mathematics concepts holistically, and help students connect learning with real-world applications. In addition, this study answers the gap in previous research that focused more on methods for improving STEM literacy without evaluating the validity of the measurement tools. The results of this study not only provide insight into the level of STEM literacy of prospective physics educators, but also create a measurement tool that can be used for similar studies in the future. Ultimately, this study contributes to continuing education by producing prospective educators who are able to build positive attitudes toward science, support engagement in citizen science projects, and strengthen technology-based STEM learning.

Method

This study uses a quantitative approach with a descriptive design to evaluate the level of STEM literacy among prospective physics teacher students. The quantitative approach was chosen because it allows for objective and measurable data collection, providing a comprehensive picture of STEM literacy capabilities. Descriptive design is used to describe existing phenomena in detail and depth, aiding in understanding the level of STEM literacy from a broad perspective.

The research instrument used in this study is a test specifically designed to measure STEM literacy. This test consists of two types of questions, namely 8 multiple-choice questions and 6 essay questions. The multiple-choice questions aim to test the basic understanding and application of STEM concepts, while the essay questions assess critical thinking skills, analysis, and the application of knowledge in real contexts. This instrument is compiled based on relevant STEM literacy indicators and has been validated by experts in the field of physics education, ensuring that the instrument is precise and accurate in measuring STEM literacy.

For data analysis, this study uses Winstep software version 5.7.1. This software was chosen because of its ability to perform data analysis with the Rasch model (Ismail Ismail, Rochintaniawati, Permanasari, & Riandi, 2022; Rizki & Yusmaita, 2021), which is very effective in evaluating the validity and reliability of measurement instruments. Winstep provides a variety of features that support in-depth analysis of item performance and learners' abilities, allowing researchers to gain more detailed insights into the data collected.

This study uses a Design-Based Research (DBR) design (Chen & Oakley, 2020; Papavlasopoulou, Giannakos, & Jaccheri, 2019; Peters, 2024), Phases of Design-Based Research (DBR), adapted from Tuckman's Model (Anderson & Shattuck, 2012; Egolf, 2022), is very relevant to the article "Improving STEM Literacy Skills in Prospective Physics Educator Students: A Comprehensive Analysis Using Rasch Measurement Theory." In the Forming phase, a research team is formed to identify key challenges and design an initial plan. The Storming phase involves developing and testing an initial prototype, overcoming conflicts, and receiving feedback. In the Norming phase, effective methods are agreed upon and instruments are refined. The Performing Phase includes the full implementation of the instrument and data analysis using Rasch Measurement Theory. Finally, the Adjourning phase completes the research by documenting the results and planning further research.

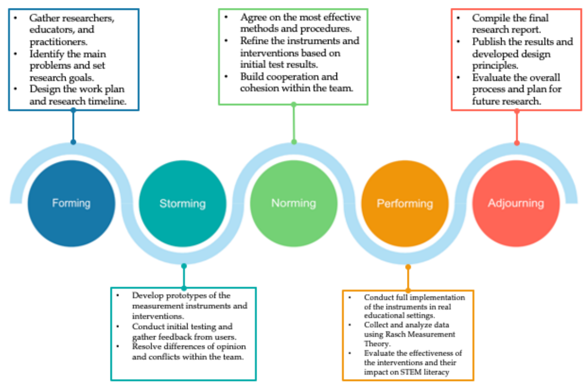

Figure 1. Phases of Design-Based Research (DBR), adapted from Tuckman's Model (Tuckman, 1965; Zirar, Muhammad, Upadhyay, Kumar, & Garza-Reyes, 2023)

This design allows researchers to continuously improve the instruments and methods based on the feedback and findings obtained during the research process. The research sample consisted of 62 prospective physics teacher students who programmed the earth and space science course. Data collected from STEM literacy tests were analyzed using the Rasch model with the help of Winstep software. This analysis includes several important aspects, namely measuring the level of STEM literacy among prospective physics teacher students, evaluating the validity and reliability of measurement instruments, analyzing the performance of items in measurement instruments, and identifying difficulties or obstacles faced by students in achieving high STEM literacy.

The results of this analysis are expected to provide a clear picture of the level of STEM literacy among prospective physics teacher students. In addition, these results will also provide information on the validity and reliability of the measurement instruments used, as well as factors that affect STEM literacy. Thus, this research not only contributes to the understanding of STEM literacy among aspiring physics teachers, but also provides a solid foundation for the development of better and more accurate measurement instruments in the future.

Result and Discussion

Result

STEM literacy measurement instruments for prospective physics education teacher students include various important dimensions, namely Content, Competence, Attitude, and STEM Literacy as a whole. To assess the effectiveness of this instrument, we need to look at its validity and reliability**.**

Validity and Reliability Instrument STEM Literacy
Validity

Rasch's analysis was carried out using JMLE estimates for dichotomy data to validate STEM literacy tests that have been adapted for Indonesia. Item and person parameters are used to validate the test. The validity of the fit of people and goods is identified according to the mean Infit and outfit mean square (MNSQ), where the acceptable range is from 0.5 to 1.5 although 1.6 is still considered acceptable. Furthermore, the ideal value for the fit criterion is close to 1.00 logit (Andrich, 2018; Boone et al., 2014). In addition, the separation of items shows that the STEM literacy test contains a variety of easy and difficult items (Boone et al., 2014). It is very important that the separation value should be more than 2 logits, where the larger the separation index, the higher the test quality (Boone et al., 2014; Fisher, 2007; Planinic et al., 2019). The results of Rasch's analysis are presented in Table 1. They assert that STEM literacy tailored to Indonesia achieves validity according to the Rasch parameters for each task and for the entire test.

