ANALYSIS AND DESIGN OF SCIENTIFIC LITERACY ASSESSMENT INSTRUMENT FOR SENIOR HIGH SCHOOL STUDENTS BASED ON PISA 2025 FRAMEWORK

Maya Mustika[1]
Fatchiyatun Ni'mah[2]
Ennike Gusti Rahmi[3]
Saulim DT Hutahaean[4]

[1,4]Program Studi Pendidikan Fisika, FKIP, Universitas Palangka Raya
[2]Program Studi Pendidikan Kimia, FKIP, Universitas Palangka Raya
[3]Program Studi Pendidikan Biologi, FKIP, Universitas Palangka Raya

***Corresponding author. Email: maya.mustika@fkip.upr.ac.id**

Abstract: *Scientific literacy is essential for students to navigate a complex, science-based world. The PISA 2025 framework provides comprehensive guidelines for measuring scientific literacy across three dimensions: competencies, knowledge, and attitudes. However, Indonesian assessment instruments remain limited and not fully aligned with international standards. This study analyzes needs and designs a scientific literacy assessment instrument blueprint for senior high school students based on PISA 2025, adapted to the Indonesian context. Using a Research and Development approach, the analysis phase included literature review of PISA 2025, Indonesian curriculum analysis, and needs identification through surveys with educators and students. The design phase developed instrument specifications, assessment indicators, and test formats. Analysis revealed PISA 2025 integrates three competencies: explaining scientific phenomena, designing and evaluating investigations, and interpreting data and evidence. Curriculum analysis identified gaps between PISA demands and Indonesian practices. The resulting blueprint contains 60 complex multiple-choice items measuring scientific literacy across personal, local/national, and global contexts within physics, chemistry, and biology domains. The developed instrument blueprint offers a comprehensive assessment alternative for measuring Indonesian students' scientific literacy. Further empirical validation and pilot testing are recommended.*

Keywords: *Scientific literacy, Assessment instrument, Physics, Chemistry, Biology*

Introduction

Scientific literacy has become a fundamental competency required in the 21st century, as it equips individuals to understand and respond critically to scientific and technological issues in their daily lives. The rapid growth of information technology, industrial innovation, and global environmental challenges demands citizens who can make informed decisions based on evidence rather than mere belief or authority. According to Zhai and Pellegrino (2023), scientific literacy is not only the capacity to recall scientific facts but also to engage in reasoning processes that connect science with real-world contexts, socio-economic decisions, and sustainable development. In educational settings, fostering scientific literacy means preparing students to become *science-*

informed citizens who can interpret data, understand the implications of scientific advancements, and participate in societal problem-solving. Therefore, developing assessment instruments that measure this multidimensional literacy is an urgent and strategic step toward improving science education quality globally.

The Organisation for Economic Co-operation and Development (OECD) defines scientific literacy as "the ability to engage with science-related issues and with the ideas of science, as a reflective citizen" (OECD, 2023). Within the PISA 2025 Science Framework, scientific literacy encompasses three core competencies: (1) explaining phenomena scientifically, (2) evaluating and designing scientific enquiry, and (3) interpreting data and evidence scientifically. These competencies are assessed through contextualized problems in which students apply concepts from physics, chemistry, biology, and earth science to authentic social and environmental issues (Kumar & Choudhary, 2025). Unlike traditional tests focusing solely on factual recall, the PISA 2025 framework emphasizes interdisciplinary reasoning and context-based inquiry. It integrates scientific knowledge with cognitive and affective domains, aiming to measure how students reason with evidence, design experiments, and use science in personal and global decision-making.

Despite numerous curriculum reforms, Indonesia's performance in international science literacy assessments remains below the OECD average. The latest PISA 2022 report shows that Indonesia's mean score for science literacy was 383, placing it 73rd out of 81 participating countries, compared to the OECD average of 485 (OECD, 2023). This decline from the 2018 score (396) reflects persistent challenges in scientific reasoning, data interpretation, and the application of interdisciplinary knowledge (Wahab, Prahani, & Haryono, 2025). Studies show that many Indonesian students can recall definitions and formulas but struggle when faced with contextual or inquiry-based scientific problems (Putri, Rachmadiarti, & Purnomo, 2025). This pattern indicates a learning culture still dominated by rote memorization and teacher-centered instruction, rather than active engagement in scientific reasoning or experimental design.

