Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
http://ojs.ikipmataram.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

April 2026. Vol. 14, No. 2
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 658-675

Mapping Students' Science Literacy Skills Using Local Wisdom-Based Physics Instruments

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Received: September 2025; Revised: March 2026; Published: April 2026

Abstract

This study addresses Indonesian students' low scientific literacy (PISA 2022) by developing and validating a Tari Boranan Lamongan–contextualized physics assessment instrument on rigid body equilibrium. Existing PISA-aligned tests are rarely embedded in local culture. At the same time, local wisdom materials often do not measure all eight PISA scientific literacy indicators, creating a gap for culturally resonant yet comprehensive diagnostic tools. This study aimed to (1) develop and validate an eight-indicator, PISA-aligned scientific literacy instrument, (2) map Grade XI students' literacy profiles across the eight indicators, and (3) explore how the Boranan context shapes students' engagement and reasoning. Using a mixed-method embedded design, 73 Grade XI students in Lamongan Regency completed eight essay-based literacy tasks, and ten students participated in semi-structured interviews. Expert validation indicated high content relevance, cultural authenticity, and indicator alignment, and reliability analysis yielded Cronbach's alpha = 0.82. Results showed most students were in the very low and low categories, with relative strengths in interpreting data (45%) and explaining phenomena (38%), but pronounced weaknesses in designing investigations (28%), evaluating credibility of information (25%), and making evidence-based decisions (30%). Interviews confirmed that cultural context enhanced engagement and visualization but did not automatically support mathematical formalization. These findings suggest that the instrument can be used diagnostically to help teachers design targeted scaffolding for higher-order literacy skills, particularly in investigation design, credibility evaluation, and evidence-based decision-making, within culturally responsive physics learning.

Keywords: Scientific literacy; Rigid body equilibrium; Local wisdom; Tari Boranan Lamongan; Physics education

How to Cite: Alhusni, H. Z., Prahani, B. K., Sunarti, T., Madlazim, M., & Kurtuluş, M. A. (2026). Mapping Students' Science Literacy Skills Using Local Wisdom-Based Physics Instruments. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *14*(2), 658–675. https://doi.org/10.33394/j-ps.v14i2.17680

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INTRODUCTION

In the 21st century, effective education is expected to cultivate not just factual knowledge but also scientific literacy (Hanifah et al., 2025; D. R. Sari et al., 2025; Turan & De Smedt, 2022; Rueter Veiga, 2020). This includes the ability to explain phenomena, evaluate investigations, interpret data critically, and make informed decisions in real-life scenarios (Khery et al., 2022; Amala et al., 2023). In physics education, topics such as rigid-body equilibrium require students to integrate conceptual reasoning, mathematical representation, and real-world interpretation, making them suitable contexts for assessing scientific literacy (Susac et al., 2021; Coletta & Steinert, 2020; Kontro & Buschhüter, 2020; Ruggieri, 2020). One cultural practice that naturally reflects these principles is Tari Boranan Lamongan, a traditional dance involving the balancing of bamboo poles, which implicitly demonstrates torque, center of mass, and static equilibrium. Embedding such culturally familiar contexts into physics tasks may help students connect abstract scientific ideas with meaningful experiences (Reuter & Leuchter, 2021; Plummer et al., 2020; Starr et al., 2020). Embedding local wisdom, such as cultural practices like Tari Boranan Lamongan, into science learning presents a promising pathway to make physics feel more meaningful and relatable. When students encounter scientific concepts in culturally familiar contexts, they often demonstrate increased engagement, stronger conceptual retention, and greater interpretive skills (Kim et al., 2021; Spencer et al., 2022; Umam et al., 2025). This approach aligns with the principles of STSE (Science, Technology, Society, Environment) education, which emphasize situating science within socio-cultural and environmental contexts to shape reflective, responsible citizens (Halwany et al., 2017; Firmino et al., 2019).

Despite this aspiration, Indonesian students' scientific literacy levels remain critically low. The PISA 2022 results indicate that only 34% of Indonesian students achieved Level 2 proficiency in science, compared to an OECD average of 76%, and very few reached the highest tiers (Hardinata et al., 2023; Bilad et al., 2024). This underperformance reflects systemic issues, including limited infrastructure, low interest in science, and insufficient teacher training (Mustafa, 2023; Cahyani & Setiawan, 2024). Additionally, national reports underscore that Indonesian student achievement, particularly in science and literacy, continues to lag behind regional peers (Annisawati & Oktora, 2024), signaling a deep learning crisis that necessitates urgent and meaningful pedagogical interventions (The Economic Impacts of Learning Losses, 2020).

A major underlying problem is the continued dominance of procedural and rote learning in science classrooms. Teachers often focus on formulaic problem-solving, with minimal emphasis on inquiry, reasoning, or context-based understanding (Solihin et al., 2024). Consequently, while students may be adept at routine calculations, they frequently struggle to transfer this knowledge to authentic situations, a deficiency confirmed by poor performance on PISA-aligned assessments, particularly in higher-order thinking dimensions (Agustin & Supahar, 2021). This challenge becomes particularly evident in physics topics such as rigid body equilibrium, where students must simultaneously reason conceptually, interpret data, and apply mathematical representations of torque and balance.

In response, researchers have experimented with culturally contextualized instruction and inquiry-based methods. For instance, Rediani et al. (2023) developed e-modules rooted in Sasi local wisdom to enhance environmental awareness and scientific literacy among pre-service teachers. Similarly, Lubis et al. (2022) implemented PBL (Project-Based Learning) grounded in local wisdom, demonstrating effectiveness in improving students' science numeracy and reasoning capabilities. Meanwhile, Faisal et al. (2023) validated science literacy instruments based on PISA frameworks via Rasch analysis, confirming their reliability in assessing multiple literacy dimensions. These studies collectively demonstrate that combining cultural context and robust assessment tools can effectively support scientific literacy.

However, limitations persist in these endeavors. The Sasi e-modules primarily targeted pre-service teachers, raising questions about their relevance for secondary students (Sihombing et al., 2025). The PBL-local wisdom integration improved numeracy but did not address indicators like credibility evaluation or decision-making (Purnadewi & Widana, 2023). Although the PISA-aligned instruments provided rigorous measurement, they often lacked cultural embedding, limiting student engagement and authenticity (Wati et al., 2017). Therefore, there remains a need for assessment tools that are both academically rigorous and culturally contextualized, particularly for secondary-level physics topics such as rigid body equilibrium. A closer examination of prior studies indicates that most instruments either use culturally neutral contexts to assess multiple literacy indicators or integrate local culture but focus on limited competencies, such as numeracy or environmental awareness. Few studies combine cultural authenticity, physics content, and comprehensive PISA-aligned literacy indicators within a single diagnostic instrument.