This research aims to improve STEM literacy competencies in prospective physics teachers. To achieve this goal, it is important to use valid and reliable instruments in measuring various aspects of STEM literacy. Based on table 1, we can analyze and interpret some relevant psychometric attributes.

The instruments used to measure STEM literacy include four main dimensions: Content, Task Competence, Attitude, and overall STEM literacy. The number of items used in each dimension varies, with Content and Task Competencies having 4 items each, Attitudes having 3 items, and overall STEM literacy covering 11 items. This number of items reflects an effort to measure each dimension comprehensively.

The average value for the MNSQ outfit item and the MNSQ Infit item shows how well the items in this instrument match the Rasch model. These values are close to 1, which indicates that the items conform to the Rasch model and are valid in measuring the attribute in question. Similarly, the MNSQ person outfit and MNSQ person Infit values were also close to 1, suggesting that the data from individuals (respondents) also corresponded to the Rasch model, which supports the validity of this instrument.

Table 1. Summary of Rasch parameters for STEM Literacy

Psychometric attribute	Content	Task Competence	Attitude	STEM Literacy
Number of items	4	4	3	11
Mean				
Item outfit MNSQ	1.03	0.95	1.00	1.03
Item infit MNSQ	1.02	1.11	1.08	1.02
Person outfit MNSQ	1.03	0.95	1.00	1.03
Person infit MNSQ	1.00	0.92	0.98	1.02
Item separation	4.47	1.56	2.74	2.23
Person separation	1.84	1.23	1.64	2.13
Unidimensionality				
Raw variance by measure	52.4%	32.6%	40.3%	
Unexplained variance 1st contrast	1.84	1.70	1.93	

In addition, item separation and person separation values provide important information about the instrument's ability to distinguish between items of varying difficulty and between individuals of varying skill levels. A high item separation value, such as 4.47 for Content, indicates that the instrument has a good ability to distinguish between items of different difficulty levels. Higher person separation values, such as 1.84 for Content, indicate that these instruments are able to distinguish between individuals with different levels of ability, which is important for constructive validity.

The unidimensionality of the instrument is also analyzed through the percentage of total variance explained by the primary dimension and the variance not explained by the first contrast. A high percentage of variance, such as 52.4% for Content, indicates that this instrument measures one major construct, which supports structural validity. Meanwhile, variance unexplained by low first contrast, such as 1.84 for Content, favors the unidimensionality of the instrument, which is important for internal validity. Overall, the analysis of this table shows that the instruments used in this study are valid and in accordance with the Rasch model. This supports the validity of the instrument in measuring STEM literacy in prospective physics teachers, so that it can be used to achieve research objectives in improving their STEM literacy competencies.

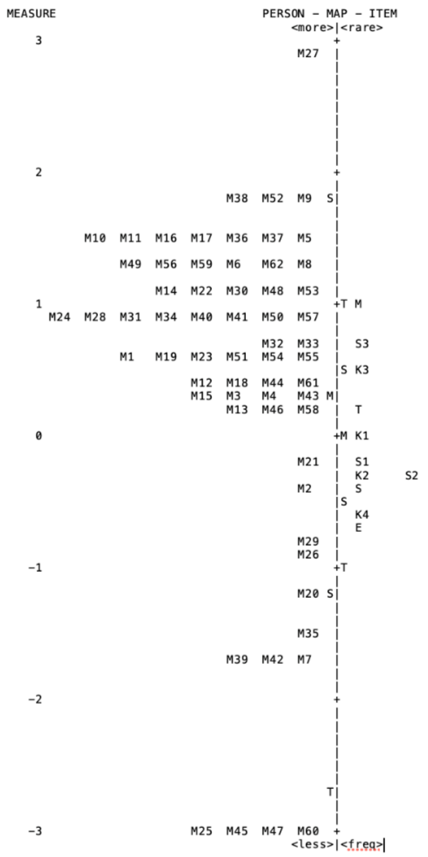

Figure 2. Wright Map

The Wright Map graph presented provides an in-depth insight into the distribution of respondents' abilities and the difficulty of items in measuring STEM literacy in prospective physics educator students. On the vertical axis, the ability and difficulty scale is measured in logits, with higher values indicating higher ability or difficulty. Respondents with codes M1 to M62 were spread along this scale, where M27 was at the highest level of capability and M25, M45, M47, and M60 were at the lowest level of capability. This indicates significant variation in STEM literacy skills among respondents, which is important to understand in the context of education.

