

AL-MUSANNIF | EDUCATIONAL STUDIES
Character, Moral, and Community-Based Education | Research



<https://journal.cognifera.web.id/index.php/al-musannif>

Item Analysis of a Physics Technological Literacy Test on Work and Energy

Abdul Rafid Fakhrun Gani*, Dewi Wulandari, Yuni Warty
Universitas Negeri Medan, Medan, Indonesia

Article History:

Received: May 21, 2026
Revised: June 17, 2026
Accepted: June 26, 2026

***Correspondence:**

Address:

Willem Iskandar Pasar V Street,
Medan, North Sumatra, Indonesia

Email:

abdulrafidfg@gmail.com

Keywords:

Technological literacy, physics education, work and energy, test instrument development.

Abstract:

This study aimed to develop and analyze a physics technological literacy test instrument on the topic of work and energy for senior high school students. This study addresses the limited availability of technological literacy assessment instruments specifically designed for the topic of work and energy in physics education. The research used a Research and Development (R&D) approach with the ADDIE development model, consisting of analysis, design, development, implementation, and evaluation stages. The instrument was developed based on three dimensions of technological literacy: knowledge, capabilities, and critical thinking and decision making. The study involved 200 students from several senior high schools in Binjai City, Indonesia. Data were analyzed using validity, reliability, and Rasch model analyses to evaluate the quality of the instrument. The results showed that the instrument was highly feasible, with evaluation expert validation of 92,13% and material expert validation of 90,4%. Practicality testing also indicated that the instrument was practical and easy to use. All items were categorized as valid and reliable, with a Cronbach's Alpha coefficient of 0.935. The Rasch analysis demonstrated that the instrument could accurately measure students' technological literacy abilities across various ability levels. The findings indicate that the developed instrument is valid, reliable, practical, and effective for measuring students' technological literacy in physics learning, and it can serve as an assessment tool for teachers to evaluate and improve students' technological literacy skills.

INTRODUCTION

Technological literacy is one of the essential 21st-century skills that students must possess in order to compete in the era of the Industrial Revolution. The International Technology Education Association (ITEA) (2007) defines technological literacy as the ability to understand, use, analysis, and evaluate technology. Technological literacy is an important competency for students, as individuals with strong technological literacy can more easily access various learning resources, thereby enhancing their competencies and academic development (Nuraeni, Pattiasina, and Ulfah 2022). Furthermore, technological literacy is not limited to understanding and utilizing technology; it also refers to the development of critical thinking skills in evaluating technology as well as understanding the ethics and responsibilities associated with its use (Davies 2011; Zam 2021). Technological literacy can be achieved when

the learning process integrates technology and science into educational practices, including both instructional activities and assessment processes (Gani and Sabani 2024).

The level of technological literacy among students in Indonesia is still categorized as low. According to the IMD World Competitiveness Center World Digital Competitiveness Ranking survey (2024), Indonesia demonstrated a relatively low score of 47.29 in terms of the knowledge required to discover, understand, and develop new technologies. The survey ranked Indonesia 53rd out of 67 participating countries. In line with these findings, a survey conducted by PUSDATEKOM reported that only 14% of approximately 28,000 teachers in Indonesia were capable of integrating technology into the learning process. The low level of technological literacy among teachers has a significant impact on the quality of the learning process (Santyadiputra and Kustono 2023). These issues highlight the necessity for both teachers and students to implement technological literacy in educational activities, as inadequate technological literacy can create learning difficulties and even trigger frustration.

Physics learning is an educational process that integrates conceptual understanding, the development of scientific attitudes, and the achievement of meaningful learning outcomes. In physics education, students are not only expected to understand laws and theories, but also to develop scientific and investigative thinking skills (Bao and Koenig 2019). In practice, physics learning cannot be separated from the use of various technologies. Technology is not merely related to the tools utilized during the learning process, but also to the subject matter discussed in instruction. Physics content is inherently connected to technological applications because many implementations of physical laws and theories are manifested in the form of technology (Gani and Sabani 2024). The application of physical laws can be observed through various technologies that operate based on physics principles. Therefore, students are required to understand and apply technologies that utilize physical laws in everyday life. In other words, students are expected to possess technological literacy skills within the context of physics learning (Farhodovna, Olimboevich, and Badriddinovich 2020).

The results of observations conducted in two schools in Binjai indicated that both schools had integrated physics learning with technological applications in everyday life. Students were assigned tasks that required them to relate technological applications to daily activities. In general, both schools assessed the learning process through three aspects, namely cognitive, affective, and psychomotor domains. Cognitive assessment was conducted through written tests measuring learning achievement, affective assessment was based on teacher observation sheets, and psychomotor assessment was evaluated through students' science process skills. Interview results also revealed that MAN Binjai had implemented technological literacy assessments for students. The existing instrument included various technology-based contexts related to fluid mechanics. However, it mainly emphasized technological products and design applications. The developed literacy test had not yet measured technological literacy in the context of technology's impact on society or the characteristics of technology itself, even though students' understanding of the societal impacts and characteristics of technology is important to assess. Therefore, it is necessary to develop an instrument capable of measuring all aspects and contexts of technological literacy comprehensively.

Technological literacy is still not widely assessed in several schools in Binjai because many teachers have not yet developed technological literacy assessment instruments. In fact, numerous studies on technological literacy have already been conducted and measured. Pearson and Garmire (2006), through technological literacy assessment standards, provided assessment dimensions as well as several examples of technological literacy tests. Research conducted by (Bahri et al. 2020) aimed to develop an assessment instrument that could be used to measure technological literacy among physics teachers in the Merauke region. Similarly, (Nikat 2020) attempted to design a formative assessment instrument for teachers in order to obtain a clearer understanding of their level of technological literacy.

Although several studies have developed technological literacy assessment instruments, most focus on teachers' competencies or general science contexts. Few studies have developed and validated technological literacy instruments specifically for physics learning, particularly on work and energy topics. Moreover, studies reporting comprehensive psychometric evaluation using both classical test theory and Rasch model analysis remain limited. Therefore, this study addresses this gap by developing and validating a technological literacy assessment instrument for senior high school physics on work and energy.

METHODS

The study was conducted in Binjai by involving two schools as the research subjects. The research was conducted from June 2025 to February 2026. The population of the study consists of two senior high schools in Binjai, namely SMAN 1 Binjai and MAN Binjai. The sample of the study consisted of 200 senior high school students from the two schools in Binjai. The sampling technique employed in this research is proportional stratified random sampling, which is a sampling technique in which the population is divided into several subgroups (strata), and samples are then randomly selected according to the proportional number of members within each stratum (Sani 2022).

