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Analysis of Science Literacy of Physics Education Students at UIN Walisongo Semarang Using the PISA Model Test Instrument

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ABSTRACT

This study aims to analyze the level of science literacy at the Physics Education Study Program UIN Walisongo Semarang by using the International Student Assessment (PISA) Model Test Instrument. Science literacy is measured based on the ability of students in analyzing, applying concepts, and using a scientific approach in the context of basic mechanics, especially in business material, energy, and power. This study involved students of Physics Education UIN Walisongo Semarang with test data showing the highest score of 84, lowest 16, and an average of 32 of the maximum score of 100. Analysis of the indicator of competency achievement shows a significant variation between the eight aspects measured. The highest indicator is the ability to analyze and apply the concept of relationship between business and kinetic energy and potential energy (39%), followed by the application of scientific methods in the concept of kinetic and potential energy (36%). Meanwhile, the lowest indicator is found in the aspect of analyzing and applying the concept of relationship between business and mechanical energy changes (16%) as well as the application of scientific methods in the concept of mechanical energy (26%). These findings indicate that students tend to experience difficulties in integrating scientific approaches and complex conceptual understanding. The results of this study indicate that the literacy of physics education students is still at a low level, with the dominance of factual and conceptual abilities that have not fully developed to the analytical and applicative levels. Therefore, innovation is needed in the learning approach and assessment that is oriented towards strengthening scientific thinking and transfers cross -context concepts. This study made an important contribution in the development of PISA -based science literacy assessment for higher education in the field of physics education, as well as supporting the strengthening of 21st century competencies in science education in Islamic tertiary institutions.

Introduction

Scientific literacy has become a central theme in science education worldwide, especially in the context of preparing future citizens who are capable of making informed decisions based on scientific reasoning. The Organisation for Economic Co-operation and Development (OECD) defines scientific literacy as the ability to engage with science-related issues, explain phenomena scientifically, evaluate and design scientific inquiries, and interpret data and evidence scientifically (PISA, 2019). In the context of 21st century skills, scientific literacy integrates conceptual understanding with procedural competence and problem-solving abilities that are vital for navigating real-world challenges (Bybee, 2013; Holbrook & Rannikmae, 2009). This conceptualization is also grounded in constructivist learning theory, which posits that learners build scientific understanding through active exploration

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and contextual problem-solving (Bruner, 1977; Vygotsky, 1978). These principles align with inquiry-based learning (IBL) frameworks that emphasize students' engagement in scientific practices such as questioning, hypothesizing, investigating, analyzing, and drawing conclusions skills that mirror the OECD-PISA science competencies (Kind & Osborne, 2017).

Despite increasing attention on scientific literacy, international large-scale assessments such as PISA have consistently reported low achievement levels among students from developing countries. Indonesia's performance in PISA 2018 and 2022 reflects this concern, with science literacy scores significantly below the OECD average. In PISA 2022, only 34% of Indonesian students met the minimum proficiency level (Level 2), far below the OECD average of 76% (Durango-Gutiérrez et al., 2023). This persistent gap highlights a critical need to reform not only secondary but also higher education practices that influence the development of future science educators. While many studies have examined science literacy among secondary school students, there is a notable lack of research focusing on science literacy among pre-service physics teachers at the higher education level. This population, however, is crucial, as they are the future educators who will shape the next generation's scientific literacy (Evagorou et al., 2009; Mubarokah et al., 2018).

This research identifies a critical gap in the literature: the absence of diagnostic studies that employ robust international instruments, such as the PISA science test model, to assess scientific literacy among university students in physics education programs. While the PISA framework has been extensively studied in secondary contexts, its application to higher education, particularly in evaluating how well pre-service physics teachers understand and apply fundamental concepts such as work, energy, and power, remains underexplored (Liu, 2009; Zeyer & and Dillon, 2012). Furthermore, there is insufficient analysis on how these students demonstrate procedural understanding through scientific inquiry methods an essential aspect of the PISA science framework (Roehl, 2015). Grounding this research within the OECD-PISA framework and informed by the pedagogical perspectives of inquiry-based learning and constructivism ensures a strong theoretical foundation for assessing and interpreting students' scientific competencies.

To address this gap, the present study analyzes the scientific literacy of students enrolled in the Physics Education Study Program at UIN Walisongo Semarang using a customized PISA-based test instrument. The test targets eight specific indicators that reflect both conceptual and procedural scientific competencies related to basic mechanics: analyzing and applying the concept of work, the relationship between work and kinetic and potential energy, mechanical energy transformation, and the concept of power.

This study contributes to the existing body of knowledge by (1) adapting and applying a PISA-based assessment tool for higher education; (2) providing detailed empirical insights into the strengths and weaknesses of pre-service physics teachers' scientific literacy; and (3) offering targeted recommendations for assessment reform and instructional strategies in physics education. The novelty of this research lies in its dual focus on both content knowledge and inquiry skills through the lens of an internationally benchmarked instrument, applied in a higher education context that has been largely overlooked in the literature. It also provides evidence-based support for redesigning curricula and assessment practices in teacher education to better equip future educators with the scientific literacy needed to meet 21st century demands (Adawiyah & Wisudawati, 2017; Osborne & and Allchin, n.d.; Waki'a, 2021).