Question items with codes S (Science), T (Technology), E (Engineering), M (Mathematics), K1 (Recognizing the features or characteristics of STEM investigations), K2 (Designing models or scientific investigations to create solutions), K3 (Making explanatory statements about STEM-related phenomena), K4 (Communicating or drawing conclusions based on evidence), S1 (Showing curiosity about STEM-related issues), S2 (Showing interest in solving STEM-related issues), and S3 (Having an awareness of the importance of STEM in life) spread along the logical scale. This distribution shows that the measurement instruments cover a wide range of difficulty levels, allowing for a comprehensive evaluation of respondents' STEM literacy abilities. For example, items with K1 codes associated with recognizing STEM investigative features are at a low difficulty level, indicating that most respondents are able to recognize investigative features or characteristics well.

This analysis also shows good instrument differentiation ability. S (Science) items such as M9 and M38 were spread across different levels of difficulty, showing variations in the science problems faced by respondents. Item T (Technology) tends to be easier, as seen in the M13, M46, and M58 which are at medium to low difficulty. In addition, items such as K2 and K3 showed that the ability to design scientific models and make explanatory statements about STEM phenomena was at a low to moderate difficulty level, demonstrating good responders' abilities in these aspects. In conclusion, this Wright Map graph provides important insights into the distribution of abilities and difficulties of items in STEM literacy measurement, supporting efforts to improve the quality of STEM literacy education among prospective physics educators through more targeted adjustments to educational programs.

Reliability

The reliability criteria were evaluated following several indicators, including Rasch parameters using the reliability of people and items (Fisher, 2007; Linacre, 2021), Cronbach's alpha (α) (Taber, 2018). WINSTEPS software results in people reliability, item reliability and Cronbach alpha (α)). Cronbach's alpha (α) value ranges from 0.61 to 0.77 for all tasks as well as for the entire test, thus indicating sufficient reliability (Taber, 2018). However, the value ranges from 0.68 to 1.00 for the reliability of people and the reliability of items. A value of more than 0.67 indicates acceptable reliability. Overall, the adapted inductive reasoning tests and all their tasks show acceptable criteria for Rasch's reliability parameters. All reliability results for tasks and tests are summarized in Table 2

Table 2. Reliability Indicators

Reliability	Instrument			STEM Literacy
	Content	Competence	Attitude	
Item reliability	0.95	0.71	0.88	0.83
Person reliability	0.77	0.60	0.73	0.82
Cronbach's alpha (α)	0.83	0.78	0.83	0.91

Table 2 of the reliability displayed provides a comprehensive view of the consistency of STEM literacy measurement instruments in prospective physics educator students. This reliability is measured through three main parameters: item reliability, person reliability, and Cronbach's alpha (α). The results of the analysis show that the reliability item values for Content (0.95), Competence (0.71), Attitude (0.88), and STEM Literacy (0.83) are all above the reliability threshold of >0.67. This indicates that the items used in this instrument are quite consistent in measuring the same construct. Notably, the Content dimension shows a very high level of consistency, ensuring that items in this category can be relied upon to accurately measure content comprehension.

Person reliability also showed mostly positive results, with scores for Content (0.77), Attitude (0.73), and STEM Literacy (0.82) above the 0.67 threshold, indicating that respondents were generally consistent in answering related items. However, the person reliability value for Competence (0.60) was below the threshold, indicating greater variation among respondents in terms of their competence. Finally, Cronbach's alpha score shows excellent internal consistency, especially on STEM Literacy (0.91), which indicates that this instrument is highly reliable for overall STEM literacy evaluation. Overall, this instrument shows good reliability and can be used to support the development of more effective and targeted STEM literacy education programs, according to the needs and abilities of students.

Level of STEM literacy among prospective physics educators

The analysis of STEM literacy among aspiring physics educators is essential to understand their level of competence and attitude. Based on the distribution table, this study identifies challenges and opportunities in improving content understanding, STEM literacy, and pedagogical competence, in order to support effective science teaching in the future.

Table 3. Level of STEM Literacy student physics educators

Instru-ment	Very high, LVP > Mean Logit + SD	High, Mean Logit + SD ≥ LVP > Mean Logit	Moderate, Mean Logit ≥ LVP > Mean Logit - SD	Low, LVP < Mean Logit - SD
STEM Literacy	1 person	34 person	15 person	12 person
Content	1 person	9 person	12 person	40 person
Compe-tence	10 person	-	19 person	33 person
Attitudes	6 person	-	23 person	33 person

Based on table 3, it can be seen that the distribution of STEM literacy levels among prospective physics educators. This table provides information about the number of people in various categories of literacy levels based on the instruments used, namely STEM Literacy, Content, Competence, and Attitudes.

In the "Very high" category, which indicates a logit score greater than the Mean Logit + SD, there is only one person for the STEM Literacy and Content instruments. However, for the Competence instrument there are 10 people and for Attitudes there are 6 people. This shows that although only a few prospective physics educators have very high STEM literacy and content understanding, quite a few shows very high competence and attitude.

In the "High" category, which includes the logit score between Mean Logit and Mean Logit + SD, there were 34 people for the STEM Literacy instrument, 9 people for Content, but none for Competence and Attitudes. This shows that the majority of aspiring educators have high STEM literacy, although their understanding of the content is still limited and nothing stands out in competence and attitude.