This study aims to bridge that gap by integrating PISA-aligned literacy indicators with the rich cultural context of Tari Boranan Lamongan. This traditional dance inherently involves physical principles of rigid-body equilibrium, torque, and balance, making it a naturally relevant framework for physics tasks. The instrument therefore assesses eight scientific literacy indicators: explaining phenomena scientifically, evaluating explanations, identifying scientific questions, designing investigations, evaluating investigations, interpreting data, evaluating credibility of information, and making evidence-based decisions.

Consequently, the primary objective of this study is to map the scientific literacy profile of secondary students across eight PISA-aligned dimensions using a culturally contextualized physics instrument based on Boranan Dance. More specifically, this study aims to:

(1) develop and validate a Boranan-based scientific literacy assessment instrument for rigid body equilibrium,
(2) map students' scientific literacy profiles across the eight indicators, and
(3) Examine how the Boranan cultural context influences students' engagement and reasoning.

Accordingly, the research questions guiding this study are:

(1) How valid and reliable is the Boranan Lamongan–based scientific literacy instrument?
(2) What is the profile of students' scientific literacy across the eight indicators?
(3) How does the cultural context of Tari Boranan Lamongan influence students' engagement and understanding when solving physics literacy tasks?

The novelty of this research lies in its integration of cultural heritage with diagnostic literacy assessment. Unlike previous models, which used either culturally decontextualized PISA tasks or culturally rich but methodologically limited materials, this study brings both together. Rather than claiming absolute novelty, this study identifies a limited number of prior works that simultaneously address all eight PISA scientific literacy indicators within a traditional cultural context in physics learning. This contribution positions the study as an effort to advance culturally responsive science education while providing a diagnostic tool for mapping students' literacy skills.

METHOD

Research Design

The present study employed a quantitative-dominant embedded mixed-methods design (QUAN-to-qual). In this design, the quantitative strand served as the primary component, while the qualitative strand was embedded to provide deeper explanations of students' reasoning and learning difficulties. The quantitative data consisted of descriptive statistics analyzing students' scientific literacy across eight indicators, whereas the qualitative data were obtained from interviews to interpret patterns emerging from the quantitative findings. The qualitative phase was conducted after the test administration, and the integration of both strands occurred during interpretation by comparing statistical results with students' explanations. This design enabled the study to measure students' literacy levels while also exploring how the cultural context of Tari Boranan Lamongan influenced their responses (Alhusni et al., 2025).

Participants

The population of this research consisted of senior high school students in Lamongan Regency, East Java, Indonesia. Participants were selected through purposive sampling based on their prior exposure to rigid body equilibrium. The sample comprised two public senior high schools, with one class from each selected. School A had 35 students, and School B had 38, for a total of 73 Grade XI students.

All participating students had previously studied rigid body equilibrium, making them suitable for investigating scientific literacy related to this topic. The schools were selected based on accessibility and their relevance to the study's cultural context (Dewi, 2020). Since the sample was limited to two schools within a single regency, the results of this study should be interpreted cautiously. They cannot be generalized to all high school students in Indonesia (Berndt, 2020).

Instrument and Scoring

The primary instrument used in this study was a scientific literacy test developed by the researchers, consisting of eight essay-type tasks aligned with eight scientific literacy indicators adapted from the PISA framework (Berndt, 2020). Each task was designed to assess students' ability to apply physics concepts in culturally meaningful situations. All tasks were contextualized in Tari Boranan Lamongan, a traditional dance that symbolizes collective strength and balance using bamboo poles. The tasks integrated key physics concepts of rigid body equilibrium, including torque, net force, center of mass, and static balance, along with mathematical reasoning.

Students' responses were evaluated using an analytic scoring rubric with four levels:
0 = incorrect or no answer
1 = partially correct answer with major misconceptions
2 = mostly correct explanation with minor errors
3 = scientifically accurate explanation supported by appropriate reasoning

The scores obtained from each item were converted into percentages using the formula:

$$\text{Score (\%)} = (\text{Obtained Score} / \text{Maximum Score}) \times 100$$

The percentage scores were then used to determine students' scientific literacy levels across the eight indicators.

Table 1. Blueprint of the scientific literacy instrument based on Tari Boranan Lamongan

Indicator of Scientific Literacy	Physics Concept (Rigid Body Equilibrium)	Task Context in Boranan Dance	Example of Expected Response
Explaining phenomena	Torque and balance	Dancer carrying a bamboo pole	Explaining why a dancer must adjust their body position
Evaluating explanations	Net force and moment	Group balance on bamboo	Assessing the correctness of a peer's explanation
Identifying questions	Center of mass	Stability of the dancer's posture	Formulating investigable questions
Designing investigations	Torque measurement	Measuring balance on bamboo	Designing an experiment with a force meter
Evaluating investigations	Experimental method	Comparing balance strategies	Evaluating design flaws
Interpreting data	Numerical data from the torque calculation	Table of force vs. distance	Drawing Conclusion
Evaluating credibility	Local vs. textbook explanation	Different sources on balance	Judging credibility
Decision making	Evidence-based application	Dance stage stability	Recommending safe design

Validation and Reliability

The instrument was evaluated through expert validation involving three experts in physics education and local cultural studies. The validation assessed several aspects, including content relevance, cultural authenticity, clarity of language, and alignment with scientific literacy indicators (Handayani et al., 2024). Each item was rated on a 4-point scale from 1 (not appropriate) to 4 (highly appropriate). The average validation scores ranged between 3.7 and 3.8, indicating that the instrument was considered valid for use in this study. Reliability analysis was conducted using Cronbach's alpha to assess the instrument's internal consistency (Faisal et al., 2023). The reliability coefficient obtained was 0.82, which indicates high reliability. The results of the validation and reliability analyses are presented in Tables 2 and 3.

Data Collection Procedures

Data were collected in two stages. First, students completed the scientific literacy test during a 90-minute classroom session under supervised conditions to ensure standardized administration. Students worked individually and were not allowed to use external resources during the test. Second, ten students were selected for semi-structured interviews to explore their reasoning processes and learning difficulties. The selection aimed to represent students with high, medium, and low performance levels based on the test results. The interviews also explored students' perspectives on integrating local culture into physics learning (Alhusni et al., 2025). All interviews were audio-recorded with participants' consent and later transcribed for analysis while maintaining anonymity. Additionally, a visual representation of Tari Boranan Lamongan was provided to help students understand the cultural context used in the questions.