This study employed a research and development (R&D) approach using both qualitative and quantitative methods. Research and development is a research method aimed at developing a product and improving existing products (Okpatrioka 2023). Descriptive research is a research method intended to systematically and factually describe a phenomenon or condition as it naturally occurs (Leedy and Ormrod 2015; Ramdhan 2021). The development model applied in this study was the ADDIE model, which consists of five stages: Analyze, Design, Develop, Implement, and Evaluate (Branch 2009). The stages of the ADDIE model are presented in Figure 1.

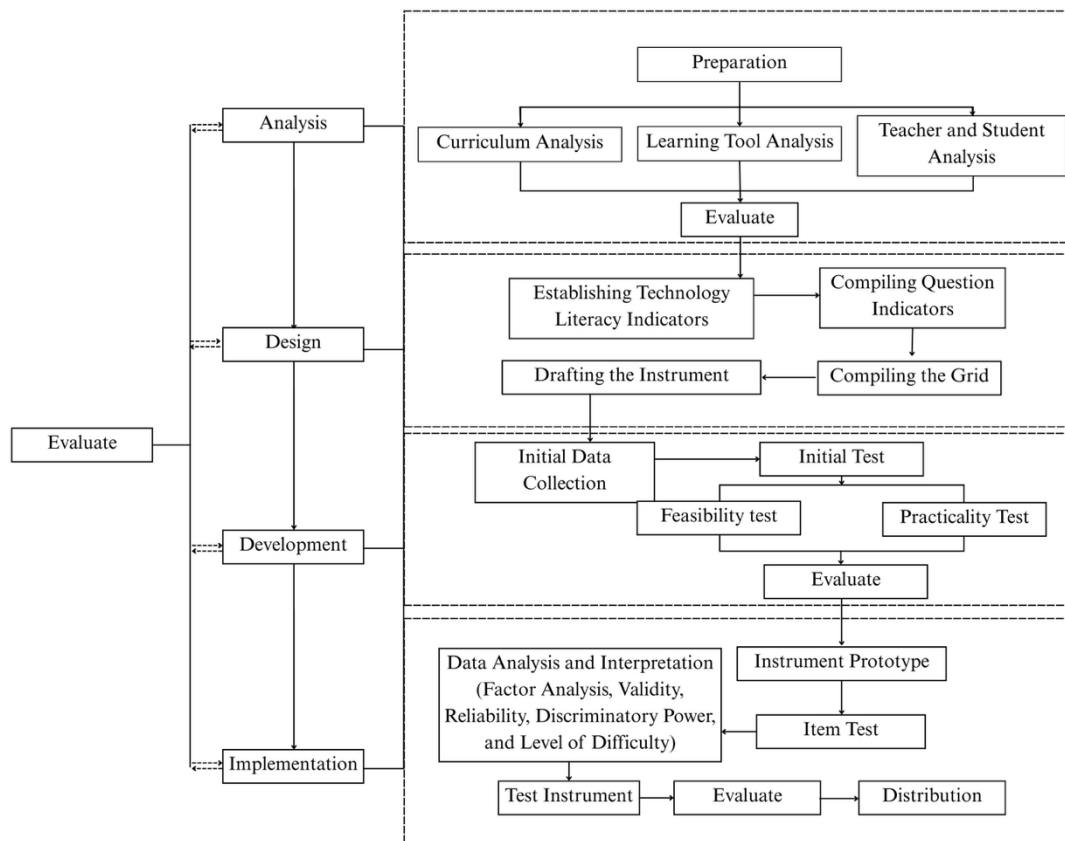


Figure 1. ADDIE Development Model

This study employed the ADDIE development model, which consists of the analysis, design, development, implementation, and evaluation stages, to develop a technological literacy test instrument for senior high school students in Binjai. The analysis stage was conducted through curriculum and ATP analysis, teacher interviews, student questionnaires, task analysis, and teaching module analysis to determine the suitability of technology literacy-based learning and assessment practices. The design stage included determining technological literacy indicators and levels, developing test item indicators, constructing the instrument blueprint, and designing a draft instrument consisting of 15 questions on the topic of work and energy (Table 1).

The development stage involved validation by experts in educational evaluation, technological literacy, physics content, and instructional design, as well as practicality testing conducted by teachers and students. Furthermore, the implementation stage was carried out in two schools involving a total of 200 students to obtain research data, while the evaluation stage was conducted throughout the entire development process in order to refine and improve the developed instrument.

Table 1. Blueprint of Technological Literacy Test

No	Variable	Indicator	Item Number	Minimum Score	Maximum Score	Cognitive Level
1	Knowledge	Understanding technological concepts related to work and energy	1, 6, 7, 11, 14	0	6	C3
2	Capability	Applying technological knowledge in real-life situations	2, 4, 8, 9, 13	0	10	C4
3	Critical Thinking and Decision Making	Analyzing, evaluating, and selecting appropriate technologies	3, 5, 10, 12, 15	0	14	C5

Item analysis in this study was conducted to ensure that the physics technological literacy test instrument possesses valid, reliable, and appropriate quality for use. The primary analysis employed the Item Response Theory (IRT) approach using the Rasch model assisted by the Jmetrik software, as this model is capable of producing objective and invariant measurements in which students' abilities and item characteristics are independent of one another. Item fit was analyzed through the Infit and Outfit Mean Square (MNSQ) values as well as Z-Standard (ZSTD), with acceptable criteria of MNSQ ranging from 0.5 to 1.5 and ZSTD ranging from -2.0 to $+2.0$. The level of item difficulty was determined based on logit values, categorized as easy items ($\text{logit} < -1.0$), moderate items (-1.0 to $+1.0$), and difficult items ($> +1.0$). Instrument reliability was analyzed through item and person reliability, while the Wright Map was used to map the compatibility between students' abilities and item difficulty levels. In addition, Differential Item Functioning (DIF) analysis was conducted to detect potential item bias. This study also employed the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA) test to measure sample adequacy and the feasibility of factor analysis. A KMO value approaching 1 indicates that the data are suitable for analysis, whereas an MSA value below 0.50 indicates that the variable is not feasible and should be eliminated. Furthermore, Exploratory Factor Analysis (EFA) was utilized to examine the construct validity of the instrument based on three main indicators, namely knowledge, capabilities, and critical thinking and decision-making. EFA was intended to ensure that the instrument items accurately represent the construct of physics technological literacy in accordance with the theoretical model that had been designed. Validity testing was conducted using Pearson correlation assisted by SPSS to determine the degree of relationship between each item and the measured variable, while reliability testing employed Cronbach's Alpha to determine the internal consistency of the instrument. An alpha value closer to 1 indicates higher reliability. In addition, discrimination index analysis was conducted to determine the ability of the items to distinguish between high-ability and low-ability students, with a discrimination index criterion greater than 0.3. Item difficulty levels were also analyzed using SPSS with the following categories: easy

(0.70–1.00), moderate (0.30–0.70), and difficult (0.00–0.30). All of these analyses were conducted to ensure that the developed test instrument is valid, reliable, objective, and appropriate for measuring students' physics technological literacy.