The "Moderate" category, which includes the logit score between Mean Logit and Mean Logit - SD, includes 15 people for STEM Literacy, 12 people for Content, 19 people for competence, and 23 people for Attitudes. This suggests that most aspiring educators are at an intermediate level for competencies and attitudes, with smaller numbers in STEM literacy and content comprehension.

The "Low" category, which includes a logit score less than the Mean Logit - SD, shows that there are 12 people with low STEM literacy, 40 people with low content understanding, 33 people with low competence, and 33 people with low attitude. This shows significant challenges in content understanding among prospective educators, as well as the presence of a large number of people who are less competent and have a low attitude towards STEM literacy.

Overall, this analysis shows that while there are some aspiring physics educators who have very high competencies and attitudes, there is a need to improve their understanding of STEM content and literacy in general. This is important to consider in designing training and development programs for prospective physics educators, so that they can be more effective in teaching and promoting STEM literacy among students.

Discussion

Validity

Validity and reliability are important aspects in the development of assessment instruments to measure literacy in various fields, including STEM (Science, Technology, Engineering, and Mathematics). In this study, Rasch's analysis was carried out using Joint Maximum Likelihood Estimation (JMLE) for dichotomous data to validate STEM literacy tests adapted for prospective physics educators in Indonesia. The validation process involves analyzing the parameters of items and people to ensure the validity of the test.

Item and person matches are identified using the infit and outfit mean square (MNSQ) statistics, with an acceptable range of 0.5 to 1.5, although values up to 1.6 are still considered acceptable (Boone et al., 2014). Ideally, the match stats are close to 1.00 logits. In addition, the reliability of item separation indicates the test's ability to distinguish between items of varying levels of difficulty, with a value of more than 2 logits indicating a high-quality test. The results of Rasch's analysis presented in Table 1 confirm that the STEM literacy test meets the validity requirements according to the Rasch parameters for each task and the overall test. Rasch's summary of parameters for STEM Literacy shows:

The item and person outfit value of MNSQ is close to 1, indicating a good match with Rasch's model. A high item separation value (for example, 4.47 for Content) indicates the test's ability to distinguish between items of different difficulty levels.

A person separation value, such as 1.84 for Content, indicates the test's ability to distinguish between individuals with different levels of ability. A high percentage of unidimensionality, such as 52.4% for Content, indicates that the instrument measures one major construct.

These findings support the validity of the instrument in measuring STEM literacy among prospective physics educators, in accordance with the standards set by previous research on the creation of valid and reliable assessment tools (Boone et al., 2014; Mukti, Elvira, & Hussin, 2023)

Realibility

The reliability criteria were evaluated using several indicators, including the Rasch and Cronbach's alpha (α) people and item reliability parameters. WINSTEPS software generates people reliability values, item reliability, and Cronbach's alpha. Cronbach's alpha score ranges from 0.61 to 0.77 for all tasks and the overall test, indicating acceptable reliability. The reliability values of people and items range from 0.68 to 1.00, with values above 0.67 indicating acceptable reliability.

Reliability indicators for STEM Literacy, Content, Competencies, and Attitudes are summarized in Table 2:

A high item reliability value (for example, 0.95 for Content) indicates consistency in measuring the same construct. A people's reliability value, such as 0.77 for Content, indicates consistency in respondents' answers. Cronbach's high alpha score, especially 0.91 for STEM Literacy, reflects excellent internal consistency. These results suggest that this instrument is reliable for measuring STEM literacy, supporting the development of consistent and reliable assessment tools, as emphasized by previous research (Barnett et al., 2023; Liu, Lin, Sheu, & Sum, 2022).

This study emphasizes the importance of developing and validating reliable and valid STEM literacy assessment instruments. Using Rasch's measurement theory, this study confirms the validity and reliability of STEM literacy tests adapted for aspiring physics educators. This rigorous validation process ensures accurate and consistent measurement of STEM literacy, contributing to the improvement of STEM education. These findings are in line with the existing literature, highlighting the importance of practical and effective assessment instruments in various domains of literacy (Ahmadi, Niknami, & Ghaffari, 2022; Laupichler, Aster, Perschewski, & Schleiss, 2023).

These validated instruments can be used to improve STEM literacy among aspiring educators, ensuring they are prepared for the challenges of teaching in the 21st century. Future research should continue to refine this instrument and explore its application in various educational contexts to further support the development of STEM competencies.

STEM Literacy Level

The distribution of STEM literacy levels among aspiring physics educators, as illustrated in the table, shows significant variation. In the "Very High" category, only one person was recorded in the STEM Literacy and Content category, while 10 people were recorded in Competency and 6 people in Attitude. This shows that although only a few prospective educators have very high STEM literacy and content understanding, a significant proportion show high competence and attitude towards STEM education.

In the "High" category, there are 34 people who achieved high STEM literacy, 6 people in Content, but not in Competency and Attitude. This suggests that a large number of aspiring educators have a strong understanding of STEM literacy, although their understanding of content, competencies, and attitudes may require further development.

The "Moderate" category, which includes individuals with scores between the logit mean and the logit mean minus standard deviation, shows 15 people with moderate STEM literacy, 7 on Content, 19 on Competency, and 23 on Attitude. This distribution shows that although many prospective educators have a moderate level of competence and attitude, fewer have moderate STEM literacy and content understanding.