Figure 1. Illustration of Tari Boranan Lamongan with bamboo props

Data Analysis

Quantitative data were analyzed using descriptive statistics, including mean scores and percentages. Students' scientific literacy levels were categorized into four groups: very low (0–25), low (26–50), medium (51–75), and high (76–100) (Ramli et al., 2022). These categories were used to identify patterns in students' performance across the eight indicators. Qualitative data from interviews were analyzed using thematic analysis, which involved several stages: familiarization with the data, initial coding, grouping similar responses, identifying patterns, and generating themes (Affandi & Nurfadhillah, 2023). Two researchers reviewed the transcripts to ensure consistency, and any differences in interpretation were resolved through discussion. Finally, the quantitative and qualitative findings were integrated to provide a comprehensive understanding of students' scientific literacy in the cultural context of Tari Boranan Lamongan.

Quantitative data were analyzed using descriptive statistics, including mean, percentage, and categorization into four levels: very low (0–25), low (26–50), medium (51–75), and high (76–100) (Ramli et al., 2022). Each indicator was mapped to profile students' strengths and weaknesses. Qualitative data from interviews were analyzed thematically, focusing on students' reasoning patterns and the role of cultural context in shaping their responses (Affandi & Nurfadhillah, 2023). The integration of both strands provided a comprehensive picture of students' scientific literacy in the context of Tari Boranan Lamongan.

RESULTS AND DISCUSSION

Instrument Validity and Reliability

The developed scientific literacy instrument was subjected to expert validation before its administration. Three experts, two in physics education and one in local cultural studies, evaluated the instrument in terms of content relevance, cultural authenticity, clarity of language, and alignment with scientific literacy indicators. As shown in Table 2, all aspects obtained mean scores between 3.7 and 3.8 (on a 4-point scale), which fall into the valid category. These results indicate that the instrument adequately represents the constructs of scientific literacy, while also authentically embedding the context of Tari Boranan Lamongan.

Table 2. Expert validation results of the scientific literacy instrument

Aspect Evaluated	Expert 1	Expert 2	Expert 3	Mean Score	Category
Content Relevance	3.8	3.9	3.7	3.8	Valid

Aspect Evaluated	Expert 1	Expert 2	Expert 3	Mean Score	Category
Cultural Authenticity	3.7	3.8	3.9	3.8	Valid
Clarity of Language	3.6	3.8	3.7	3.7	Valid
Alignment with Indicators	3.9	3.8	3.8	3.8	Valid

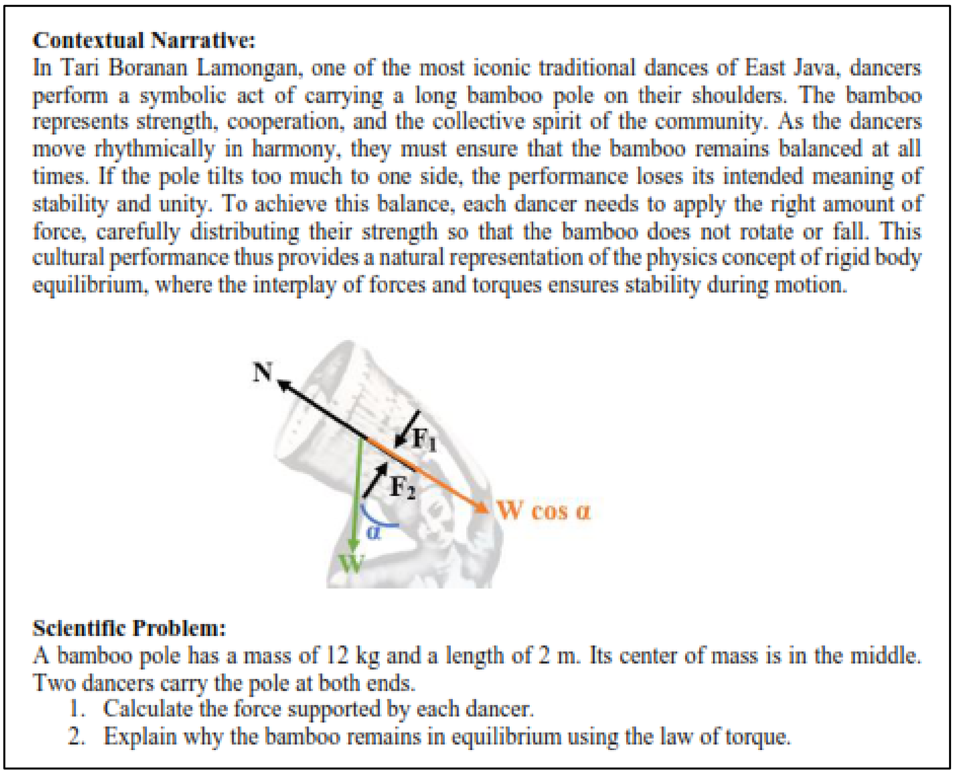
Furthermore, the instrument's reliability was assessed using Cronbach's Alpha, a widely used statistical measure of internal consistency. As shown in Table 3, the reliability coefficient was 0.82, indicating high reliability. This suggests that the instrument items were consistent and reliable in measuring students' scientific literacy across multiple indicators.

Table 3. Reliability test results

Number of Items	Cronbach's Alpha	Category
8	0.82	High reliability

Taken together, these results demonstrate that the instrument was both valid and reliable, making it feasible to apply to assess students' scientific literacy skills in the context of rigid-body equilibrium problems based on Tari Boranan Lamongan. These validity and reliability results provide evidence of the instrument's measurement quality and consistency; however, they do not by themselves establish the novelty of the study. The novelty is grounded in the design choice to embed Tari Boranan Lamongan as a culturally authentic context aligned with PISA-based literacy indicators, a research gap identified in the Introduction and reiterated in the Conclusion. These results indicate that the developed instrument is not only statistically valid and reliable but also capable of authentically representing the local cultural context of Boranan dance, making it suitable for mapping students' science literacy.

Figure 2 provides an example of a scientific literacy item based on Tari Boranan Lamongan. This example illustrates how local cultural practices can be integrated into physics learning. The contextual narrative connects the symbolic act of carrying bamboo poles to the scientific principle of rigid-body equilibrium. At the same time, the accompanying problem requires students to perform both force calculations and conceptual reasoning using torque balance. The diagram further supports students' understanding by linking abstract physical concepts to a real and culturally meaningful situation.



Contextual Narrative:

In Tari Boranan Lamongan, one of the most iconic traditional dances of East Java, dancers perform a symbolic act of carrying a long bamboo pole on their shoulders. The bamboo represents strength, cooperation, and the collective spirit of the community. As the dancers move rhythmically in harmony, they must ensure that the bamboo remains balanced at all times. If the pole tilts too much to one side, the performance loses its intended meaning of stability and unity. To achieve this balance, each dancer needs to apply the right amount of force, carefully distributing their strength so that the bamboo does not rotate or fall. This cultural performance thus provides a natural representation of the physics concept of rigid body equilibrium, where the interplay of forces and torques ensures stability during motion.