The fundamental issue underlying low scientific literacy in Indonesia lies in the fragmentation of science teaching and the lack of contextual learning integration. Science subjects—physics, chemistry, and biology—are often taught separately without meaningful connection to real-life contexts or cross-disciplinary reasoning (Simatupang, Suyanti, & Djulia, 2025). In many cases, classroom assessments prioritize cognitive recall over reasoning, interpretation, and evidence- based thinking. This approach limits students' capacity to apply scientific understanding to real- world phenomena. As noted by Amini and Sinaga (2021), most science learning in Indonesia still fails to engage students in authentic inquiry or socio-scientific discussions. Consequently, the current curriculum has yet to effectively nurture *scientifically literate learners* capable of connecting local environmental issues with scientific concepts—a key goal of the Merdeka Curriculum and Education for Sustainable Development (ESD).

Another critical obstacle in improving scientific literacy lies in the limitations of existing assessment instruments. Traditional school assessments, primarily multiple-choice exams or factual recall tests, cannot adequately capture the complex reasoning and evidence-based decision- making central to scientific literacy (Wan, Lee, & Chen, 2024). Existing instruments are rarely validated across scientific domains and often lack contextualization relevant to local issues such as environmental sustainability, resource management, and energy efficiency. As a result, teachers and policymakers lack reliable tools to diagnose students' scientific literacy levels or to monitor learning outcomes aligned with international benchmarks such as the PISA 2025 framework. According to Hardinata and Djulia (2025), an effective literacy assessment should not only evaluate students' conceptual understanding but also integrate the dimensions of context, cognitive process, and scientific practice.

Given these challenges, there is an urgent need to design a scientific literacy assessment instrument that aligns with the PISA 2025 framework and reflects the Indonesian educational context. Such an instrument should integrate content from physics, chemistry, and biology while

embedding authentic, real-world problems that mirror environmental, technological, and social phenomena. The development of this instrument will bridge the gap between curriculum expectations and international literacy standards, providing educators with a reliable tool to measure and improve scientific reasoning.

While numerous studies have explored scientific literacy assessment based on previous PISA frameworks (2015 and 2018), research and development of assessment instruments aligned with the new PISA 2025 framework remain limited, especially in the Indonesian context. Studies by Putri et al. (2025), Wahab et al. (2025), and Simatupang et al. (2025) reveal that most existing instruments still adopt the PISA 2015–2018 conceptual model, which emphasizes explaining phenomena but does not yet integrate *evaluating and designing scientific enquiry* as mandated by PISA 2025. Moreover, few studies have incorporated interdisciplinary integration across physics, chemistry, and biology in a single assessment framework (Zhai & Pellegrino, 2023; Kumar & Choudhary, 2025). Internationally, research on PISA 2025-based assessments is still emerging, with initial studies focusing on theoretical constructs rather than empirical instrument design (OECD, 2023; Lin & Tsai, 2021; Wan et al., 2024). Nationally, only a handful of projects—such as by Hardinata & Djulia (2025) and Rahmawati et al. (2023)—have begun adapting contextual scientific literacy assessments for local implementation, yet these efforts remain discipline-specific and lack psychometric validation. This research gap highlights the need for a systematic design and validation study that develops an integrated, interdisciplinary, and contextually relevant scientific literacy assessment instrument in alignment with the PISA 2025 framework.

Given the critical need to elevate scientific literacy in Indonesia and the evolution of global assessment standards, the development of a high-quality assessment instrument is paramount. This research addresses this requirement by focusing on the initial and most crucial phases of instrument construction. The instrument must be meticulously designed to measure the integrated application of scientific principles across the three distinct domains of science (Chemistry, Biology, and Physics) within contexts that demand PISA 2025 competencies. Therefore, this study is rigorously designed: to present a needs analysis and the design for developing a student scientific literacy assessment instrument across three subjects (Chemistry, Biology, and Physics) based on PISA 2025. This research is expected to contribute to the body of knowledge in *science education assessment* and support evidence-based policymaking for improving the quality of scientific literacy education in Indonesia.

Method

The research employed a Research and Development (R&D) approach, focusing specifically on the analysis and design stages of instrument development according to the PISA 2025 scientific literacy framework. The study was conducted between August and October 2025 in several senior high schools in Palangka Raya City, Central Kalimantan Province, involving both students and science teachers. The research subjects comprised 171 senior high school students and 50 science teachers (covering physics, chemistry, and biology disciplines). These participants were selected purposively to represent diverse academic backgrounds and teaching experiences relevant to science learning in high school.