RESULTS AND DISCUSSION

The final product of this study is a technological literacy-based test instrument on the topic of work and energy for senior high school/Islamic senior high school (SMA/MA) students. The selection of the work and energy topic was based on the results of preliminary observations conducted in the sample schools, which were subsequently formulated into the research problem.

Table 1 illustrates the alignment between the technological literacy dimensions, indicators, cognitive levels, and corresponding test items. This alignment demonstrates that the developed instrument was systematically constructed to ensure content representation across all targeted dimensions of technological literacy. Furthermore, the inclusion of various cognitive levels ranging from understanding to evaluation supports the instrument's ability to assess students' technological literacy comprehensively.

This instrument was designed to measure students' technological literacy skills and has undergone validation, testing, and evaluation stages by educational evaluation experts and physics content experts (Fahrurrozi and Rahmawati 2021; Hamidah and Wulandari 2021). The feasibility test results are presented in Table 2.

Table 2. Expert Validation Result

No	Item Test	Evaluation Expert	Material Expert
1	Item 1	90%	90%
2	Item 2	92%	92%
3	Item 3	94%	90%
4	Item 4	92%	92%
5	Item 5	90%	88%
6	Item 6	92%	90%
7	Item 7	94%	92%
8	Item 8	92%	88%
9	Item 9	92%	90%
10	Item 10	94%	90%
11	Item 11	92%	92%
12	Item 12	90%	88%
13	Item 13	92%	90%
14	Item 14	94%	92%
15	Item 15	92%	92%

The feasibility test results indicated that the instrument was highly appropriate for use. The evaluation expert assessment obtained an average score of 92.13%, which was categorized as highly feasible, particularly in terms of construct and language aspects. Meanwhile, the material expert provided a score of 90.4%, which also fell into the highly feasible category. Nevertheless, several suggestions were provided, particularly regarding the need to increase and diversify the technological contexts used in the critical thinking and decision-making

indicators, especially in items requiring students to select the most appropriate technology. Feedback from both validators was used as the basis for revising and improving the instrument.

The practicality test was conducted by physics teachers at MAN Binjai and SMAN 1 Binjai, and the results showed that the instrument was categorized as practical. In terms of construct, the instrument was considered appropriate with respect to relevance, presentation time, result management, efficiency, instructions for use, and overall appearance.

Table 3. Practicality Result

Indikator	Kriteria
Relevance	90%
Time of presentation	93%
Results management	95%
Efficiency	90%
Process instructions	90%
Appearance	93%

The practicality test results indicated that the instrument was practical to use, with percentage scores ranging from 90% to 95%. In other words, teachers strongly agreed that the technological literacy instrument was easy to implement. Overall, the developed instrument was considered practical, user-friendly, and capable of effectively measuring students' technological literacy skills. Suggestions from validators and practitioners served as the basis for refining and improving the instrument before its further implementation in the learning process.

The field testing involved students from MAN Binjai and SMAN 1 Binjai. A total of 200 students participated in the study. Both schools were selected because they had implemented the Merdeka Curriculum and possessed adequate facilities to support physics learning. Therefore, the participants represented urban secondary school students with relatively similar educational backgrounds.

All item indicators were analyzed using the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA) correlation statistics to evaluate each indicator. The results of the KMO-MSA test are presented in Table 4.

Table 4. KMO-MSA Indicator Value

No	Variabel	Nilai Signifikansi	Nilai MSA	Kategori
1	Knowledge	0.000	0,830	Valid
2	Capability	0.000	0,749	Valid
3	Critical Thinking and Decision Making	0.000	0,818	Valid

The instrument trial involved three variables of technological literacy, namely the aspects of knowledge, capabilities, and critical thinking and decision-making, each consisting of five test items. A variable is considered to meet the criteria if it has a significance value of less than 0.05 (Aswar, Haeruddin, and Hasdiansa 2023). The analysis results showed that the first variable obtained a significance value of 0.00 and was therefore categorized as valid. The second variable also demonstrated a significance value of 0.00 and was classified as valid.

Similarly, the third variable obtained a significance value of 0.00 and was declared valid. Based on these findings, it can be concluded that all three variables were consistent with the constructs being measured. Therefore, the developed test instrument was considered valid both in terms of the individual test items and the variables represented. The MSA values for each item are presented in Table 5.

Table 5. Hasil Nilai MSA

Variable	MSA Value	Standard Value
Item 1	0.847	0,5
Item 2	0.849	0,5
Item 3	0.908	0,5
Item 4	0.913	0,5
Item 5	0.929	0,5
Item 6	0.945	0,5
Item 7	0.940	0,5
Item 8	0.920	0,5
Item 9	0.912	0,5
Item 10	0.957	0,5
Item 11	0.917	0,5
Item 12	0.966	0,5
Item 13	0.905	0,5
Item 14	0.944	0,5
Item 15	0.974	0,5

The results of the factor analysis indicated that all variables had obtained MSA values that met the required criteria, meaning that each variable could be analyzed further. Furthermore, Figure 2 presents the extraction results in detail using the Principal Components Analysis (PCA) method.

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.565	57.103	57.103	8.565	57.103	57.103	3.846	25.640	25.640
2	1.275	8.499	65.601	1.275	8.499	65.601	3.708	24.722	50.362
3	1.010	6.730	72.332	1.010	6.730	72.332	3.296	21.970	72.332
4	.743	4.952	77.283						
5	.519	3.462	80.745						
6	.439	2.930	83.675						
7	.396	2.637	86.312						
8	.389	2.591	88.903						
9	.329	2.194	91.097						
10	.320	2.136	93.234						
11	.261	1.743	94.977						
12	.254	1.694	96.671						
13	.214	1.424	98.096						
14	.171	1.141	99.236						
15	.115	.764	100.000						

Extraction Method: Principal Component Analysis.

Figure 2. Principal Components Analysis Result

Based on the factor analysis using the Principal Component Analysis (PCA) method, three factors with eigenvalues greater than 1 were obtained, namely 8.565, 1.275, and 1.010, indicating that these factors were appropriate to retain. These three factors explained variances

of 57.103%, 8.499%, and 6.730%, respectively, with a cumulative total variance of 72.332%. After rotation, the variance contributions became more evenly distributed at 25.640%, 24.722%, and 21.970%, respectively. Therefore, it can be concluded that the instrument possesses three main factors capable of representing the measured constructs and supporting the construct validity of the instrument. The emergence of three factors representing knowledge, capability, and critical thinking and decision-making supports the theoretical framework of technological literacy adopted in this study. Similar dimensions have been reported in technological literacy studies conducted in engineering education. However, the present findings demonstrate that these dimensions can also be identified within a physics learning context. This finding provides preliminary empirical evidence that technological literacy can be operationalized and measured through physics content, particularly in topics that closely relate scientific principles to technological applications such as work and energy.