Scientific Problem:

A bamboo pole has a mass of 12 kg and a length of 2 m. Its center of mass is in the middle. Two dancers carry the pole at both ends.

1. Calculate the force supported by each dancer.
2. Explain why the bamboo remains in equilibrium using the law of torque.

Figure 2. Example of a scientific literacy item based on Tari Boranan

Because the instrument targets eight distinct scientific literacy indicators, a single example item may not fully reflect the range of tasks included. Therefore, an additional example item targeting a different indicator (e.g., evaluating credibility or decision making) is recommended to be included either as an additional figure or in an appendix/supplementary material. If journal space is limited, the full instrument can be provided as an Appendix or Supplementary Material, and this can be explicitly stated in the Method section to improve transparency and replicability.

Students' Scientific Literacy Performance

The scientific literacy test was administered to two schools, each represented by a single class: School A (35 students) and School B (38 students), for a total of 73 participants. Students' scores were categorized into four levels: very low (0–25), low (26–50), moderate (51–75), and high (76–100).

The results reveal that the majority of students in both schools fell into the very low category, indicating significant difficulties in connecting scientific concepts with the local wisdom context of Tari Boranan Lamongan. A considerable number of students also fell into the low category, indicating that although they could recall certain concepts or perform basic calculations, their ability to evaluate, design investigations, and make scientific judgments remained limited. Only a few students (1–3 per school) reached the moderate category, and none reached the high category.

Table 4. Distribution of students' scientific literacy scores by category

School	Very Low (0–25)	Low (26–50)	Moderate (51–75)	High (76–100)	Total
School A (n = 35)	20 (57.1%)	12 (34.3%)	3 (8.6%)	0 (0.0%)	35
School B (n = 38)	22 (57.9%)	15 (39.5%)	1 (2.6%)	0 (0.0%)	38
Total (n = 73)	42 (57.5%)	27 (37.0%)	4 (5.5%)	0 (0.0%)	73

The distribution is also illustrated in Figure 3, which clearly shows that the very low and low categories dominate the overall performance. In contrast, the moderate category is only represented by a very small number of students, and the high category is completely absent. This finding underscores the urgent need to strengthen students' scientific literacy, especially in higher-order skills such as investigation design and decision-making based on evidence. However, given that the sample is limited to two schools in one regency, this implication should be interpreted as localized evidence rather than a general conclusion. To avoid overgeneralization, this result is better interpreted in relation to broader national findings, including PISA reports and Indonesian studies that similarly show challenges in higher-order scientific reasoning.

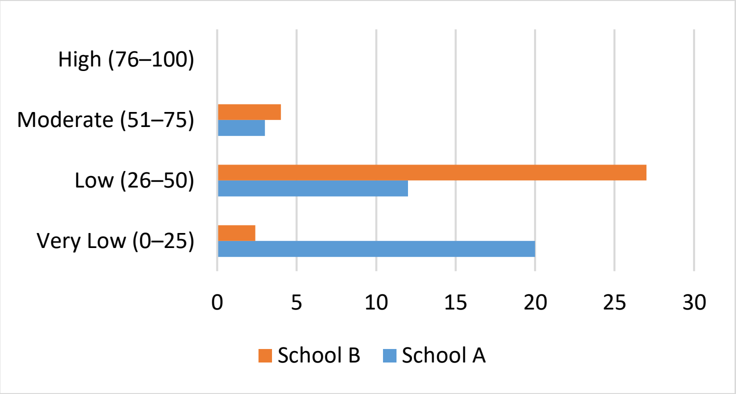


Figure 3. Comparison of categories for each school

Performance Per Scientific Literacy Indicator

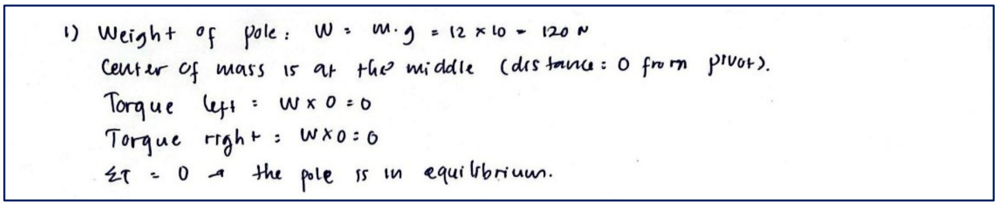
To gain deeper insight into students' literacy skills, their average scores were analyzed based on the eight indicators of scientific literacy. As presented in Table 5, the performance varied considerably across indicators.

Table 5. Average score and achievement percentage by indicator

No	Scientific Literacy Indicator	Average Score (0–100)	Achievement (%)	Category
1	Evaluating scientific concepts to explain a phenomenon/problem	38	38%	Low
2	Evaluating explanations based on scientific concepts	36	36%	Low
3	Identifying scientific questions	34	34%	Low
4	Designing a scientific investigation	28	28%	Very Low
5	Evaluating investigation results	32	32%	Very Low
6	Interpreting data and facts scientifically	45	45%	Moderate (highest)
7	Evaluating the credibility of scientific information	25	25%	Very Low (lowest)
8	Making decisions based on credible scientific information	30	30%	Very Low

The results indicate that the highest performance was in interpreting data and facts scientifically (Indicator 6), with an average score of 45 (moderate category). This suggests that students are better at handling numerical information and drawing basic conclusions when data are presented in tabular or graphical form. In contrast, the lowest performance was in evaluating the credibility of scientific information (Indicator 7), with an average score of 25 (very low). This finding highlights that students face serious challenges in critically judging the validity of statements or claims when connecting science with cultural contexts. This profile is consistent with the 2022 PISA report, which shows that Indonesian students perform poorly in higher-order thinking skills. To reduce redundancy, the detailed indicator-by-indicator interpretation is synthesized in the next subsection by grouping indicators into relative strengths (Indicators 1 and 6) and weaknesses (Indicators 4, 7, and 8), supported by representative student responses. Accordingly, Figures 4–11 are retained as evidence examples, but the discussion focuses on cross-indicator patterns rather than repeating similar commentary eight times.

First, in this indicator, students were tasked with evaluating scientific concepts to explain a specific phenomenon or problem. The aim was to assess their ability to connect theory to real-world scenarios.