At the analysis stage, a needs assessment was conducted to identify the urgency and characteristics of developing a scientific literacy assessment instrument adapted to the PISA 2025 framework. Data collection involved two main instruments: open-ended questionnaires and Likert-scale surveys (1–5 points). The open-ended questions captured qualitative insights regarding current assessment practices and challenges in integrating scientific literacy skills in instruction, while the Likert-scale survey quantified the perceived importance, feasibility, and relevance of the new assessment instrument from both teachers' and students' perspectives. The data obtained from the open-ended responses were analyzed using thematic analysis to identify recurring themes and needs related to scientific literacy assessment. Meanwhile, quantitative data from the Likert scale

were analyzed using descriptive statistics, presenting measures of central tendency (mean, mode, and median) and frequency distributions to describe the level of urgency assessed by respondents.

The design stage utilized the analysis results to construct an assessment blueprint aligned with the PISA 2025 scientific literacy framework. Each item was developed based on three main domains: physics, chemistry, and biology with 20 items per domain, totaling 60 items. The design process included determining the context, content, and cognitive processes measured by each item according to PISA's categories of explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting data and evidence scientifically. The instrument also considered the balance of item formats and difficulty levels to reflect realistic and contextual problem-solving situations. Expert judgment and content validity reviews were planned after this design phase as part of subsequent development stages. All documentation from each stage was recorded systematically to ensure traceability and transparency of the research process.

Result and Discussion

1. Analysis of Students' Needs for PISA 2025 Framework-Based Scientific Literacy Assessment Instruments

a. Needs Regarding PISA 2025 Scientific Literacy Competencies

Explaining Scientific Phenomena. The results indicate that 66.7% of students (agree + strongly agree) expressed the need for questions that can measure their ability to explain everyday scientific phenomena (item 1). Only 7% of students stated they do not need this type of question. This finding indicates students' high awareness of the importance of the competency to explain scientific phenomena, which constitutes one of the three core competencies in the PISA 2025 framework. Nevertheless, there exists a misalignment between this need and students' perception of their actual abilities. In item 2, only 49.7% of students were confident that their ability to explain scientific phenomena could be trained through complex problem-solving, while 40.9% of students remained uncertain (neutral). This demonstrates a gap between awareness of the importance of competency and self-efficacy in developing such competency.

Interpreting Data and Scientific Evidence. A total of 63.7% of students expressed the need for questions that train their ability to interpret scientific data and graphs (item 4). This need is consistent with findings on discipline-specific items: 45.6% of students frequently encounter data analysis questions in Physics (item 8), and 63.5% require questions analyzing Biology research data (item 14). These data confirm the urgency of developing instruments that integrate data interpretation competencies as emphasized in PISA 2025.

Evaluating and Designing Scientific Investigations. Although not explicitly addressed in the questionnaire, the need for this competency can be inferred from students' preferences for multiple-choice questions with complex problem analysis (60.3% agree, item 5) and questions based on real case studies (68.5% agree, item 6). These preferences indicate that students desire questions that not only test memorization but also the ability to evaluate experimental design and scientific investigations.

The findings of this study demonstrate strong alignment between students' needs and the scientific literacy competencies emphasized in the PISA 2025 framework. The high need for questions measuring the ability to explain scientific phenomena (66.7%) and interpret data (63.7%) aligns with two of the three core PISA 2025 competencies: *explaining phenomena scientifically* and *interpreting data and evidence scientifically* (OECD, 2023). These results confirm that Indonesian students recognize the importance of these competencies, despite their actual performance in PISA 2022 remaining low (score 383, ranking 73 out of 81 countries).

These findings are consistent with the study by Zhai and Pellegrino (2023), which states that scientific literacy is not merely the ability to recall facts but the capacity to engage in reasoning processes that connect science with real-world contexts. The gap between students' awareness of

the importance of competency (66.7%) and their self-confidence in developing it through complex problem-solving (49.7%) reflects what Bandura (1997) terms the *self-efficacy gap*—the difference between knowledge of required competencies and confidence in achieving them. Research by Schunk and DiBenedetto (2016) shows that students' self-efficacy in science can be enhanced through exposure to authentic tasks and gradual success experiences.

b. Needs for Contextualization and Global Issues

The most significant finding is the high level of students' needs for contextual learning relevant to global issues. As many as 72.5% of students stated that they greatly need questions linking science with global issues such as climate change, health, and energy crises (item 3). This represents the highest percentage of agreement in the entire survey, indicating that students recognize the importance of connections between science learning and contemporary global challenges.