Although previous technological literacy studies have predominantly been conducted in engineering and technology education (Pearson and Garmire 2006; Rupnik and Avsec 2020; Avsec and Kocijancic 2014; Avsec and Jamšek 2015; Gu, Xu, and Hong 2019), the present findings suggest that a similar multidimensional structure can also be identified in physics education contexts. Therefore, this study extends existing technological literacy research by providing empirical evidence that the dimensions of knowledge, capability, and critical thinking and decision-making can be measured through physics learning materials, particularly on the topic of work and energy. Previous studies have primarily focused on technological literacy assessment in engineering education. The present study extends this line of research by applying the technological literacy framework to secondary physics education and demonstrating that the dimensions of knowledge, capability, and critical thinking can also be measured within the context of work and energy learning.

Table 6. Factor Loading Analysis

Variable	Factor Group		
	1	2	3
Item 1	0.855		
Item 2	0.900		
Item 3			0.843
Item 4		0.662	
Item 5			0.773
Item 6	0.673		
Item 7		0.512	
Item 8	0.652		
Item 9	0.638		
Item 10			0.686
Item 11	0.556		
Item 12			0.588
Item 13		0.869	
Item 14		0.757	
Item 15		0.513	

Loading values indicate the correlation between variables and the factors formed. The higher the loading value, the stronger the relationship between the variable and the factor. The knowledge indicator in Factor 1 included items 1, 2, 6, 8, 9, and 11. Among these, items 1, 6, and 11 were consistent with the originally planned construct. The capability indicator in Factor 2 included items 4, 7, 13, 14, and 15. Items 4 and 13 were identified as being consistent with the intended construct. Meanwhile, the critical thinking and decision-making indicator in Factor 3 included items 3, 5, 10, and 12. All of these items were consistent with the planned construct.

In the factor analysis, the KMO-MSA values obtained for the three variables were knowledge (0.830), capabilities (0.749), and critical thinking and decision-making (0.818), all of which exceeded the minimum threshold of 0.5. In addition, the significance values for all three variables were 0.000 (<0.05), indicating that the data were appropriate for further analysis (Aswar, Haeruddin, and Hasdiansa 2023). These findings suggest that the construct structure of the instrument was consistent with the dimensions of technological literacy that had been designed. Although technological literacy assessment has been widely discussed in engineering and technology education, studies focusing on technological literacy instruments in physics education remain limited. Previous research has primarily developed instruments to measure technological literacy among engineering students or within technology-oriented learning environments. Consequently, there is still a lack of validated assessment tools specifically designed to evaluate technological literacy in secondary physics learning contexts, particularly on the topic of work and energy. The present study addresses this gap by developing and validating a technological literacy instrument tailored to physics education. Unlike engineering-based instruments, which often emphasize technological design and professional problem-solving, the developed instrument integrates physics concepts with technological contexts that are relevant to senior high school students. Therefore, the findings contribute to expanding technological literacy assessment beyond engineering education and provide an initial framework for measuring technological literacy within physics learning environments.

This finding was further supported by the extraction results using the Principal Component Analysis (PCA) method, which produced three main factors with eigenvalues greater than 1 and a cumulative total variance of 72.332%. This value indicates that most of the data variation could be explained by the three extracted factors, thereby supporting the construct validity of the instrument. Nevertheless, the factor loading analysis revealed that not all test items were grouped perfectly according to the initial indicators. Several items shifted across factors, indicating the presence of overlap among constructs. This condition is still acceptable in instrument development research; however, it suggests the need for refinement in the wording or contextualization of the items so that they more specifically represent the intended indicators being measured (Baharum et al. 2023; Güvendir and Özkan 2022).

Item validity testing was conducted to evaluate the extent to which each test item was capable of measuring the intended aspects of technological literacy. Through this analysis, valid and appropriate items could be identified, as well as items that required revision or elimination. The validity test was conducted using Pearson correlation analysis, and the results are presented in Table 7.

The validity test results indicated that all 15 items accurately measured students' technological literacy. Furthermore, the item validity test using Pearson correlation analysis showed that all test items had relatively high correlation values ranging from 0.643 to 0.839 and were categorized as valid. This finding demonstrates that each item was capable of accurately measuring aspects of technological literacy. Therefore, it can be concluded that all test items were appropriate for use without requiring elimination.

Table 7. Pearson Correlation Result Test

No	Variable	Correlation Value	Category
1	Item 1	0.684	Valid
2	Item 2	0.719	Valid
3	Item 3	0.675	Valid
4	Item 4	0.709	Valid
5	Item 5	0.695	Valid
6	Item 6	0.819	Valid
7	Item 7	0.742	Valid
8	Item 8	0.811	Valid
9	Item 9	0.792	Valid
10	Item 10	0.793	Valid
11	Item 11	0.839	Valid
12	Item 12	0.838	Valid
13	Item 13	0.643	Valid
14	Item 14	0.732	Valid
15	Item 15	0.784	Valid

The reliability test was conducted to determine the consistency level of the instrument in measuring students' technological literacy abilities. A reliable instrument is expected to produce stable and consistent results when administered under relatively similar conditions. Reliability testing was carried out using Cronbach's Alpha analysis, and the results are presented in Figure 3.

Reliability Statistics	
Cronbach's Alpha	N of Items
.935	15

Figure 3. Reliability Result Test

The developed instrument was categorized as reliable, with a Cronbach's Alpha reliability coefficient of $0.935 > 0.60$. These results indicate that all test items were reliable and dependable. In terms of reliability, the instrument obtained a Cronbach's Alpha value of 0.935, which falls into the very high category. This finding demonstrates that the instrument possesses excellent internal consistency, enabling it to produce stable and trustworthy data. High reliability also indicates that the test items have strong interrelationships in measuring the same construct.

Discrimination index analysis was conducted to determine the ability of each test item to distinguish between students with high and low levels of ability. A good test item is one that

can clearly differentiate between these two groups. The discrimination index results are presented in Table 8.

The discrimination index analysis showed that all test items were categorized as good, indicating that the instrument was capable of effectively distinguishing between students with high and low levels of ability. The discrimination values ranged from 0.3001 to 0.6648, which exceeded the minimum acceptable criterion of 0.30. These findings demonstrate that the developed instrument possessed adequate discriminatory power and was effective in differentiating students' technological literacy abilities.