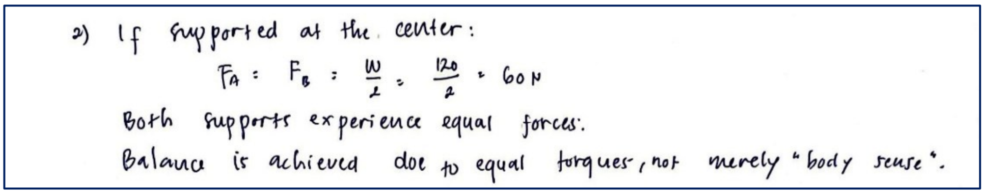


1) Weight of pole: W = m.g = 12 × 10 = 120 N
Center of mass is at the middle (distance: 0 from pivot).
Torque left : W × 0 = 0
Torque right : W × 0 = 0
Στ = 0 → the pole is in equilibrium.

Figure 4. Student answers to the evaluation of scientific concepts to explain a phenomenon/problem indicator

The average score of 38% indicates that most students struggle with making these connections effectively. The difficulty lies in understanding complex scientific concepts and applying them in context. Students may lack familiarity with linking theoretical knowledge to practical problems. To improve, a more hands-on approach to learning, like using case studies or interactive experiments, could enhance their understanding. Additionally, providing clearer examples of how to apply concepts in real situations may help bridge the gap between theory and practice.

Students were asked to evaluate the validity of scientific explanations using key concepts. This requires not only understanding the concepts but also the ability to assess the strength of the explanations critically.



2) If supported at the center:

$F_A = F_B = \frac{W}{2} = \frac{120}{2} = 60$ N

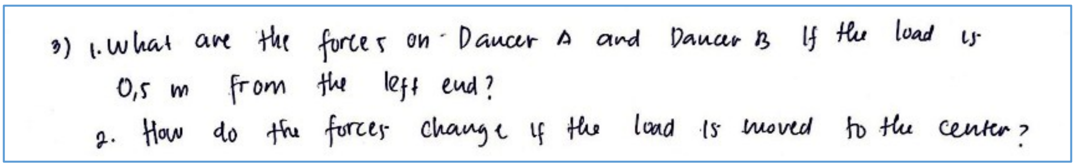
Both supports experience equal forces.

Balance is achieved doe to equal torques, not merely "body sense".

Figure 5. Student answers to the evaluation explanations based on the scientific concepts indicator

With a score of 36%, students are having difficulty assessing the robustness of scientific explanations. This may be due to their inability to critically analyze the reliability of information or compare competing scientific perspectives. Introducing activities that emphasize critical thinking skills, such as comparing scientific models or engaging in debates, could improve their ability to evaluate explanations. Teaching methods focused on assessing information sources would also benefit students in this area.

This indicator focuses on students' ability to identify relevant scientific questions, a fundamental skill in scientific inquiry. The goal was to determine whether they could discern the right questions to ask in a scientific investigation.



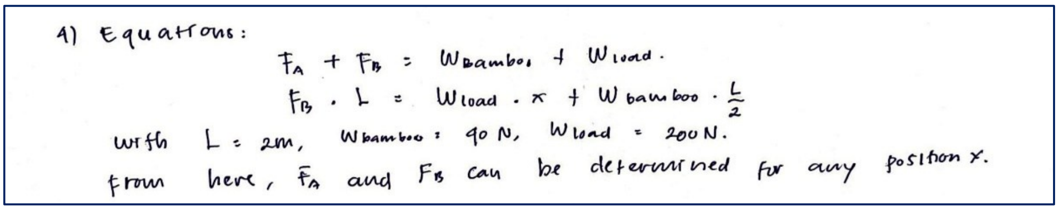
3) 1. What are the forces on Dancer A and Dancer B if the load is 0,5 m from the left end?

2. How do the forces change if the load is moved to the center?

Figure 6. Student answers to the identifying scientific questions indicator

A 34% score suggests that students find it challenging to formulate meaningful scientific questions. This may stem from a lack of practice in differentiating between a hypothesis, a testable question, and a broad inquiry. More structured exercises focused on question formulation, such as giving students a scenario and asking them to formulate testable questions, would help improve this skill.

Students were expected to design a scientific investigation, demonstrating their ability to plan and structure an experiment. This includes formulating a hypothesis, identifying variables, and proposing a data-collection method.



4) Equations:

$F_A + F_B = W_{bamboo} + W_{load}$.

$F_B \cdot L = W_{load} \cdot x + W_{bamboo} \cdot \frac{L}{2}$

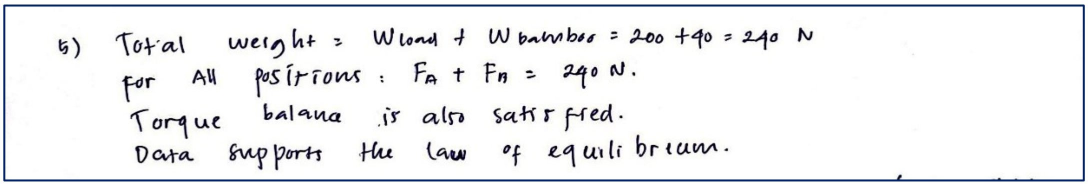
with $L = 2$m, $W_{bamboo} = 40$ N, $W_{load} = 200$ N.

From here, F_A and F_B can be determined for any position x.

Figure 7. Student answers to the design of a scientific investigation indicator

A very low score of 28% shows that most students struggle significantly with this task. The challenge lies in the complexity of designing experiments, which requires a clear understanding of the scientific method and the ability to organize steps logically. To address this, it would be beneficial to break down the process into smaller, more manageable tasks. Providing templates for experimental design and walking through the steps in class could give students a clearer framework to work from.

This indicator assessed students' ability to critically evaluate the results of an investigation and interpret whether the findings supported the hypothesis.



5) Total weight = $W_{load} + W_{bamboo} = 200 + 40 = 240$ N

For All positions: $F_A + F_B = 240$ N.

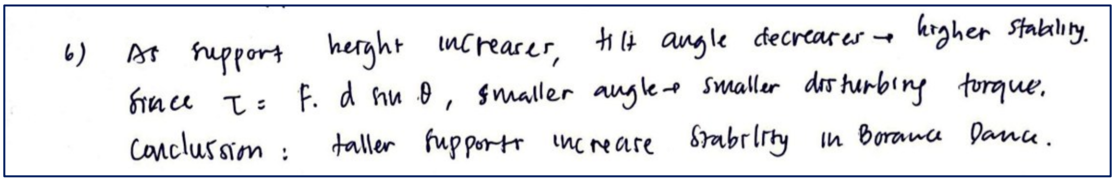
Torque balance is also satisfied.

Data supports the law of equilibrium.

Figure 8. Student answers to the evaluation of the investigation results indicator

A 32% score indicates that many students struggle to assess the significance of their results properly. This may stem from difficulties in understanding data analysis or interpreting outcomes. Incorporating more practice with interpreting data through guided exercises and visual aids, such as graphs and charts, can help students develop stronger evaluation skills.

