

Evaluating Scientific Literacy Through Competency Aspects of the PISA 2025 Framework: A Focus on Climate Change

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Abstract. Scientific literacy is a critical competency for preparing students to engage with real-world issues, especially global challenges such as climate change. The PISA 2025 framework redefines scientific literacy by emphasizing competency aspects, namely: explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting data and evidence scientifically. This study aimed to evaluate students' scientific literacy based on these competency aspects within the context of climate change. A quantitative descriptive approach was employed. Data were collected through a scientific literacy test aligned with PISA 2025 indicators, as well as questionnaires, interviews, and classroom observations. The average scientific literacy score was 68.82%, categorized as moderate. Students' distribution across PISA proficiency levels was as follows: Level 1 (1.28%), Level 2 (7.69%), Level 3 (17.95%), Level 4 (34.62%), Level 5 (32.05%), and Level 6 (6.41%). Internal factors influencing scientific literacy, including motivation and self-efficacy, had an average score of 71.75%, while external factors such as learning environment and teacher support scored 71.07%, both in the moderate category. These findings indicate that although many students reached intermediate to high competency levels, the application of contextual, issue-based, and inquiry-oriented instructional strategies remains essential. Such approaches can further enhance students' ability to apply scientific reasoning in understanding and addressing complex environmental issues like climate change.

Keywords: Scientific Literacy, PISA 2025 Framework, Competency Aspects, Climate Change, Factors of Scientific Literacy

1 Introduction

The rapid advancement of science and technology in the 21st century requires strong scientific literacy skills [1]. Scientific literacy is not only about understanding scientific concepts but also about the ability to apply this knowledge across various aspects of life, including material, cultural, and intellectual contexts [2]. With adequate scientific literacy, individuals are better prepared to face modern challenges and contribute to societal progress. Students with high levels

of scientific literacy tend to be more responsive to real-life problems and able to apply their knowledge in practical situations [3].

Scientific literacy serves as a key foundation for building superior and high-quality human resources in education [4]. The aim of national education in Indonesia in the 21st century is to develop high-quality human capital, one of which is through science education[5]. The teaching strategies adopted by each country significantly affect what is taught in science classrooms [6]. With a strong foundation in science, students are better able to understand the role of science in everyday life and to recognize their responsibilities within society. This contributes to shaping a generation that is aware of the impacts of science and technology in their lives [7].

The purpose of science education is to foster scientific literacy through the acquisition of fundamental knowledge, supporting sustainable resource management, and cultivating critical thinking skills to engage in scientific inquiry [8]. Developing science education among students can enhance critical thinking, argumentation skills, knowledge-building processes, collaboration, and scientific attitudes [9]. Understanding science also equips students with the ability to comprehend scientific processes, concepts, and attitudes while enabling them to solve problems independently [10].

According to Sutrisna (2021), literacy is crucial for students since it involves not only the comprehension of scientific ideas but also their application in daily life. The improvement of personal well-being through mastery of science depends heavily on scientific literacy. Moreover, since creativity, judgment, and problem-solving skills are critical, scientific literacy is also a fundamental requirement in the workplace. Students with high scientific literacy can develop critical thinking and understand the role of science in addressing environmental, health, and economic issues [11]. Scientific literacy is therefore essential for cultivating students' critical, analytical, and evaluative thinking skills toward scientific information to draw sound conclusions [12].

However, Indonesia's performance in the Programme for International Student Assessment (PISA) 2022 showed that the average score in scientific literacy was 383, which is significantly below the OECD average of 485 [13]. This indicates that many Indonesian students have yet to reach the required proficiency level in scientific literacy. This score reflects students' struggles in analyzing and applying concepts to problem-solving, as they often rely on rote memorization rather than conceptual understanding. The decline in literacy skills, including scientific literacy, has also been linked to the lack of students' interest in reading and writing, which negatively impacts their general literacy competence[14].

Applying suitable science process skills in the classroom is necessary to improve scientific literacy. Since highly qualified instructors have a direct impact on educational quality, increasing teacher competency is an excellent way to raise students' scientific literacy [15]. In order to assist students understand scientific concepts, communicate effectively in scientific language, and recognize the connections between science, technology, and society, teachers play a crucial role.

Instruction that emphasizes scientific literacy allows students to become more proficient readers and critical consumers of scientific information. Student-centered learning further supports the development of literacy, enabling students to identify problems, use scientific information, and

make evidence-based decisions. Nevertheless, most assessments still prioritize factual recall over knowledge application, leaving higher-order thinking skills underdeveloped [16]

Scientific literacy can be promoted through science-based learning that equips students with the capacity to address future challenges with scientific approaches [17]. Developing a culture of scientific literacy in schools is also crucial, which may be achieved through experiments, environmental preservation, disaster preparedness, outdoor studies, and the provision of adequate literacy-supporting facilities. Such initiatives not only foster understanding of scientific ideas but also enable students to apply them in everyday life, thereby supporting sustainable scientific literacy [18].