Table 8. Discrimination Test Result

No	Variable	Discrimination Value	Category
1	Item 1	0,4012	Good
2	Item 2	0,6222	Good
3	Item 3	0,3001	Good
4	Item 4	0,4685	Good
5	Item 5	0,3001	Good
6	Item 6	0,5	Good
7	Item 7	0,496	Good
8	Item 8	0,5314	Good
9	Item 9	0,6648	Good
10	Item 10	0,390	Good
11	Item 11	0,5833	Good
12	Item 12	0,5132	Good
13	Item 13	0,4851	Good
14	Item 14	0,5216	Good
15	Item 15	0,4576	Good

The item difficulty test was conducted to classify the test items according to their level of difficulty, namely easy, moderate, or difficult. This analysis is important to ensure that the distribution of item difficulty levels is balanced and aligned with the objectives of the assessment.

Table 9. Item Difficulty Test Result

No	Variable	Difficulty Value	Category
1	Item 1	0,7658	Easy
2	Item 2	0,6015	Moderate
3	Item 3	0,3653	Moderate
4	Item 4	0,4695	Moderate
5	Item 5	0,3360	Moderate
6	Item 6	0,7683	Easy
7	Item 7	0,6475	Moderate
8	Item 8	0,536	Moderate
9	Item 9	0,5475	Moderate
10	Item 10	0,3575	Moderate
11	Item 11	0,7141	Easy
12	Item 12	0,3546	Moderate
13	Item 13	0,428	Moderate
14	Item 14	0,6075	Moderate
15	Item 15	0,3428	Moderate

The item difficulty analysis indicated that most test items were categorized as moderate, while several items, such as Item 1 and Item 6, were classified as easy. This distribution suggests that the instrument possessed a balanced level of difficulty and was appropriate for measuring students across varying ability levels. Moderate items are considered effective in providing accurate information about students' competencies because they are neither too difficult nor too easy.

The Rasch Model analysis was conducted to examine the quality of the test items and students' responses in greater depth. Through this approach, information regarding item fit to the model, item difficulty levels, and students' abilities could be identified on the same measurement scale, thereby providing more comprehensive information about the quality of the instrument. The results of the Rasch Model analysis are presented in Figures 4. and 5.

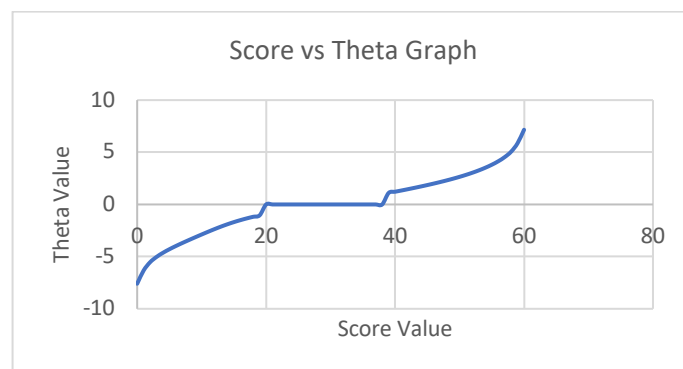


Figure 4. Graph of Score vs Theta of Student Ability

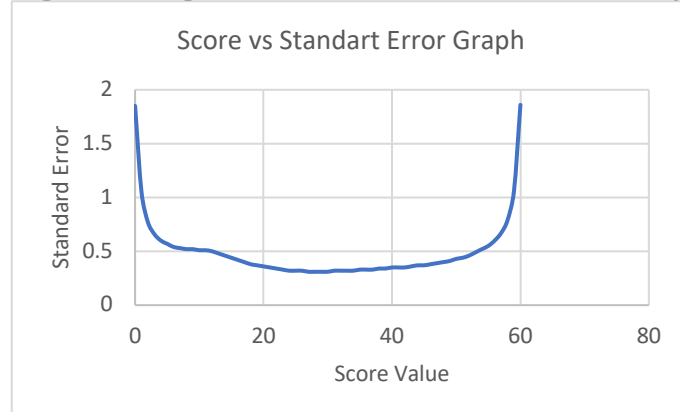


Figure 5. Graph of Score vs. Standard Error of Student Ability

Based on the results of the Rasch model analysis of the score table, theta values, and standard errors, a consistent relationship can be observed between students' raw scores and their estimated abilities (theta). The higher the score obtained, the higher the theta value achieved. This indicates that the instrument was capable of measuring technological literacy abilities progressively according to students' levels of competence.

The lowest theta value was found at a score of 0, with a value of -7.5976 , while the highest theta value was obtained at a score of 60, with a value of 7.1590 . This range demonstrates that the instrument possesses a broad measurement scope, enabling it to distinguish students with very low abilities from those with very high abilities.

In terms of standard error values, the measurement error tended to be larger at extreme scores (very low and very high), namely 1.85 at a score of 0 and 1.86 at a score of 60. Meanwhile, in the Moderate score range, the standard error values were relatively small and stable, ranging from 0.31 to 0.37. This finding indicates that the estimation of students' abilities was more accurate within the moderate ability range than at the extreme ability levels.

Overall, these results indicate that the developed technological literacy test instrument possesses strong measurement capabilities, as reflected by the logical relationship between scores and estimated abilities, as well as relatively small measurement errors across most score ranges. Therefore, the instrument can be considered sufficiently accurate in estimating students' abilities based on the Rasch model.

From the perspective of measurement accuracy, the standard error values were relatively small within the moderate ability range (0.31–0.37), although they increased at extreme scores. This phenomenon is common in Rasch analysis because ability estimations at extreme scores tend to be less stable. Nevertheless, overall, the instrument still demonstrated a high level of precision in measuring technological literacy abilities (Tarigan et al. 2022).

These findings also indicate that the distribution of students' technological literacy abilities tended to spread proportionally across the measured ability range (Maulana et al. 2023). This suggests that the instrument was not only capable of identifying students with average abilities, but was also sensitive in detecting differences in both low- and high-level abilities (Lestari et al. 2022; Salsabila, Nurihsan, and Sunarya 2023). In other words, the instrument demonstrated strong diagnostic functionality in comprehensively mapping students' technological literacy profiles.

Furthermore, the unidimensional nature demonstrated by the Rasch model strengthens the conclusion that this instrument consistently measures a single primary construct, namely technological literacy (Ocy, Rahayu, and Makmuri 2023; Ummah, Mardhiya, and Mulyanti 2022). This consistency is important because it ensures that variations in scores genuinely reflect differences in students' abilities rather than being influenced by factors outside the measured construct.