Here, students were asked to interpret data and facts in a scientific context, requiring them to draw conclusions based on empirical evidence.

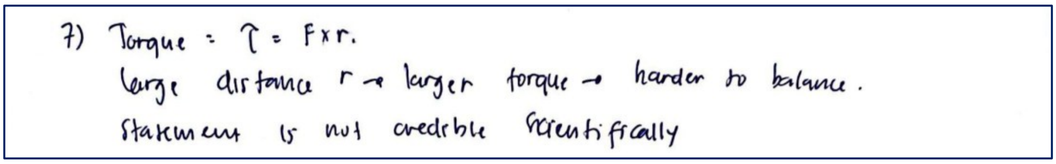


6) As support height increases, tilt angle decreases → higher stability.
Since $\tau = F . d \sin \theta$, smaller angle → smaller disturbing torque.
Conclussion : taller supports increase stability in Borance Dance.

Figure 9. Student answers to the interpreting data and facts scientifically indicator

The moderate score of 45% suggests that while students have some ability to interpret data, there is still room for improvement. The challenge here likely involves making sense of complex data and distinguishing between correlation and causation. Introducing more hands-on data interpretation tasks, such as analyzing real-world data sets, would enhance their understanding. Encouraging the use of critical thinking tools to assess the data would also benefit students.

In this task, students were asked to evaluate the credibility of scientific information and distinguish between reliable sources and questionable claims.

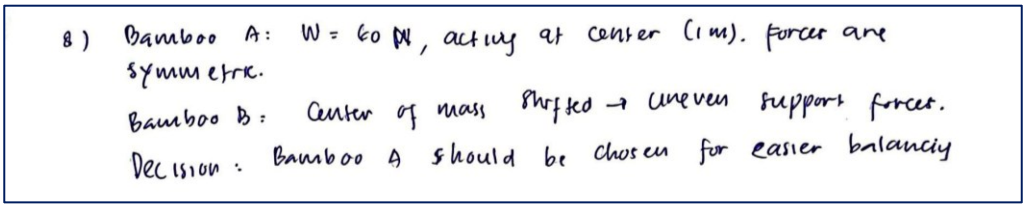


7) Torque = $\tau = F \times r$.
large distance r → larger torque → harder to balance.
Statement is not credible scientifically

Figure 10. Student answers to the evaluation of the credibility of the scientific information indicator

The very low score of 25% indicates that students have significant difficulty in assessing the credibility of scientific sources. This could be due to a lack of awareness of what makes information credible and how to evaluate sources. Teaching students about the principles of source evaluation, including peer review, authority, and bias, would help them develop the skills necessary to assess the credibility of scientific information. Practical exercises in evaluating articles or news stories would be beneficial.

This indicator aimed to assess how students make decisions based on scientifically credible information. It tests their ability to apply trustworthy data in decision-making processes.



8) Bamboo A: W = 60 N, acting at center (1 m). forces are symmetric.
Bamboo B: Center of mass shifted → uneven support forces.
Decision : Bamboo A should be chosen for easier balancing

Figure 11. Student answers to the making decisions based on credible scientific information indicator

With a 30% score, students struggle to make informed decisions based on reliable scientific information. This may reflect a lack of practice in applying scientific findings to real-world situations. Incorporating decision-making scenarios that require students to use credible scientific information to make choices would strengthen their ability to apply knowledge in practical contexts. Discussions on the implications of scientific data in societal issues also promote better decision-making.

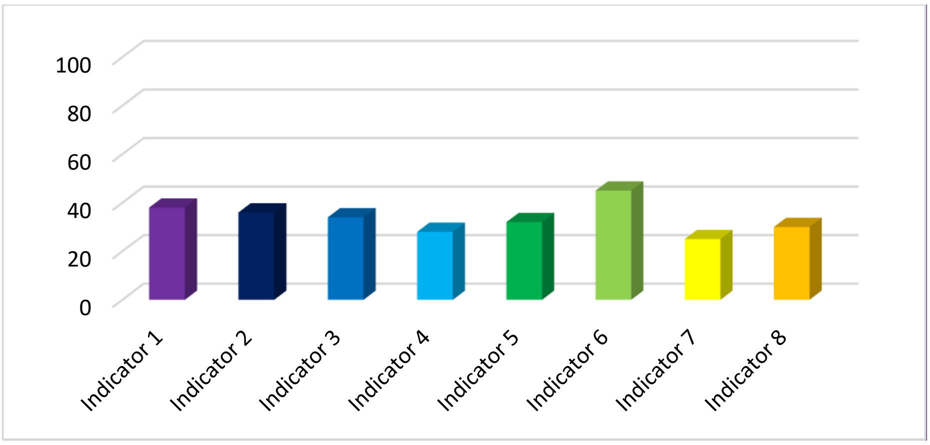


Figure 12. Indicators and average scores

Moreover, when instructional implications are proposed, they should be more explicitly anchored in the inquiry-based and culturally contextualized learning literature rather than in purely intuitive recommendations. Therefore, future revisions may cite empirical studies on inquiry scaffolding, argumentation, and contextualized STEM learning to support the recommended strategies.

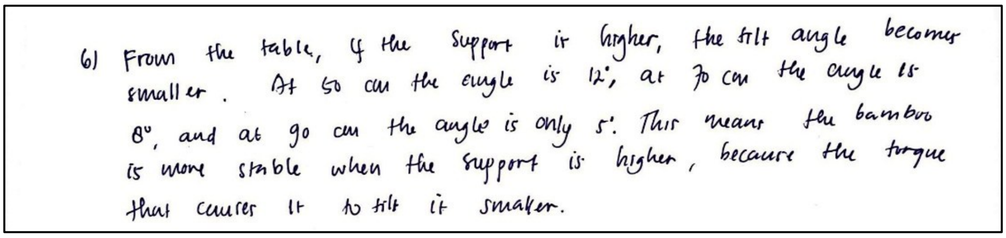
Students' Strengths and Weaknesses

Despite the generally low overall performance, the analysis revealed several notable strengths in students' scientific literacy. Many students demonstrated the ability to explain observable phenomena and perform basic calculations related to rigid-body equilibrium. This indicates that students are comfortable with straightforward applications of formulas, such as torque and force balance.

As summarized in Table 6, the highest achievement was observed in Indicator 6 (Interpreting data and facts) and Indicator 1 (Explaining a phenomenon using scientific concepts). These findings suggest that students could make connections between numerical data and physical reasoning and apply the concept of the center of mass in simple contexts.