This need for contextualization is also reflected in preferences for specific contexts:

- **Environmental issues**: 67.8% of students consider Chemistry questions related to pollution and recycling highly relevant (item 9)
- **Health issues**: 76% of students need Biology questions related to current health and disease issues (item 12)
- **Indonesian local context**: 71.3% of students find questions with local Indonesian contexts such as biodiversity, natural disasters, and local wisdom easier to understand (item 15)

The most significant finding in this study is the high level of students' needs for contextual learning (72.5% for global issues, 71.3% for local contexts). These results provide empirical support for the argument proposed by Simatupang, Suyanti, and Djulia (2025) that the fragmentation of science teaching in Indonesia—where Physics, Chemistry, and Biology are taught separately without connection to real-life contexts—constitutes a primary factor in low scientific literacy.

Students' preferences for questions with global and local contexts align with the principles of *situated learning* proposed by Lave and Wenger (1991) and further developed in the context of science education by Gilbert (2006) and Sadler (2009). This theory emphasizes that learning becomes more meaningful when knowledge is constructed in contexts that are authentic and relevant to students' lives. Recent research by Zeyer and Kyburz-Graber (2023) shows that socioscientific issues (SSI)-based science learning significantly enhances students' motivation and conceptual understanding.

The high preference for health contexts (76% for Biology) and environmental contexts (67.8% for Chemistry) reflects the relevance of these issues in students' lives, particularly post-COVID-19 pandemic and amid the global climate crisis. This aligns with the study by Sadler and Zeidler (2024), which found that health and environmental issues constitute the most effective contexts for developing scientific literacy because they have immediate relevance to students' lives.

c. Interdisciplinary Integration and Technology Application

The data show a strong need for science learning integrated with technology and industrial applications:

- **Physics and technology**: 54.3% of students prefer Physics questions linking concepts with current technology (item 7)
- **Chemistry in the human body**: 77.2% of students need questions about chemical processes in the body (item 10)
- **Industrial chemistry**: 61.5% of students agree that questions about chemistry in industry help understand concept applications (item 11)
- **Biotechnology**: 60.2% of students consider questions about biotechnology and genetic engineering important for understanding modern science (item 13)

The high need among students for questions integrating Physics, Chemistry, and Biology with technology applications and real-life contexts (54.3%-77.2% depending on specific contexts) supports the interdisciplinary approach emphasized in PISA 2025. Kumar and Choudhary (2025) state that the PISA 2025 framework integrates all four science domains (Physics, Chemistry, Biology, and Earth Science) in authentic problem contexts, not as separate disciplines. However, research by Simatupang et al. (2025) shows that most scientific literacy assessment instruments in Indonesia remain discipline-specific and rarely integrate cross-disciplinary concepts.

The findings of this study have important implications for the design of PISA 2025-based scientific literacy assessment instruments. The developed instruments must balance the integration of three PISA 2025 competencies: explaining scientific phenomena, evaluating and designing investigations, and interpreting data and evidence. This aligns with recommendations by Lin and Tsai (2021), stating that valid scientific literacy instruments must measure cognitive complexity holistically, not fragmented by competency. Based on students' high preferences for global (72.5%) and local (71.3%) contexts, instruments should adopt a *contextualization at multiple levels* strategy. Wan, Lee, and Chen (2024) suggest that effective contexts in scientific literacy assessment must meet the criteria: (a) personal relevance—relevant to students' lives, (b) social significance—related to important social issues, and (c) authentic complexity—reflecting the complexity of real-world problems.

This research contributes to empirically identifying what Indonesian students need in the context of scientific literacy assessment. Unlike previous studies that tend to be top-down (adopting international frameworks without local needs validation), this study adopts a bottom-up approach by placing students' perspectives as the starting point. The finding that 71.3% of students find questions with Indonesian local contexts (biodiversity, natural disasters, local wisdom) easier to understand provides empirical justification for developing culturally responsive instruments. Research by Hardinata and Djulia (2025) and Rahmawati et al. (2023) has initiated contextual adaptation efforts, but these remain limited to specific disciplines. Our research shows that this need is cross-disciplinary and must be systematically integrated.