Finally, the "Low" category, which includes those whose scores are below the mean logit minus standard deviation, reveals significant challenges. Twelve people had low STEM literacy, 40 people with low content understanding, and 33 people each with low competence and attitude. This highlights the need for targeted interventions to improve overall STEM content knowledge and literacy among these educators.

These findings emphasize the importance of improving digital skills among aspiring physics educators. The digital literacy of prospective physics teachers is generally low, highlighting the need for improvement in the fields of data and information literacy, communication, collaboration, and digital content creation. This emphasizes the importance of improving digital skills among aspiring physics educators to address this gap (Rizal, 2023).

The multidisciplinary nature of STEM literacy, emphasizes the importance of integrating science, technology, engineering, and mathematics in an educational environment. Their study emphasizes the role of mathematical skills in promoting STEM literacy, demonstrating the interconnectedness of different disciplines in building a comprehensive understanding of STEM concepts (Ghani, Zhai, & Ahmad, 2021). Finally, the "Low" category, which includes those whose scores are below the mean logit minus standard deviation, reveals significant challenges. Twelve people had low STEM literacy, 40 people with low content understanding, and 33 people each with low competence and attitude. This highlights the need for targeted interventions to improve overall STEM content knowledge and literacy among these educators.

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The multidisciplinary nature of STEM literacy, emphasizes the importance of integrating science, technology, engineering, and mathematics in an educational environment. Their study emphasizes the role of mathematical skills in promoting STEM literacy, demonstrating the interconnectedness of different disciplines in building a comprehensive understanding of STEM concepts (Ghani, Zhai, & Ahmad, 2021).

The positive impact of the implementation of the STEM approach on the scientific competence and literacy of prospective teachers. This suggests that incorporating STEM strategies in teacher education programs can significantly improve educators' scientific knowledge and skills, which are critical for effective physics teaching (Asiyah, Febrini, Topano, Mustamin, & Hakim, 2024).

In conclusion, the combination of these studies emphasizes the importance of improving STEM literacy among aspiring physics educators through targeted interventions on digital literacy, multidisciplinary skills, technology integration, and scientific competence. By addressing these aspects, educational institutions can better prepare aspiring physics educators to teach and promote STEM literacy among students, thus encouraging a more science-literate generation.

Conclusion

STEM literacy among prospective physics educators varies significantly. Most prospective educators fall into the moderate to low categories, with only a few demonstrating very high levels of STEM literacy. This highlights the need for targeted interventions to enhance competencies and attitudes toward STEM literacy, including digital literacy, multidisciplinary skills, technology integration, and scientific competence. STEM literacy measurement instrument used in this study has been confirmed as valid and reliable based on Rasch analysis. Therefore, this instrument can be used to evaluate and improve the STEM literacy of prospective physics educators in the future. This research underscores the importance of educational institutions in preparing future educators to effectively teach and promote STEM literacy. Hence, the study makes a significant contribution to understanding the current level of STEM literacy among prospective physics educators and provides practical recommendations for improving STEM education in the future.

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Conflicts of Interest
The authors declare no conflict of interest.

References

Agussuryani, Q., Sudarmin, S., Sumarni, W., Cahyono, E., & Ellianawati, E. (2022). STEM Literacy in Growing Vocational School Student HOTS in Science Learning: A Meta-Analysis. *International Journal of Evaluation and Research in Education*, *11*(1), 51–60. https://doi.org/10.11591/ijere.v11i1.21647

Ahmad Kamal, F., Subali, B., Astuti, B., Rusilowati, A., & Widiyatmoko, A. (2024). Development of STEM-Based Digital Student Worksheet to Improve Students' Numeracy and Science Literacy. *Jurnal Penelitian Pendidikan IPA*, *10*(5 SE-Research Articles), 2454–2464. https://doi.org/10.29303/jppipa.v10i5.6689

Ahmadi, A., Niknami, S., & Ghaffari, M. (2022). Type 2 Diabetes Health Literacy Assessment Tool: Translation and Psychometric Evaluation of the Iranian Version. *International Journal of Endocrinology and Metabolism*, *20*(2). https://doi.org/10.5812/ijem-116983

Ali, R., Bhadra, J., Siby, N., Ahmad, Z., & Al-Thani, N. J. (2021). A STEM Model to Engage Students in Sustainable Science Education through Sports: A Case Study in Qatar. *Sustainability*, Vol. 13. https://doi.org/10.3390/su13063483

Anderson, T., & Shattuck, J. (2012). Design-Based Research: A Decade of Progress in Education Research? *Educational Researcher*, *41*(1), 16–25. https://doi.org/10.3102/0013189X11428813

Andrich, D. (2018). Advances in social measurement: A Rasch measurement theory. In *Perceived Health and Adaptation in Chronic Disease* (pp. 66–91). Routledge.