Table 6. Indicators showing students' strengths

Indicator	Description of Strength	Example of Evidence
1. Explaining scientific phenomena	Students could explain why the bamboo remains stable when lifted at its midpoint.	Correct explanation mentioning the center of mass at the middle → balance achieved.
6. Interpreting data	Students successfully linked numerical tables (height vs. tilt angle) with the concept of stability.	Conclusion: "Higher support means smaller tilt angle, therefore more stable."



6) From the table, if the support is higher, the tilt angle becomes smaller. At 50 cm the angle is 12°, at 70 cm the angle is 8°, and at 90 cm the angle is only 5°. This means the bamboo is more stable when the support is higher, because the torque that causes it to tilt it smaller.

Figure 13. Student response in interpreting data

The student correctly interpreted the data and identified the relationship between support height and tilt angle. The explanation shows that the student understood the principle of torque balance. These strengths align with prior Indonesian findings that students tend to perform relatively better on representational and data-handling tasks than on evaluative or decision-oriented components of scientific literacy (Hasyim et al., 2024).

In contrast to their strengths, students also exhibited several weaknesses in scientific literacy, particularly in higher-order skills. The lowest performance was observed in Indicators 7 (Evaluating credibility of scientific information), 4 (Designing scientific investigations), and 8 (Making decisions based on data). These areas require not only knowledge of formulas but also critical thinking, evaluation, and decision-making abilities, which many students struggled to demonstrate.

As shown in Table 7, the most common difficulties include the inability to propose systematic investigation steps, a tendency to accept unscientific claims without justification, and vague or incomplete answers when asked to justify decisions with evidence.

Table 7. Indicators showing students' weaknesses

Indicator	Description of Weakness	Example of Student Response
4. Designing scientific investigations	Students could not specify variables or procedures clearly when asked to design an investigation.	"Measure the pole many times until it is balanced." (unclear and lacks steps)
7. Evaluating the credibility of scientific information	Students often agreed with incorrect statements without applying torque principles.	"Yes, the farther the load, the more balanced it becomes." (contradicts torque law)
8. Making decisions based on evidence	Students offered personal opinions rather than evidence-based arguments.	"Bamboo B is better because it looks stronger," without reference to the center of mass.

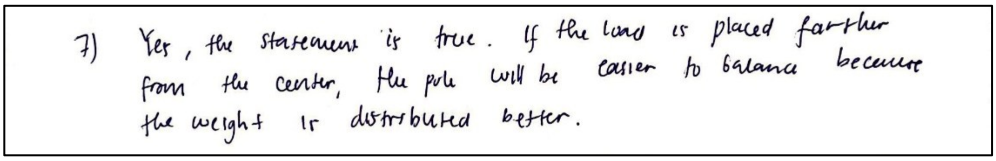

7) Yes, the statement is true. If the load is placed farther from the center, the pole will be easier to balance because the weight is distributed better.

Figure 14. Student response in evaluating credibility

The student accepted the incorrect claim that placing the load farther from the center improves balance. However, the answer shows no application of the torque principle, which actually predicts greater imbalance as distance increases. This indicates weaknesses in evaluating information credibility and in applying fundamental physics concepts to real-world situations.

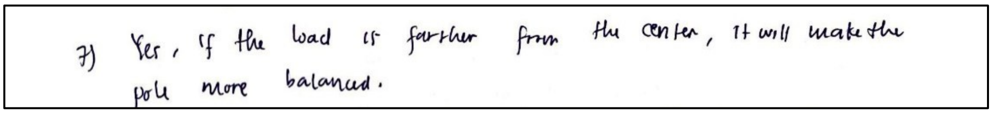

7) Yes, if the load is farther from the center, it will make the pole more balanced.

Figure 15. Direct agreement without reasoning

This response shows that the student accepted the claim at face value, without providing any scientific reasoning. It reflects a lack of critical evaluation and reliance on intuition rather than applying physics principles.

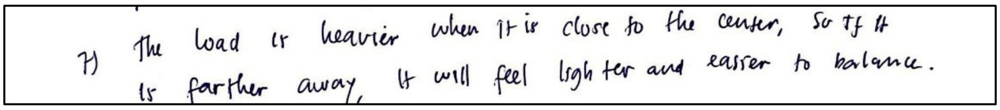

7) The load is heavier when it is close to the center, so if it is farther away, it will feel lighter and easier to balance.

Figure 16. Misconception in reasoning

Here, the student attempted to justify the claim, but with a misconception. They incorrectly assumed that weight depends on position, rather than recognizing that torque increases with distance.

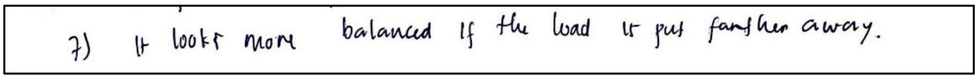

7) It looks more balanced if the load is put farther away.

Figure 17. Incomplete justification

This response lacks a scientific explanation and is purely observational or opinion-based. The absence of reference to torque or equilibrium shows difficulty in applying conceptual knowledge to evaluate statements critically.

These weaknesses indicate that while students can handle basic calculations, they struggle to transfer knowledge into designing investigations, evaluating information, and making scientific decisions. A potential methodological consideration is that essay-based items require extended written reasoning and may increase cognitive load, which could partly account for lower performance on higher-order indicators. In addition, analytic scoring may involve rater judgment; therefore, future work could strengthen scoring objectivity by reporting inter-rater reliability (e.g., Cohen's kappa/ICC) and providing more detailed rubric exemplars.

Effect of Cultural Context (Tari Boranan)

The use of local cultural context, in this case Tari Boranan Lamongan, had a noticeable effect on students' engagement during the learning process. Many students said the cultural narrative helped them feel more connected to the scientific problems because Boranan is part of their familiar environment. The symbolic act of carrying bamboo poles, for example, made the abstract concept of torque and equilibrium appear more relevant and meaningful.

However, despite this cultural familiarity, several students still encountered difficulties in linking the narrative context with mathematical formulations. While they understood the story of dancers balancing bamboo, translating this situation into equations made balancing equations a challenge. This indicates that cultural context can effectively increase interest and relevance, but must be supported with structured scaffolding to bridge the gap to formal physics reasoning.