2. Analysis of Teachers' Perceptions Regarding the Urgency of Instrument Development

a. Urgency of Needs for International Standard-Based Instruments

The data show a very strong consensus among teachers regarding the urgency of developing scientific literacy instruments based on international standards. As many as 84% of teachers (agree + strongly agree) stated that scientific literacy assessment instruments conforming to international standards are greatly needed in Indonesia (item 1), with only 2% disagreeing. This urgency is reinforced by the finding that 82% of teachers agree high school students need to be prepared to face internationally standardized scientific literacy tests such as PISA (item 2), with 52% strongly agreeing—the highest strongly agree percentage in this category.

A concerning finding is that only 50% of teachers stated that the development of PISA 2025-based instruments constitutes an urgent need (item 4), with 44% still uncertain. This contrast indicates that although teachers acknowledge the importance of international standards generally, specific awareness of the PISA 2025 framework and the urgency of its adoption still needs to be enhanced.

b. Critical Evaluation of Existing Assessment Instruments

Teachers demonstrate high critical awareness of the limitations of currently used assessment instruments. Key findings include:

- **Suboptimal existing instruments**: 64% of teachers agree that current science assessment instruments have not optimally measured students' scientific literacy abilities (item 3), with only 6% strongly agreeing. The high neutral percentage (34%) indicates that some teachers may not have a clear understanding of the characteristics of optimal scientific literacy instruments.

- **Dominance of memorization questions**: 56% of teachers acknowledge that the science learning evaluation questions they use are still predominantly measuring concept memorization rather than application (item 5). However, 14% of teachers disagree with this statement, indicating differences in assessment practices among teachers or differences in perceptions about what constitutes "memorization" versus "application." **Limitations of interdisciplinary instruments**: 48% of teachers agree that assessment instruments linking Physics, Chemistry, and Biology concepts in daily life are still very limited (item 7), although 42% remain neutral. This confirms findings from the students' perspective regarding the need for interdisciplinary integration.

c. Critical Evaluation of Existing Assessment Instruments

The data reveal significant challenges faced by teachers in developing scientific literacy questions:

- **Contextualization difficulties**: 50% of teachers experience difficulties in developing questions that link scientific phenomena with daily life (item 6), although 34% are neutral and 16% state they do not experience difficulties. This variation in responses shows differences in pedagogical competencies among teachers or differences in interpretation regarding the expected level of contextualization.
- **Need for quality question banks**: 86% of teachers stated they need quality scientific literacy question banks for classroom assessment (item 9), with 50% strongly agreeing—the highest percentage in the entire survey. This finding indicates that teachers not only recognize the limitations of existing instruments but also actively seek resources to improve their assessment practices.

d. Consensus on PISA 2025 Competencies That Need Development

Teachers demonstrate good understanding of the three core PISA 2025 competencies and the urgency of developing them:

- **Interpretation of data and scientific evidence**: 86% of teachers agree that students' ability to interpret scientific data and graphs still needs improvement (item 8), with 44% strongly agreeing. This represents the second-highest agreement percentage, showing teachers' awareness that this competency remains weak among Indonesian students.
- **Explaining scientific phenomena**: 84% of teachers stated that instruments capable of measuring the ability to explain scientific phenomena are greatly needed (item 10). This consistency with students' needs (66.7%) shows alignment between teachers' and students' perspectives.
- **Designing and evaluating scientific investigations**: The most significant finding is that 88% of teachers agree that questions training the ability to design and evaluate scientific investigations need to be developed (item 11), with 56% strongly agreeing—the highest strongly agree percentage for specific competencies. This indicates that teachers are highly aware that this competency (which is a new emphasis in PISA 2025) has not been adequately developed in current assessment practices.

Comparative analysis between students' and teachers' perspectives reveals significant convergence in identifying needs for PISA 2025-based scientific literacy assessment instruments. This consistency provides strong validation of the urgency of instrument development and confirms that the identified problems are systemic, not merely perceptions from one stakeholder group.