Ardianto, D., Firman, H., Permanasari, A., & Ramalis, T. R. (2019). What is Science, Technology, Engineering, Mathematics (STEM) Literacy? *Proceedings of the 3rd Asian Education Symposium (AES 2018)*, 381–384. Atlantis Press. https://doi.org/10.2991/aes-18.2019.86

Aryadoust, V., Tan, H. A. H., & Ng, L. Y. (2019). A Scientometric review of Rasch measurement: The rise and progress of a specialty. *Frontiers in Psychology*, *10*, 2197. https://doi.org/10.3389/fpsyg.2019.02197

Asiyah, Febrini, D., Topano, A., Mustamin, A. A., & Hakim, M. A. R. (2024). Measuring the Impact of Islamic Values-Based Scientific Literacy on Scientific Competency of Madrasah Teachers. *International Journal of Learning, Teaching and Educational Research*, *23*(4), 476–496. https://doi.org/10.26803/ijlter.23.4.25

Barnett, L. M., Jerebine, A., Keegan, R., Watson-Mackie, K., Arundell, L., Ridgers, N. D., … Dudley, D. (2023). Validity, Reliability, and Feasibility of Physical Literacy Assessments Designed for School Children: A Systematic Review. *Sports Medicine*, *53*(10), 1905–1929. https://doi.org/10.1007/s40279-023-01867-4

Blanchin, M., Guilleux, A., Hardouin, J.-B., & Sébille, V. (2020). Comparison of structural equation modelling, item response theory and Rasch measurement theory-based methods for response shift detection at item level: A simulation study. *Statistical Methods in Medical Research*, *29*(4), 1015–1029. https://doi.org/10.1177/0962280219884

Boone, W., Staver, J., & Yale, M. (2014). *Rasch Analysis in the Human Sciences*. Springer. https://doi.org/10.1007/978-94-007-6857-4

Braund, M. (2021). Critical STEM literacy and the COVID-19 pandemic. *Canadian Journal of Science, Mathematics and Technology Education*, *21*(2), 339–356. https://doi.org/10.1007/s42330-021-00150-w

Browne, J. P., & Cano, S. J. (2019). A Rasch measurement theory approach to improve the interpretation of patient-reported outcomes. *Medical Care*, *57*, S18–S23. https://doi.org/10.1097/MLR.0000000000001096

Bruckermann, T., Greving, H., Schumann, A., Stillfried, M., Börner, K., Kimmig, S. E., … Harms, U. (2021). To know about science is to love it? Unraveling cause–effect relationships between knowledge and attitudes toward science in citizen science on urban wildlife ecology. *Journal of Research in Science Teaching*, *58*(8), 1179–1202. https://doi.org/10.1002/tea.21697

Chen, K.-Z., & Oakley, B. (2020). Redeveloping a global MOOC to be more locally relevant: design-based research. *International Journal of Educational Technology in Higher Education*, *17*, 1–22.