Methods

This study employed a descriptive quantitative research design to analyze the scientific literacy of pre-service physics teachers using a custom-developed assessment instrument modeled on the PISA science literacy framework. The research was conducted at the Physics Education Study Program, UIN Walisongo Semarang, involving students enrolled in the Basic Physics 1 course.

The test instrument consisted of 45 multiple choice questions that reflect the domain of scientific literacy based on OECD-PISA competencies. The items focused on the topic of work and energy core components of the Basic Physics 1 curriculum and were designed to measure students' ability to explain phenomena scientifically, evaluate and design scientific inquiries, and interpret data and evidence. Each question included context-rich scenarios to evaluate not only conceptual understanding but also the application of scientific reasoning in realistic situations. The instrument underwent expert validation by three university-level science educators and two assessment experts. A pilot test was conducted to ensure clarity, reliability, and content validity.

Data Collection

Data were collected through a paper-based test administered during scheduled lecture hours. Students were informed of the purpose of the research and participated voluntarily. Each item was scored based on a rubric aligned with PISA's competency levels. The maximum possible score was 100, with a minimum of 0.

Data Analysis

Descriptive statistics were used to calculate the minimum, maximum, and average scores across all participants. In addition, percentage scores for each indicator were calculated to determine the extent of students' mastery in both conceptual and procedural dimensions. The results were interpreted with reference to PISA performance levels and the targeted scientific competencies.

Result and Discussions

The results of this study provide a comprehensive snapshot of the scientific literacy competencies of pre-service physics teachers, particularly in the context of work and energy. Based on the test scores of 84 students from UIN Walisongo Semarang, the scientific literacy level was found to be alarmingly low. Table 1 presents the summary of overall performance.

Table 1
Summary of Students' Scientific Literacy Scores

Component	Percentage (%)
Lowest Score	84
Highest Score	16
Mean Score	32

The average score of 32 out of 100 places the majority of students below the minimum proficiency threshold defined by OECD-PISA, indicating a widespread difficulty in mastering essential scientific competencies (OECD, 2019). These findings resonate with prior studies that highlight the persistent struggle of Indonesian students in applying scientific concepts to real-life scenarios (Bangkara et al., 2022; Oktavia et al., 2018).

In-depth analysis was conducted on eight specific indicators derived from the scientific literacy framework. The performance breakdown by each indicator is presented in Table 2.

The highest competency was observed in Indicator 3 (39%), which deals with the relationship between work and kinetic or potential energy. However, even this score remains below a satisfactory benchmark. The lowest performance was recorded in Indicator 5 (16%), which involves analyzing and applying the relationship between work and mechanical energy transformation. This result points to a significant weakness in integrating theoretical concepts with dynamic physical processes.

Table 2
Scientific Literacy Competency Breakdown by Indicator

No	Competency Indicator	Percentage (%)
1	Analyzing and applying the concept of work	34
2	Applying scientific methods to the concept of work	33
3	Analyzing and applying the relationship between work and kinetic/potential energy	39
4	Applying scientific methods to kinetic/potential energy concepts	36
5	Analyzing and applying the relationship between work and changes in mechanical energy	16
6	Applying scientific methods in the context of mechanical energy	26
7	Analyzing and applying the concept of power	25
8	Applying scientific methods in the context of power	34

A deeper exploration of these findings suggests several interconnected causes. First, the dominance of traditional, lecture-centered instruction in physics education significantly limits opportunities for students to engage in active exploration and reasoning. Studies have repeatedly demonstrated that passive learning environments result in surface-level understanding, where students memorize formulas without grasping underlying principles (Kang et al., 2021; Krolevetskaya et al., 2022; Videla et al., 2021). This instructional culture appears to be prevalent even at the tertiary level in Indonesian universities (Hidajat, 2023).

Second, limited exposure to authentic, real world problem solving may hinder students' ability to transfer learned knowledge to novel contexts a key component of scientific literacy (Akinbobola & Afolabi, 2010; PISA, 2019). In this study, even students who demonstrated moderate understanding of static concepts like work and kinetic energy failed to exhibit competence when required to analyze energy transformation processes, suggesting difficulties in system-level reasoning (McLure et al., 2024; Opfermann et al., 2017).

Third, assessment practices within the Basic Physics 1 course may not adequately measure or encourage literacy-oriented competencies. If existing assessments focus primarily on computation and algorithmic tasks, students will likely adopt rote strategies rather than scientific reasoning (Kohl & Finkelstein, 2005). This discrepancy between instructional objectives and assessment practices has been well documented in both developed and developing contexts (Lazonder & Harmsen, 2016).

Another crucial factor is the limited development of metacognitive and representational skills among the students. Energy related concepts inherently require students to move fluently between mathematical expressions, conceptual models, and real-life scenarios (Opfermann et al., 2017). Yet, many students struggle with these representational translations, resulting in fragmented and context-bound understandings. The ability to visualize and connect mechanical energy processes is especially critical in solving problems related to energy conservation and transformation areas where students performed most poorly in this study.