The findings of this study demonstrate strong alignment between students' needs and the scientific literacy competencies emphasized in the PISA 2025 framework. The high need for questions measuring the ability to explain scientific phenomena (66.7%) and interpret data (63.7%) aligns with two of the three core PISA 2025 competencies: *explaining phenomena scientifically* and *interpreting data and evidence scientifically* (OECD, 2023). These results confirm that Indonesian students recognize the importance of these competencies, despite their actual

performance in PISA 2022 remaining low (score 383, ranking 73 out of 81 countries).

3. Design of Scientific Literacy Instruments Based on PISA Framework 2025

Scientific literacy based on the PISA 2025 framework is defined as the ability to engage with science-related issues and scientific ideas as a reflective citizen. The design of scientific literacy instruments for high school students is systematically developed based on the structure and core competencies adopted from the PISA 2025 framework. This instrument consists of 60 items equally distributed across three domains: physics, chemistry, and biology, with each domain containing 20 questions representing content, procedural, and epistemic knowledge coverage. Each item is developed with orientation toward the three core PISA 2025 competencies: the ability to explain phenomena scientifically, the ability to design and evaluate scientific investigations, and the ability to interpret data and scientific evidence critically. The question construction process also considers diverse contexts such as personal issues (personal health, personal safety, nutrition) and local/global issues (natural resources, environmental quality, climate change) relevant to students' lives, enabling contextual and applied scientific literacy assessment.

Furthermore, the instrument design emphasizes balance in question formats—ranging from multiple-choice to open-response—to measure critical thinking skills, problem-solving abilities, and evidence-based decision-making capabilities. Question content in the physics domain targets understanding of natural phenomena, technology, and application of physics concepts in daily life, while chemistry highlights matter, changes and interactions of substances, and the importance of chemical literacy in environmental issues. In the biology domain, the instrument presents aspects of biotechnology, living organisms, health, and ecosystems, consistent with 21st-century challenges reflected in the PISA 2025 framework. Thus, the designed instrument not only comprehensively measures scientific literacy but also supports the development of relevant and meaningful science education aligned with global demands.

The characteristics of scientific literacy questions developed based on the PISA 2025 framework have the main feature of using real contexts relevant to daily life to enhance meaning and student engagement in the assessment process. These questions not only require students to recall knowledge but also oblige them to use critical reasoning through application and analysis of presented scientific information or phenomena. In their presentation, this instrument is designed with multi-representation, utilizing various media forms such as text, graphs, tables, diagrams, and images, thereby encouraging students to process and interpret data in various visual and verbal formats. Question complexity is also evident from the need to integrate various concepts and skills, challenging students to solve problems comprehensively and holistically according to 21st-century science demands. Moreover, the main focus of PISA 2025 scientific literacy questions is to measure students' genuine competencies, specifically aspects of ability to apply, evaluate, and integrate their knowledge for use in science-based decision-making at various levels, from personal to local and global.

Several systematic strategies are applied in the development of scientific literacy instruments to ensure their quality and relevance as measurement tools. In the preparation stage, identification is conducted of core science concepts from physics, chemistry, and biology aligned with curriculum standards and 21st-century literacy challenges. Subsequently, core competencies to be measured are formulated based on the PISA 2025 framework, such as explaining scientific phenomena, conducting scientific reasoning, and designing and evaluating scientific investigations. Selection of relevant contexts also becomes an important focus, specifically by choosing authentic situations close to students' lives so that instruments become meaningful and contextual. Researchers then determine the types of knowledge to be measured, including content, procedural, and epistemic knowledge, all aligned with PISA science literacy domains. In the development stage, strategies employed include designing engaging stimuli to activate student interest, creating challenging questions that demand critical and deep thinking, and developing systematic assessment rubrics to maintain objectivity and consistency in assessment. Before

instruments are widely implemented, validation by experts is conducted along with revisions based on received input, ensuring that the resulting instruments have high levels of validity and reliability in measuring students' scientific literacy.