https://doi.org/10.1186/s41239-020-0178-6
Egolf, R. S. (2022). *Exploration of Tuckman's Model of Group Development: Perceived Applications and Prevalence among Adventure Education Practitioners*. Prescott College.
Falloon, G., Hatzigianni, M., Bower, M., Forbes, A., & Stevenson, M. (2020). Understanding K-12 STEM education: A framework for developing STEM literacy. *Journal of Science Education and Technology*, *29*, 369–385. https://doi.org/10.1007/s10956-020-09823-x
Fisher, W. P. J. (2007). Rating Scale Instrument Quality Criteria. *Rasch Measurement Transactions*, *21*(1), 1095.
Ghani, U., Zhai, X., & Ahmad, R. (2021). Mathematics skills and STEM multidisciplinary literacy: Role of learning capacity. *STEM Education*, *1*(2), 104–113. https://doi.org/10.3934/steme.2021008
Ginting, F. W., Mellyzar, M., & Lukman, I. R. (2023). Analysis of Student Environmental Literacy: PjBL-Based Learning that is Integrated STEM. *Jurnal Penelitian Pendidikan IPA*, *9*(1 SE-Research Articles), 242–248. https://doi.org/10.29303/jppipa.v9i1.2599
Gravel, B. E., Tucker-Raymond, E., Kohberger, K., & Browne, K. (2018). Navigating worlds of information: STEM literacy practices of experienced makers. *International Journal of Technology and Design Education*, *28*, 921–938. https://doi.org/10.1007/s10798-017-9422-3
Hariyadi, S., Rofi, A., Santosa, T. A., Taqiyuddin, & Sakti, B. P. (2023). Effectiveness of STEM-Based Mind Mapping Learning Model to Improve Students' Science Literacy in the Era of Revolution 4.0. *Jurnal Penelitian Pendidikan IPA*, *9*(10 SE-Review), 791–799. https://doi.org/10.29303/jppipa.v9i10.5125
Huang, X., Erduran, S., Luo, K., Zhang, P., & Zheng, M. (2023). Investigating in-service teachers' STEM literacy: the role of subject background and gender. *Research in Science & Technological Education*, 1–21. https://doi.org/10.1080/02635143.2022.2153243
Hubbard, K. (2021). Disciplinary literacies in STEM: what do undergraduates read, how do they read it, and can we teach scientific reading more effectively? *Higher Education Pedagogies*, *6*(1), 41–65. https://doi.org/10.1080/23752696.2021.1882326
Ismail, Afriana, J., & Saputra, M. (2015). Models of integrated STEM (Sceince, Technology, Engneering, and Mathematis) Learning to Build Scientific Literacy. *Proceeding of International Seminar on Science Education*. Yogyakarta: UNY. https://doi.org/10.13140/RG.2.1.1914.8888
Ismail, I, Permanasari, A., & Setiawan, W. (2016). STEM virtual lab: An alternative practical media to enhance student's scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *5*(2), 239–246. https://doi.org/10.15294/jpii.v5i2.5492
Ismail, Ismail, Permanasari, A., & Setiawan, W. (2016). Efektivitas virtual lab berbasis STEM dalam meningkatkan literasi sains siswa dengan perbedaan gender. *Jurnal Inovasi Pendidikan IPA*, *2*(2), 190. https://doi.org/10.21831/jipi.v2i2.8570
Ismail, Ismail, Rochintaniawati, D., Permanasari, A., & Riandi, R. (2022). Content Study Of 7th-Grade Science Textbooks Using An Esd Viewpoint On Living Things And Their Surroundings. *Ta'dib*, *25*(1), 117–128. https://doi.org/10.31958/jt.v25i1.5447
Jackson, C., Mohr-Schroeder, M. J., Bush, S. B., Maiorca, C., Roberts, T., Yost, C., & Fowler, A. (2021). Equity-oriented conceptual framework for K-12 STEM literacy. *International Journal of STEM Education*, *8*, 1–16. https://doi.org/10.1186/s40594-021-00294-z
Junge, R., Bulc, T. G., Anseeuw, D., Yavuzcan Yildiz, H., & Milliken, S. (2019). *Aquaponics as an Educational Tool BT - Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future* (S. Goddek, A. Joyce, B. Kotzen, & G. M. Burnell, Eds.). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-15943-6_22
Karimah, F., & Wulandari, F. (2023). The Influence of an Integrated STEM Project-Based Learning toward garScience Literacy Abilities Students in Elementary School. *Jurnal Penelitian Pendidikan IPA*, *9*(11 SE-Research Articles), 10446–10456. https://doi.org/10.29303/jppipa.v9i11.4171
Kleppang, A. L., Steigen, A. M., & Finbråten, H. S. (2020). Using Rasch measurement theory to assess the psychometric properties of a depressive symptoms scale in Norwegian adolescents. *Health and Quality of Life Outcomes*, *18*, 1–8. https://doi.org/10.1186/s12955-020-01373-5
Laksono, A., Rusilowati, A., & Widiyatmoko, A. (2023). Development and Validation of STEM-Based Science Digital Worksheet on Object Motion Material for Junior High School Students . *Jurnal Penelitian Pendidikan IPA*, *9*(5 SE-Research Articles), 2664–2669. https://doi.org/10.29303/jppipa.v9i5.3720
Laupichler, M. C., Aster, A., Perschewski, J.-O., & Schleiss, J. (2023). Evaluating AI Courses: A Valid and Reliable Instrument for Assessing Artificial-Intelligence Learning through Comparative Self-Assessment. *Education Sciences*, Vol. 13. https://doi.org/10.3390/educsci13100978

Lestari, H., Rahmawati, I., Siskandar, R., & Dafenta, H. (2021). Implementation of Blended Learning with A STEM Approach to Improve Student Scientific Literacy Skills During The Covid-19 Pandemic. *Jurnal Penelitian Pendidikan IPA*, *7*(2 SE-Research Articles), 224–231. https://doi.org/10.29303/jppipa.v7i2.654

Linacre, John M. (2021). *Winsteps® Rasch measurement computer program User's Guide*. Beaverton, Oregon: Winsteps.com.

Liu, C.-Y., Lin, L. L., Sheu, J.-J., & Sum, R. K. (2022). Psychometric Validation of Senior Perceived Physical Literacy Instrument. *International Journal of Environmental Research and Public Health*, Vol. 19. https://doi.org/10.3390/ijerph19116726

Moullin, J. C., Ehrhart, M. G., & Aarons, G. A. (2018). Development and testing of the Measure of Innovation-Specific Implementation Intentions (MISII) using Rasch measurement theory. *Implementation Science*, *13*, 1–10. https://doi.org/10.1186/s13012-018-0782-1

Mukti, T. S., Elvira, M., & Hussin, Z. B. (2023). Development of the Game-based HOTS Assessment Instrument for Measuring Science Literacy Skills of Islamic Elementary School Students. *Al Ibtida: Jurnal Pendidikan Guru MI*, *10*(1), 63. https://doi.org/10.24235/al.ibtida.snj.v10i1.11393

Papavlasopoulou, S., Giannakos, M. N., & Jaccheri, L. (2019). Exploring children's learning experience in constructionism-based coding activities through design-based research. *Computers in Human Behavior*, *99*, 415–427. https://doi.org/10.1016/j.chb.2019.01.008

Patricia Diane Mouboua, Fadeke Adeola Atobatele, & Olateju Temitope Akintayo. (2024). Bridging STEM and linguistic gaps: A review of multilingual teaching approaches in science education. *Open Access Research Journal of Multidisciplinary Studies*, *7*(2), 086–097. https://doi.org/10.53022/oarjms.2024.7.2.0030

Peters, C. N. (2024). Children's books for research-based outreach and science communication pedagogy. *Geoscience Communication*, *7*(2), 81–90. https://doi.org/10.5194/gc-7-81-2024