The broad distribution of theta values also implies that the instrument can be applied to student populations with heterogeneous levels of ability. This is highly relevant in classroom learning contexts, where variations in students' abilities are generally quite substantial. Therefore, teachers may utilize the measurement results to group students, design differentiated learning activities, and provide interventions tailored to the needs of individual students.

However, the increasing standard error values at extreme scores indicate that the interpretation of results for students with very low or very high abilities should be approached cautiously (Ummah, Mardhiya, and Mulyanti 2022). Under such conditions, additional supporting data or complementary instruments may be required to improve measurement accuracy.

Through the analysis of average scores for each item, patterns of students' achievement and variations in ability can be identified. These findings provide an important basis for evaluating the effectiveness of the implemented learning process while also formulating more appropriate strategies for improving students' technological literacy.

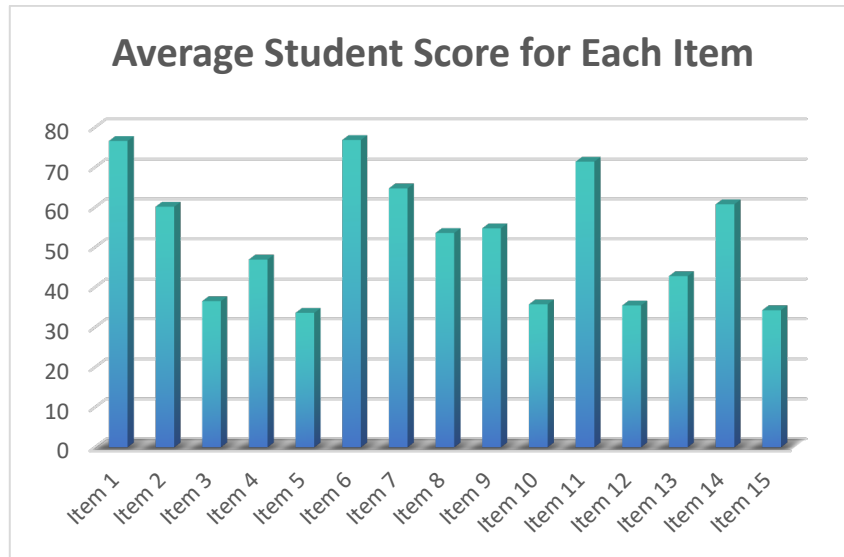


Figure 6. Average Student Score for Each Item

The results of the analysis of students' average scores on each test item indicated significant variations in achievement across the technological literacy indicators. In the knowledge indicator (items 1, 6, 7, 11, and 14), most scores were categorized as relatively high. Items 1 and 6 even demonstrated the highest average scores compared to the other items, indicating that students possessed a fairly strong understanding of the fundamental concepts related to the tested material. This finding suggests that the basic cognitive aspects of technological literacy had been mastered by most students. Furthermore, in the capability indicator (items 2, 4, 8, 9, and 13), students' average scores were categorized as moderate. This indicates that students' ability to apply knowledge within the context of technology use was still developing. Although the scores were not as low as those in the critical thinking indicator, these results suggest that students had not yet fully optimized their ability to operate or utilize technology in an applied manner. Meanwhile, in the critical thinking and decision-making indicator (items 3, 5, 10, 12, and 15), the average scores tended to be lower than those of the other two indicators. Several items, such as items 3, 5, and 10, demonstrated relatively low scores, indicating that students still experienced difficulties in analyzing information, evaluating alternatives, and making technology-based decisions. This condition is understandable because critical thinking skills are classified as higher-order thinking skills that require continuous practice and habituation to develop effectively. This result is consistent with previous studies in physics and technology education that reported students often perform better on knowledge-oriented tasks than on higher-order thinking tasks involving analysis and decision making. The finding suggests that classroom instruction still tends to emphasize conceptual understanding rather than technological problem-solving and evaluation activities. Therefore, future instructional practices should provide more opportunities for students to engage in authentic technological decision-making situations.

The lowest achievement was observed in the critical thinking and decision-making dimension, indicating that students still experience difficulties in evaluating technological alternatives, analyzing evidence, considering risks and benefits, and making decisions based on

logical scientific reasoning. This finding is consistent with previous technological literacy studies, which have identified decision-making as one of the most challenging dimensions because it requires the integration of conceptual knowledge, technological understanding, and evidence-based argumentation (Korkeaniemi, Lindfors, and Kiviranta 2025; Pearson and Garmire 2006). The relatively low performance in this dimension may be attributed to learning practices that predominantly emphasize conceptual understanding and routine problem-solving rather than activities involving evaluation, argumentation, and decision-making. According to Dewey's theory of reflective thinking (1933), critical thinking develops through active inquiry, evidence analysis, and reflection on alternative solutions, suggesting that these competencies require more complex learning experiences than the acquisition of factual knowledge alone (Dewey 1933). Although previous technological literacy research has mainly been conducted within engineering and technology education contexts, studies focusing on technological literacy assessment in secondary physics education remain limited. Therefore, the present study extends existing technological literacy research by demonstrating that the dimensions of knowledge, capability, and critical thinking and decision-making can be effectively measured within the context of physics learning, particularly on the topic of work and energy. These findings also imply that efforts to enhance students' technological literacy should not only focus on strengthening conceptual understanding but should also provide opportunities for students to apply physics concepts in authentic technological contexts, evaluate technological solutions, and justify decisions using scientific evidence. Consequently, instructional approaches such as Problem-Based Learning (PBL) and Socio-Scientific Issues (SSI) may be particularly beneficial because they engage students in analyzing real-world technological problems, evaluating alternative solutions, and making informed decisions, thereby supporting a more balanced development of all dimensions of technological literacy (Arends 2012; Tan 2003; Kumar, Choudhary, and Singh 2024).

Although the instrument demonstrated satisfactory psychometric properties, the findings should be interpreted within the context of the participating schools. Since the study involved students from only two schools in Binjai City, caution should be exercised when generalizing the results to other regions, school types, or student populations. Further validation involving larger and more diverse samples is recommended to strengthen the generalizability of the instrument.

The findings have several implications for educational practice. First, the instrument can be used by physics teachers as a diagnostic assessment tool to identify students' technological literacy levels before and after instruction. Second, the lower performance observed in the critical thinking and decision-making dimension indicates the need for learning approaches that emphasize problem-solving, technology evaluation, and decision-making activities. Approaches such as STEM-based learning, project-based learning, and inquiry-based learning may provide opportunities for students to develop these competencies (Avsec and Jamšek 2015; Heywood 2023; Begen and Atasoy 2024; Whitman et al. 2012). Third, the instrument can support curriculum evaluation by providing evidence regarding students' readiness to apply technological knowledge in real-world contexts.