Table 8. Summary of student interview responses on the effect of the Tari Boranan context

Category	Description	Example Student Response
Positive Engagement	Students felt more interested and connected because Boranan is familiar and part of their daily life or local culture.	*"It was interesting because I know Boranan Dance, so I could imagine the bamboo and how it is carried."* (Student A)
Enhanced Visualization	Students could easily imagine the physical situation (bamboo, dancers, balance) when solving problems.	*"The example makes sense because I often see the dance."* (Student C)
Difficulty in Mathematical Connection	Students struggled to translate cultural narrative into physics equations (torque, center of mass, equilibrium).	*"I liked the story, but when I saw the formula with torque, I was still confused about how to use it with the bamboo."* (Student B)
Partial Understanding	Students could understand the cultural context, but provided incomplete or non-mathematical explanations in their answers.	*"It looks more stable if carried in the middle, but I do not know how to calculate it."* (Student D)

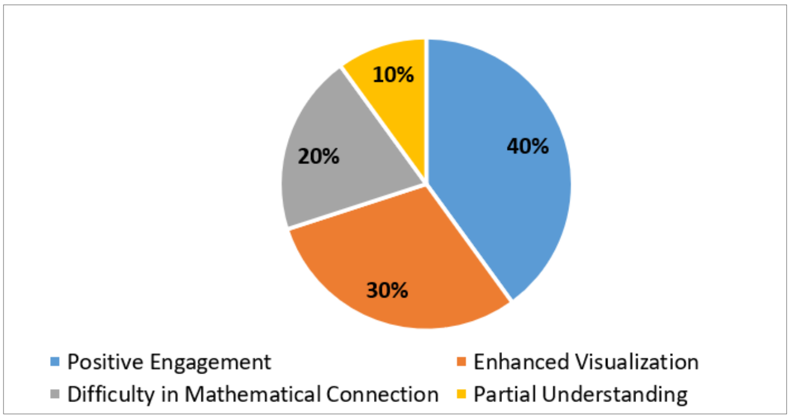


Figure 18. Primary perception of boranan context (%)

Interviews with 10 students about the use of cultural context in Boranan dance revealed diverse perceptions. Most students assessed that this local context had a positive impact on their engagement in learning, with 40% stating they felt more engaged because the material was closer to their own experiences. A total of 30% of students admitted that they still had difficulty connecting cultural narratives with mathematical formulas, especially when applying the concepts of torque and equilibrium. Meanwhile, 20% of students felt helped in visualising physical situations because they were familiar with seeing or knowing the practice of Boranan dance in their environment. The remaining 10% of students demonstrated partial understanding of the cultural context but were unable to provide a complete scientific explanation. This distribution indicates that using local context can enhance relevance and engagement, but further efforts are needed to bridge the gap between narrative understanding and stronger mathematical application.

These responses show that cultural integration increases relevance and motivation, but further pedagogical strategies are needed to connect cultural narratives with scientific and mathematical reasoning. The findings of this study affirm that embedding Tari Boranan Lamongan as a local cultural context in scientific literacy assessment can enhance students' engagement and meaning-making in physics learning. Such place-based approaches align with recent research indicating that connecting scientific content with students' everyday cultural experiences fosters motivation and relevance, ultimately supporting more authentic engagement (A. Sari & Rahman, 2024). In our case, students expressed positive engagement and easier visualization, underscoring how cultural contexts help anchor abstract scientific concepts in familiar realities.

Despite the increased engagement, many students still struggled to translate Boranan's narrative into formal physics reasoning, especially when applying torque and equilibrium equations. This gap reflects broader challenges documented in contextual learning research: while cultural narratives foster initial interest, effective learning requires scaffolding that explicitly bridges narrative contexts and scientific formalism (Saddhono et al., 2020). Compared with prior claims that culturally contextualized instruction automatically improves conceptual mastery, the present findings nuance this view: cultural context appears to primarily strengthen engagement and visualization, whereas improvement in mathematical formalism requires structured scaffolding and explicit modeling of how narratives map onto physics representations.

Limitations

This study has several limitations. First, the sample was restricted to two schools in one regency, limiting generalizability beyond the local context. Second, instrument evaluation relied on expert content validation and Cronbach's alpha; future studies may strengthen validity evidence through construct validation and item-level modeling (Rasch/IRT). Third, the analysis was descriptive and did not include inferential comparisons between groups; subsequent research with larger samples may test differences across school types or student backgrounds. These limitations should be considered when interpreting implications and recommendations.

CONCLUSION

This study developed and implemented a scientific literacy instrument grounded in the cultural context of Tari Boranan, Lamongan, to assess students' understanding of rigid-body equilibrium. Overall, the findings indicate that the instrument demonstrates acceptable psychometric quality and can be used to map students' scientific literacy within a culturally contextualized physics setting. The results show a clear pattern in students' literacy profiles. Students perform relatively better in interpreting data and observable phenomena. However, they experience substantial difficulties in higher-order competencies such as evaluating the credibility of information and designing scientific investigations. These findings suggest that while students possess basic analytical abilities, their critical reasoning and inquiry skills remain underdeveloped. The integration of the Boranan Lamongan dance context enhances students' engagement and helps them visualize physical situations more concretely. However, the cultural narrative alone does not automatically lead to a deeper conceptual or mathematical understanding of physics. This indicates that contextual learning must be accompanied by structured instructional support that explicitly connects cultural experiences with scientific models and formal representations. Taken together, the study highlights the potential of culturally contextualized assessment as a meaningful approach to exploring students’ scientific literacy, while also revealing the areas that require further pedagogical attention.

RECOMMENDATION

Based on the findings of this study, several recommendations can be proposed. First, physics teachers are encouraged to incorporate local cultural contexts into classroom activities to enhance students’ engagement and relevance of learning, while simultaneously providing explicit guidance that links cultural narratives with scientific reasoning and mathematical representations. Second, instructional strategies should focus particularly on strengthening higher-order literacy skills, especially those related to designing scientific investigations, evaluating information credibility, and making evidence-based decisions. These competencies were identified as the weakest aspects of students’ scientific literacy in the present study. Third, future research may explore the development of learning media or instructional models specifically designed to support these weaker indicators of scientific literacy, for example, through inquiry-based activities, argumentation tasks, or digital learning environments that guide students step-by-step in connecting cultural contexts with formal physics concepts. Finally, further studies with broader samples and more advanced measurement approaches are recommended to deepen understanding of how culturally contextualized science learning can support the development of scientific literacy across different educational settings.

ACKNOWLEDGMENT

The authors would like to express their gratitude to the Direktorat Pengabdian kepada Masyarakat (DPPM) Jakarta for the opportunity and support provided in the development of this research through the main contract number 090/C3/DT.05.00/PL/2025. Appreciation is also extended to the Lembaga Penelitian dan Pengabdian kepada Masyarakat (LPPM) Universitas Negeri Surabaya (UNESA) for the guidance, supervision, and facilitation during the preparation process. The realization of this work would not have been possible without the collaboration and support of both institutions.

FUNDING INFORMATION

This research was funded by Direktorat Pengabdian kepada Masyarakat (DPPM), grant number (contract) 090/C3/DT.05.00/PL/2025,

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Titin Sunarti	✓	✓		✓			✓	✓		✓	✓	✓	✓	
Madlazim	✓	✓		✓						✓				
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CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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