Planinic, M., Boone, W. J., Susac, A., & Ivanjek, L. (2019). Rasch analysis in physics education research: Why measurement matters. *Physical Review Physics Education Research*, *15*(2), 20111. https://doi.org/10.1103/PhysRevPhysEducRes.15.020111

Putri, N. H. D., & Ramli, R. (2023). Preliminary Study: Development of STEM-Based E-Students Worksheet to Improve Learners' Science Literacy Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(4 SE-Research Articles), 2271–2275. https://doi.org/10.29303/jppipa.v9i4.3011

Rasmussen, S. E., Aaby, A., Søjbjerg, A., Mygind, A., Maindal, H. T., Paakkari, O., & Christensen, K. S. (2023). The Brief Health Literacy Scale for Adults: Adaptation and Validation of the Health Literacy for School-Aged Children Questionnaire. *International Journal of Environmental Research and Public Health*, Vol. 20. https://doi.org/10.3390/ijerph20227071

Rizal, R. (2023). Could the digital literacy of preservice physics teachers be improved by Learning Management System Supported Smartphone (LMS3) application in a physics online lecture? *Physics Education*, *58*(2), 25004. https://doi.org/10.1088/1361-6552/aca864

Rizki, M., & Yusmaita, E. (2021). Pengembangan Butir Soal Literasi Kimia pada Materi Ikatan Kimia Menggunakan Model Rasch. *Edukimia*, *3*(2), 121–134. https://doi.org/10.24036/ekj.v3.i2.a282

Sole, F. B. (2021). Implementation of STEM-Based Learning for Strengthening Science Literacy of Students. *Jurnal Penelitian Pendidikan IPA*, *7*(SpecialIssue SE-Review), 382–388. https://doi.org/10.29303/jppipa.v7iSpecialIssue.1266

Stemler, S. E., & Naples, A. (2021). Rasch measurement v. Item response theory: knowing when to cross the line. *Practical Assessment, Research & Evaluation*, *26*, 11. https://doi.org/10.7275/v2gd-4441

Sujud, R., Rahmawati, Y., & Utami, A. D. (2024). Development of Science Literacy Through Group Choice STEM-PjBL Projects Integrated with Matter State Changes. *Jurnal Penelitian Pendidikan IPA*, *10*(5 SE-Research Articles), 2552–2564. https://doi.org/10.29303/jppipa.v10i5.6441

Supriyatman, S., Kade, A., Darmadi, I. W., Miftah, M., Supriyadi, S., & Ismail, I. (2024). Competence of Junior high Schools' Science Teachers in Implementing Laboratory Teaching: A Case Study on Palu, Centre Celebes. *Jurnal Penelitian Pendidikan IPA*, *10*(6 SE-Research Articles), 3114–3122. https://doi.org/10.29303/jppipa.v10i6.7510

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, *48*, 1273–1296.

Tang, K., & Williams, P. J. (2019). STEM literacy or literacies? Examining the empirical basis of these constructs. *Review of Education*, *7*(3), 675–697. https://doi.org/10.1002/rev3.3162

Techakosit, S., & Nilsook, P. (2018). The development of

STEM literacy using the learning process of scientific imagineering through AR. *International Journal of Emerging Technologies in Learning (IJET)*, *13*(1), 230–238. https://doi.org/10.3991/ijet.v13i01.7664

Tenney, K., Stringer, B. P., LaTona-Tequida, T., & White, I. (2023). Conceptualizations and limitations of STEM literacy across learning theories. *Journal of Microbiology & Biology Education*, *24*(1), e00168-22. https://doi.org/10.1128/jmbe.00168-22

Tuckman, B. W. (1965). Developmental sequence in small groups. *Psychological Bulletin*, *63*(6), 384. https://doi.org/10.1037/h0022100

Wahyu, Y., Edu, A. L., & Helmon, A. (2023). STEM-based PjBL Learning Model with Manggaraians Indigenous Science Content to Improve Science Literacy: is it Effective? . *Jurnal Penelitian Pendidikan IPA*, *9*(10 SE-Research Articles), 8263–8273. https://doi.org/10.29303/jppipa.v9i10.4963

Widiyatmoko, A., Nugrahani, R., Yanitama, A., & Darmawan, M. S. (2023). the Effect of Virtual Reality Game-Based Learning To Enhance Stem Literacy in Energy Concepts. *Jurnal Pendidikan IPA Indonesia*, *12*(4), 648–657. https://doi.org/10.15294/jpii.v12i4.48265

Wu, Z., Huang, L., Liu, Y.-K., & Chiang, F.-K. (2024). Developing a Framework of STEM Literacy for Kindergarten Children. *Research in Science Education*, 1–23. https://doi.org/10.1007/s11165-024-10157-6

Zarestky, J., & Vilen, L. (2023). Adult STEM Education for Democratic Participation. *Adult Learning*, *34*(3), 157–167. https://doi.org/10.1177/10451595231153133

Zirar, A., Muhammad, N., Upadhyay, A., Kumar, A., & Garza-Reyes, J. A. (2023). Exploring lean team development from the Tuckman's model perspective. *Production Planning & Control*, 1–22. https://doi.org/10.1080/09537287.2023.2275693