CONCLUSION

The developed technological literacy-based test instrument on the topic of work and energy demonstrated satisfactory feasibility, practicality, validity, reliability, and effectiveness for assessing students' technological literacy in physics. The evaluation expert validation (92.13%) and material expert validation (90.4%) categorized the instrument as highly feasible, while the practicality assessment indicated that it was well accepted by both teachers and students. Furthermore, item analysis and Rasch model analysis confirmed that the instrument possessed acceptable psychometric properties and was capable of accurately measuring students' technological literacy across different ability levels.

The measurement results showed that students achieved relatively high performance on the knowledge indicator, moderate performance on the capability indicator, and relatively low performance on the critical thinking and decision-making indicator. These findings indicate that students have acquired fundamental knowledge of physics-related technology but still encounter challenges in applying technological concepts and making critical decisions in real-world contexts.

From an educational perspective, the developed instrument can serve as a practical classroom assessment tool for diagnosing students' technological literacy profiles and identifying dimensions that require further improvement. The assessment results may assist teachers in designing more targeted technology-integrated physics learning activities and support curriculum implementation aimed at developing students' technological literacy.

This study was limited to the topic of work and energy and involved only senior high school students from a limited geographical area, which may restrict the generalizability of the findings. Therefore, future research is recommended to validate the instrument using larger and more diverse populations, examine its application across different physics topics and educational levels, and employ Confirmatory Factor Analysis (CFA) to provide stronger evidence of construct validity and support the wider implementation of the instrument in physics education.

AUTHOR STATEMENTS

Funding

This research received no external funding and was conducted independently by the authors.

Author Contributions

The first author conceptualized the study, designed the research methodology, developed the technological literacy assessment instrument, collected the data, conducted the statistical analyses, interpreted the findings, and prepared the original manuscript draft. The second author contributed to the research design, supervised the development and validation of the assessment instrument, assisted in data interpretation, and critically reviewed the manuscript for important intellectual content. The third author provided overall academic supervision, contributed to the refinement of the theoretical framework and research methodology, reviewed the analytical results, critically revised the manuscript to enhance its scientific quality, and approved the final version for publication. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. The technological literacy assessment instrument and supporting research materials may also be shared for academic and research purposes in accordance with applicable ethical guidelines.

Ethical Approval

This study was conducted in accordance with the ethical principles for research involving human participants. All participants voluntarily agreed to participate and provided informed consent prior to data collection. Participant confidentiality and anonymity were maintained throughout the study.

Acknowledgments

The authors would like to express their sincere gratitude to Universitas Negeri Medan for providing academic support throughout this research. The authors also sincerely thank the principals, physics teachers, and students of SMA Negeri 1 Binjai and MAN Binjai for their valuable participation and cooperation during the instrument validation and field-testing process. Special appreciation is extended to the expert validators and colleagues who provided insightful suggestions and constructive feedback, which significantly enhanced the quality, validity, and scientific rigor of this study.

REFERENCES

- Arends, Richard I. 2012. *Learning to Teach*. New York: McGraw-Hil.
- Aswar, Nurul Fadilah, M Ikhwan Maulana Haeruddin, and Ilma Wulansari Hasdiansa. 2023. "Pengaruh Inovasi Dan Entrepreneurial Orientation Terhadap Keunggulan Bersaing UMKM Di Kota Makassar." *Jurnal Ilmiah Bisnis & Kewirausahaan* 12 (1): 61–68.
- Avsec, Stanislav, and Janez Jamšek. 2015. "Technological Literacy for Students Aged 6–18: A New Method for Holistic Measuring of Knowledge, Capabilities, Critical Thinking and Decision-Making." *International Journal of Technology and Design Education* 26 (1): 43–60. <https://doi.org/10.1007/s10798-015-9299-y>.
- Avsec, Stanislav, and Slavko Kocijancic. 2014. "The Effect of The Use of an Inquiry-Based Approach in an Open Learning Middle School Hydraulic Turbine Optimisation Course." *World Transactions on Engineering and Technology Education* 12 (3): 329–37.
- Baharum, Hafidza, Aniza Ismail, Zainudin Awang, Lisa McKenna, Roszita Ibrahim, Zainah Mohamed, and Nor Haty Hassan. 2023. "The Study Adapted Instruments Based on Confirmatory Factor Analysis (CFA) to Validate Measurement Models of Latent Constructs." *International Journal of Environmental Research and Public Health* 20 (4): 2860.
- Bahri, Syamsul, Mitra Rahayu, Desy Kumala Sari, and Merta Simbolon. 2020. "Analysis of Information and Communication Technology Literacy Capabilities to The High School Physics Teacher in Merauke." *Gravity : Jurnal Ilmiah Penelitian Dan Pembelajaran Fisika* 6 (1): 47–53. <https://doi.org/10.30870/gravity.v6i1.6365>.
- Bao, Lei, and Kathleen Koenig. 2019. "Physics Education Research for 21st Century Learning." *Disciplinary and Interdisciplinary Science Education Research* 1 (1): 1–12. <https://doi.org/10.1186/s43031-019-0007-8>.
- Begen, Nazire, and Hilal Atasoy. 2024. "Technological Literacy and Employment: An Inquiry into the Adoption of Learning Technologies." *Telecommunications Policy* 48 (10): 1–23. <https://doi.org/10.1016/j.telpol.2024.102864>.
- Branch, Robert Maribe. 2009. *Instructional Design: The ADDIE Approach*. New York: Springer.