Moreover, the curriculum structure and teacher preparation models may lack alignment with the multidimensional goals of scientific literacy. For instance, while the Indonesian national curriculum emphasizes the importance of 21st century skills, its implementation in university level science education remains inconsistent and often disconnected from pedagogical innovation (Kohler et al., 2022; Muchson et al., 2024). If faculty members are not provided with adequate professional development in inquiry-based and constructivist pedagogies, they may resort to traditional methods that inhibit students' critical engagement.

Cultural dimensions may also play a role. In collectivist educational settings like Indonesia, students are often hesitant to express uncertainty, challenge authority, or take intellectual risks behaviors that are essential for inquiry and scientific argumentation (Triandis, 2020). This could explain the low scores in items that required independent reasoning or hypothesis evaluation.

Lastly, access to well-designed instructional media, simulations, and laboratory experiences is often limited. Practical and contextualized learning experiences have been shown to significantly enhance scientific literacy by allowing students to directly observe and manipulate variables (Wieman, 2017). Without such opportunities, abstract concepts such as energy conservation or transformation may remain elusive.

Taken together, the results of this study suggest that improving scientific literacy among pre-service physics teachers requires comprehensive reform not only in curriculum design and assessment alignment, but also in pedagogical practice, institutional support, and cultural adaptation. Future research should investigate intervention based models that integrate inquiry learning, STEM context, and socio-scientific issues into physics instruction. This would not only strengthen students' scientific reasoning but also empower them as future educators who can promote scientific literacy at the school level.

The data shows nuanced trends in the scientific literacy of physics education students. The low scores on indicators involving conceptual relationships and scientific methods point to deeper learning challenges. Rather than issues of infrastructure which are not relevant in this context cognitive, pedagogical, and epistemological factors offer more plausible explanations.

Students' fragmented understanding of energy systems is a key concern. Studies like those by Geller et al., (2019) and Darling-Hammond et al. (2020) show that many students compartmentalize concepts such as work, energy, and power, lacking the ability to relate them within a coherent scientific model. This issue is compounded by instruction that focuses on procedural fluency over conceptual integration (Nordine et al., 2024).

In indicators involving scientific methods, students scored consistently low. This suggests that students are not routinely engaging in practices such as variable identification, hypothesis formation, or evidence-based reasoning. According to Viehmann et al. (2024), scientific reasoning is significantly underdeveloped in pre-service teachers who lack sustained exposure to inquiry-based science teaching.

Indicator 5, which scored the lowest, involves understanding the transformation of mechanical energy. This aligns with prior research indicating that energy transformation is one of the most misunderstood topics in physics (Tatar & Oktay, 2007). Students often retain everyday misconceptions like energy being "used up" even after formal instruction. Without instructional strategies targeting these alternative conceptions, students struggle to apply conservation principles in complex systems.

Another area of concern is students' representational competence. Scientific literacy requires the ability to interpret and shift between graphs, equations, diagrams, and verbal models. The low performance across indicators requiring these skills is consistent with findings from Ramma et al. (2024), who argue that representational fluency predicts physics understanding better than raw content knowledge.

Cognitive overload may also be at play. Solving problems that involve integrating work, energy, and power across representations places a high demand on working memory. Plass's et al. (2019) cognitive load theory suggests that without scaffolding strategies, students will resort to rote techniques and fail to generalize learning.

While UIN Walisongo provides adequate laboratory facilities, these alone do not ensure inquiry competence. Research by Pedaste et al. (2015) emphasizes that the quality of inquiry cycles planning, experimenting, analyzing is more critical than the presence of equipment. Effective facilitation of scientific discourse and reflective thinking is key.

Furthermore, pedagogical identity plays a crucial role. A study by Kotsis (2024) in the Indonesian context found that teacher candidates who actively engage in discussions, lesson planning, and reflection develop stronger scientific reasoning and confidence. This aligns with the notion that beliefs and dispositions shape engagement in science practices.

In summary, the low scientific literacy scores across indicators stem not from lack of access, but from instructional strategies that do not sufficiently promote conceptual coherence, epistemic practices, and metacognitive awareness. Addressing these through targeted pedagogical interventions, reflective teaching practices, and aligned assessments is essential.

Conclusions

The findings of this study indicate that students' scientific literacy is critically low, with an average score of only 32 out of 100. This suggests that most students have not yet achieved the basic level of scientific proficiency expected in physics education. The analysis of specific indicators reveals substantial gaps in several key areas, particularly in understanding the relationship between work and changes in mechanical energy, as well as in applying scientific methods in energy-related contexts. Even in indicators that are relatively more straightforward, student performance did not exceed 40%. These results highlight the urgent need for pedagogical improvements that focus on strengthening conceptual understanding, enhancing the application of scientific methods, and contextualizing physics concepts within real-life situations. Targeted instructional strategies and curriculum adjustments are essential to support the development of meaningful and functional scientific literacy among students.

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