2 Method

This research employed a descriptive quantitative design aimed at evaluating the scientific literacy competence of tenth-grade students on the topic of environmental change. A total of 78 students were selected through purposive sampling, specifically those who were studying environmental change material.

Data were collected using a variety of instruments. The primary tool was a scientific literacy test constructed based on the PISA 2025 framework, covering indicators from three core competencies: explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence scientifically. The primary source of data comprised science literacy test items, which were examined and analyzed quantitatively, whereas interviews, observations, and questionnaires served as supporting data and were analyzed qualitatively.

3 Result and Discussion

3.1 Students' Scientific Literacy Skills in the Competency Aspect

Students' scientific literacy abilities in the competency aspect are shown in Table 1 below.

Table 1. Students' Scientific Literacy Skills in the Competency Aspect

Aspect	Indicator	Percentage	Average	Category
Competency	Explaining scientific phenomena	34.08	29.47	Very Low
	Designing and evaluating scientific inquiry as well as interpreting data and scientific evidence critically	24.20		
	Investigating, evaluating, and using scientific information for decision-making and actions	30.13		

The results showed that the most mastered competency indicator was explaining scientific phenomena, with a percentage of 34.08%. Students were able to answer teachers' questions related to environmental change topics, make predictions, propose simple solutions, and formulate basic hypotheses. However, they were not able to build explanatory models or explain

the broader impact of scientific knowledge. This indicates that students' scientific literacy skills are still limited to recognizing and recalling simple science concepts, predicting outcomes, and proposing solutions, but not yet developing deeper reasoning skills [19].

The lowest achievement was found in the competency of designing and evaluating scientific investigations and interpreting data and evidence critically, with a percentage of 24.20%. Classroom observations revealed that students had difficulties formulating relevant questions, designing appropriate experiments, and analyzing data. Teaching was still dominated by traditional lecture methods, with students mostly taking notes and memorizing information without being actively involved in inquiry or problem-solving activities. The lack of inquiry-based and investigative learning opportunities has hindered students' development of critical thinking and scientific reasoning [20].

For the competency of investigating, evaluating, and using scientific information for decision-making and action, students achieved 30.13%. The findings indicated that they were not yet able to evaluate information critically, differentiate claims based on scientific evidence, construct arguments from data, or make decisions supported by evidence. This weakness is attributed to the lack of classroom practices that engage students in evaluating information and using evidence as the basis for argumentation and decision-making [21].

Overall, the findings suggest that students' scientific literacy skills in the competency aspect are still dominated by descriptive abilities such as recalling concepts and making simple predictions. Higher-order thinking skills such as designing investigations, interpreting data, and constructing scientific arguments remain underdeveloped due to teacher-centered learning and the limited use of inquiry-based approaches [22].

3.2 Students' Scientific Literacy Skills Based on Scientific Literacy Levels

Distribution of respondents across scientific literacy levels showed in **Figure 1**. The majority of students are concentrated at Level 3 (24.82%), while the lowest percentages are found at Level 6 (4.56%).

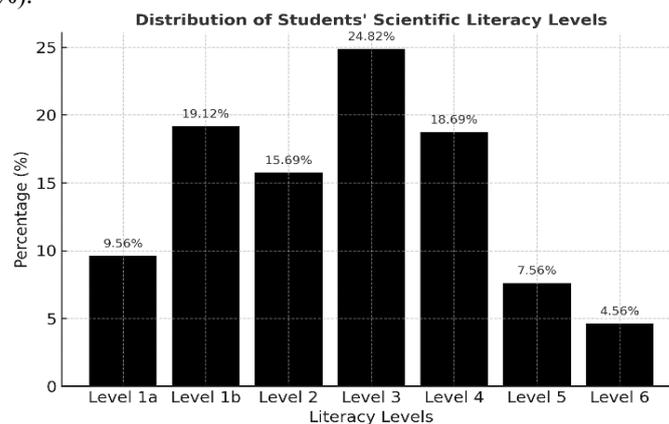


Fig.1. Distribution of Students' Scientific Literacy Levels

According to the analysis results, 9.56% of the students were classified at level 1a of scientific literacy, indicating that they possessed basic yet limited scientific knowledge. As per the OECD (2023b), students at this level are capable of recognizing simple scientific explanations of phenomena in their surroundings and can refer to basic scientific information or evidence[23]. When seeking information, these students can identify one pertinent source from multiple options and comprehend its principal findings. Furthermore, they are able to select an appropriate experimental design by controlling a single variable, although their procedural knowledge remains elementary.

A total of 15.69% of students achieved level 2 adequate science literacy by providing appropriate explanations in familiar contexts, drawing conclusions based on simple investigations, and solving problems using scientific reasoning, allowing students to be better prepared to deal with everyday science and technology situations (OECD, 2023b). An adequate level of science literacy allows students to actively participate in everyday science and technology situations while demonstrating sufficient basic scientific competence, preparing them to face challenges and apply scientific knowledge in a variety of contexts in their lives[24][25].