- Davies, Randall S. 2011. "Understanding Technology Literacy: A Framework for Evaluating Educational Technology Integration." *TechTrends* 44: 45–52.
- Dewey, John. 1933. *How We Think*. Boston: D.C. Heath.
- Fahrurrozi, Muh, and Siti Nur Laili Rahmawati. 2021. "Pengembangan Model Instrumen Evaluasi Menggunakan Aplikasi Kahoot Pada Pembelajaran Ekonomi." *Jurnal PROFIT Kajian Pendidikan Ekonomi Dan Ilmu Ekonomi* 8 (1): 1–10. <https://doi.org/10.36706/jp.v8i1.13090>.
- Farhodovna, Atoeva Mehriniso, Arabov Jasur Olimboevich, and Kobilov Bakhtiyor Badriddinovich. 2020. "Innovative Pedagogical Technologies For Training The Course Of Physics." *The American Journal of Interdisciplinary Innovations and Research* 2 (12): 82–91. <https://doi.org/10.37547/tajir/volume02issue12-12>.
- Gani, Abdul Rafid Fakhrun, and Sabani. 2024. "Analisis Kebutuhan Penilaian Berbasis Literasi Teknologi Pada Materi Fluida." *Jurnal Pendidikan MIPA* 14 (1): 276–81.
- Gu, Jianjun, Meidan Xu, and Jonchao Hong. 2019. "Development and Validation of a Technological Literacy Survey." *International Journal of Science and Mathematics Education* 17 (1): S109–24. <https://doi.org/10.1007/s10763-019-09971-6>.
- Güvendir, Meltem Acar, and Yeşim Özer Özkan. 2022. "Item Removal Strategies Conducted in Exploratory Factor Analysis: A Comparative Study." *International Journal of Assessment Tools in Education* 9 (1): 165–80.
- Hamidah, Miske Hayunia, and Siti Sri Wulandari. 2021. "Pengembangan Instrumen Penilaian Berbasis Hots Menggunakan Aplikasi 'Quizizz.'" *Efisiensi : Kajian Ilmu Administrasi* 18 (1): 105–24. <https://doi.org/10.21831/efisiensi.v18i1.36997>.
- Heywood, John. 2023. "Lessons for Education, Engineering and Technological Literacy from the Experience of Britain's Vaccine Task Force (VTF)." In *ASEE Annual Conference and Exposition, Conference Proceedings*. <https://doi.org/10.18260/1-2--43418>.
- ITEA. 2007. *Standards for Technological Literacy: Content for the Study of Technology*. Reston: International Technology Education Association.
- Korkeaniemi, Arttu, Eila Lindfors, and Leena Kiviranta. 2025. "Teaching Technology to Young Learners: Teachers' Individual Competencies." *International Journal of Technology and Design Education*, 1–21. <https://doi.org/10.1007/s10798-025-09973-2>.
- Kumar, Vishal, Sanjiv Kumar Choudhary, and Rajni Singh. 2024. "Environmental Socio-Scientific Issues as Contexts in Developing Scientific Literacy in Science Education: A Systematic Literature Review." *Social Sciences and Humanities Open* 9 (December 2023): 100765. <https://doi.org/10.1016/j.ssaho.2023.100765>.
- Leedy, Paul D, and Jeanne Ellis Ormrod. 2015. *Practical Research*. Pearson Education Limited.
- Lestari, Weni, Indah Wigati, Moh Ismail Sholeh, and Desi Pramita. 2022. "Instrumen Literasi Digital Guru Menggunakan Model Rasch." *Orbital: Jurnal Pendidikan Kimia* 6 (2): 104–13.
- Maulana, Slamet, Ani Rusilowati, Sunyoto Eko Nugroho, and Endang Susilaningsih. 2023. "Implementasi Rasch Model Dalam Pengembangan Instrumen Tes Diagnostik." In *Prosiding Seminar Nasional Pascasarjana*, 6:748–57.
- Nikat, Rikardus Feribertus. 2020. "Analisis Kemampuan Literasi Teknologi Calon Guru Fisika Melalui Online Formative Assessment." *Quantum: Jurnal Inovasi Pendidikan Sains* 11 (2): 112–22. <https://doi.org/10.20527/quantum.v11i2.8739>.

- Nuraeni, Rini, Petrus Jacob Pattiasina, and Anisah Ulfah. 2022. "Peran Literasi Teknologi Dalam Dunia Pendidikan." *Al-Madrasah: Jurnal Pendidikan Madrasah Ibtidaiyah* 6 (3): 659–66. <https://doi.org/10.35931/am.v6i3.1045>.
- Ocy, Dwi Rismi, Wardani Rahayu, and Makmuri Makmuri. 2023. "Rasch Model Analysis: Development of Hots-Based Mathematical Abstraction Ability Instrument According to Riau Islands Culture." *AKSIOMA: Jurnal Program Studi Pendidikan Matematika* 12 (4): 3542–60.
- Okpatrioka. 2023. "Research and Development (R&D) Penelitian Yang Inovatif Dalam Pendidikan." *Dharma Acariya Nusantara: Jurnal Pendidikan, Bahasa Dan Budaya* 1 (1): 86–100.
- Pearson, Greg, and Elsa Garmire. 2006. *Tech Tally: Approaches to Assessing Technological Literacy*. National Academies Press.
- Ramadhan, Muhammad. 2021. *Metode Penelitian*. Jakarta: Cipta Media Nusantara.
- Rupnik, Denis, and Stanislav Avsec. 2020. "Effects of a Transdisciplinary Educational Approach on Students' Technological Literacy." *Journal of Baltic Science Education* 19 (1): 121–41. <https://doi.org/10.33225/jbse/20.19.121>.
- Salsabila, Fadiya, Juntika Nurihsan, and Yaya Sunarya. 2023. "Pengujian Validitas Dan Reliabilitas Instrumen Manajemen Diri Remaja: Rasch Model Analysis." *Jurnal Bimbingan Dan Konseling Terapan* 7 (1): 15.
- Sani, Ridwan Abdullah. 2022. *Metodologi Penelitian Pendidikan*. Jakarta: Kencana.
- Santyadiputra, Gede Saindra, and Djoko Kustono. 2023. "Prinsip-Prinsip Pembelajaran Menuju Peningkatan Kemampuan Literasi Teknologi : Sebuah Kajian Literatur." *Kumpulan Artikel Mahasiswa Pendidikan Teknik Informatika* 12 (1): 1–6.
- Tan, Oon Seng. 2003. *Problem-Based Learning Innovation: Using Problems to Power Learning in the 21st Century*. Gale Cengage Learning.
- Tarigan, Elsa Febrina, Suriati Nilmarito, Khairani Islamiyah, Ayi Darmana, and Retno Dwi Suyanti. 2022. "Analisis Instrumen Tes Menggunakan Rasch Model Dan Software SPSS 22.0." *Jurnal Inovasi Pendidikan Kimia* 16 (2): 92–96.
- Ummah, Khoerul, Julia Mardhiya, and Sri Mulyanti. 2022. "Pengembangan Instrumen Tes Penguasaan Konsep Representasi Kimia Pada Lima Indikator Asam Basa Dari Alam: Analisis Dengan Rasch Model." *Jurnal Tarbiyah* 29 (2): 212–25.
- Whitman, Lawrence E., Mandy C. Phelps, Karen V. Reynolds, and Barbara S. Chaparro. 2012. "Assessing Technological Literacy of Middle School Students." *ASEE Annual Conference and Exposition, Conference Proceedings*. <https://doi.org/10.18260/1-2--20976>.
- Zam, Embung Megasari. 2021. "Peran Literasi Teknologi Informasi Dan Komunikasi Pada Pembelajaran Jarak Jauh Di Masa Pandemi Covid-19." *EDUTECH: Jurnal Inovasi Pendidikan Berbantuan Teknologi* 1 (1): 9–18.