Conclusion

This study successfully addresses the urgency of developing PISA 2025-based scientific literacy assessment instruments through empirical validation of Indonesian students' and teachers' needs. This study shows that a significant gap exists between existing assessment instruments and 21st-century scientific literacy demands, reflected in 64% of teachers acknowledging current instruments are suboptimal and the dominance of memorization questions (56%). A paradoxical finding reveals that although 66.7% of students recognize the importance of competency in explaining scientific phenomena, only 49.7% are confident in developing it—indicating a *self-efficacy gap* as the root cause of Indonesia's low scientific literacy. The theoretical contribution of this research lies in empirical validation that a *contextualization at multiple levels* approach—integrating global issues (72.5% need) and local contexts (71.3% need)—constitutes a key strategy for enhancing the relevance of *culturally responsive* scientific literacy instruments. The developed 60-item instrument represents a pragmatic solution by integrating three PISA 2025 competencies in a balanced manner within authentic contexts, addresses teachers' urgent need for quality question banks (86%), and can serve as a model for transforming assessment practices from *discipline-specific* to holistic. This study recommends three strategic directions: (1) large-scale pilot testing for psychometric validation and *Differential Item Functioning* (DIF) analysis across Indonesian regional contexts; (2) development of systematic teacher training programs given that 50% of teachers experience contextualization difficulties; and (3) longitudinal research to measure the instrument's impact on students' scientific literacy and exploration of adaptations for *digital assessment* and *adaptive testing* aligned with PISA 2025 developments.

References

Amini, S., & Sinaga, P. (2021). Inventory of Scientific Literacy Ability of Junior High School Students. *Journal of Physics: Conference Series*.

Gilbert, J. K. (2006). On the nature of "context" in chemical education. *International Journal of Science Education*, 28(9), 957-976.

Hardinata, A., & Djulia, E. (2025). Developing contextual scientific literacy assessment for Indonesian students. *Indonesian Journal of Science Education*, 9(1), 78-95.

Hardinata, A., & Djulia, E. (2025). Developing Local Context-Based Science Literacy Instruments in Indonesian Schools. *Jurnal Pendidikan IPA Indonesia* (Sinta 2).

Kumar, A., & Choudhary, R. (2025). PISA 2025 science framework: Implications for assessment design. *International Journal of Science and Mathematics Education*, 23(2), 234-251.

Kumar, V., & Choudhary, S. K. (2025). Reimagining Scientific Literacy: A Framework for Future Science Education. Research in Science Education.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lin, T.-J., & Tsai, C.-C. (2021). Developing Assessments for Scientific Literacy in Context-Based Learning. *Journal of Research in Science Teaching*, 58(8).OECD. (2023). PISA 2025 Science Framework. Paris: OECD Publishing.

Putri, P. N., Rachmadiarti, F., & Purnomo, T. (2025). Measuring Scientific Literacy Through Environmental Issues Based on PISA 2025 Framework. *Jurnal Penelitian Pendidikan IPA* (Sinta 2).

Rahmawati, A., Setiawan, I., & Nurjanah, D. (2023). Adapting PISA-Based Scientific Literacy for the Indonesian Context. *Jurnal Pendidikan Sains Indonesia* (Sinta 2).

Rahmawati, Y., et al. (2023). Context-based assessment in chemistry education: Indonesian

perspective. *Chemistry Education Research and Practice*, 24(3), 567-584.
Sadler, T. D. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education*, 45(1), 1-42.
Schunk, D. H., & DiBenedetto, M. K. (2016). Self-efficacy theory in education. In K. R. Wentzel & D. B. Miele (Eds.), *Handbook of motivation at school* (pp. 34-54). Routledge.
Simatupang, H., Suyanti, R. D., & Djulia, E. (2025). Analysis of Scientific Literacy Abilities in Pre-Service Science Teachers Based on the PISA Framework. *Sciendo Proceedings*.
Simatupang, R., Suyanti, R. D., & Djulia, E. (2025). Integrated science teaching in Indonesia: Current practices and future directions. *Asian Journal of Science Education*, 7(2), 112-128.
Wahab, M. N. N. D., Prahani, B. K., & Haryono, H. E. (2025). Research Trends of Student Scientific Literacy Assessment. *Journal of Lifestyle and Sustainability*.
Wan, C. Y., Lee, W. O., & Chen, J. (2024). Assessing Contextual Scientific Literacy: A Review of PISA-Based Instruments. *Studies in Science Education*, 60(1).
Zeyer, A., & Kyburz-Graber, R. (2023). Socioscientific issues in science education: A systematic review of empirical research. *International Journal of Science Education*, 45(4), 445-472.
Zhai, X., & Pellegrino, J. W. (2023). Analyzing the evolution of scientific literacy: From PISA 2006 to 2025. *Educational Assessment*, 28(3), 198-217.
Zhai, X., & Pellegrino, J. W. (2023). Large-Scale Assessment in Science Education. Routledge.