Given that 24.82% of students achieved Level 3, it is clear that some students exhibited more sophisticated scientific literacy abilities, such as the ability to more clearly and methodically identify scientific problems, choose pertinent information to explain technology and natural phenomena, and use basic investigation models or strategies to solve problems. Additionally, students have developed succinct, fact-based assertions by interpreting and applying scientific principles from a variety of fields. However, there is still opportunity for progress in a number of areas, including the application of increasingly sophisticated scientific knowledge to enhance analytical and synthesis skills. Therefore, these accomplishments show that students' science literacy skills have improved, but they also highlight the need for more work to enhance these skills (OECD, 2023b).

Approximately 18.69% of students achieved Level 4, signifying their capability to address complex problems involving real-world phenomena and necessitating the ability to draw conclusions regarding the contributions of science and technology. At this level, students exhibit a commendable ability to organize, integrate, and relate various scientific and technological concepts to pertinent, everyday contexts. Some students have already demonstrated the ability to communicate their conclusions using scientific knowledge and evidence[26].

With 7.56% of students achieving Level 5, it is evident that some students have demonstrated more advanced science literacy skills, namely, integrating scientific concepts to understand familiar phenomena in various contexts, making accurate predictions, and identifying the strengths and limitations of scientific models. Students can also design investigations by evaluating alternative experimental designs, interpreting complex data, and evaluating the interpretations [27]. In addition, students can search for information from trusted sources based on scientific criteria and standard data verification procedures and justify their choices.

Level 6 was achieved by 4.56% of the students. Students who achieved Level 6 demonstrated a very high level of scientific literacy, integrating scientific concepts from various disciplines to construct complex models and consider their limitations. They were able to use these models to construct or evaluate scientific explanations of complex phenomena and make predictions about future developments or their potential implications for society. In addition, students at this level

can identify and explain the objectives of various types of investigations and determine which questions can be answered through scientific investigation, enabling them to apply scientific knowledge broadly and deeply in various contexts.

Low student achievement can be attributed to students' lack of experience and practice in applying, identifying, and explaining science concepts in various complex life situations, which are factors contributing to low science literacy. Students' science literacy achievement at a high level is still low because students are rarely given the opportunity to work on problems that require understanding from various sources of information and are relevant to everyday life; therefore, they have not been able to develop optimal science literacy skills [28].

3.1 Factors Affecting Students' Scientific Literacy Skills

The analysis of internal and external factors provides insights into the elements that influence students' scientific literacy skills. Internal factors consist of interest, motivation, and learning habits, while external factors include learning models and methods, school facilities and infrastructure, as well as parental support. These factors collectively contribute to shaping students' ability to understand and apply scientific concepts in various contexts. **Table 2** presents the percentage, average score, and category that represent the contribution of each indicator to students' scientific literacy achievement.

Table 2. Internal and External Factors Affecting Students' Scientific Literacy Skills

Factor Type	Indicator	Sub-indicator	Percentage	Average	Category
Internal	Interest	Enjoyment in learning	79.80	71.75	Moderate
	Motivation	Enthusiasm in participating in lessons	79.32		
External	Learning habits	Learning readiness	56.15	71.07	Moderate
	Learning Models & Methods	Implementation of learning strategies in schools	69.86		
	School Facilities	Availability of facilities and infrastructure supporting literacy	75.16		
	Parental Support	Parents' attention	68.20		

Both internal and external factors exert a significant influence on students' scientific literacy, with complex interactions shaping their cognitive and metacognitive engagement. Internally, students' interest, motivation, and learning habits are critical determinants of active participation in learning activities [29]. Students who infrequently ask questions, neglect note-taking, or avoid autonomous tasks exhibit passive learning behaviors, which impede the development of higher-order thinking skills, including critical analysis, evaluation, and application of scientific concepts. Such disengagement further compromises the internalization of knowledge, thereby constraining the advancement of scientific literacy. Additionally, boredom and the absence of clearly defined learning objectives diminish attention, curiosity, and intrinsic motivation, fostering reactive rather than proactive learning behaviors, and limiting the ability to connect scientific content to real-life contexts[30].

Externally, instructional models and methods, school infrastructure, and parental involvement play pivotal roles in supporting the development of scientific literacy [31]. Empirical observations indicate that teachers infrequently employ interactive visual media, such as illustrations, photographs, videos, or films, and seldom organize learning activities beyond the classroom, reducing opportunities for contextualized learning [32]. While teacher-led clarifications are provided, these interventions are insufficient to cultivate sustained interest and cognitive engagement. Although schools offer fundamental learning resources including adequately equipped laboratories, comprehensive textbooks, and appropriate furniture deficiencies in ventilation, lighting, computing facilities, and projectors undermine the quality of interactive instruction. Limited parental engagement, particularly in providing consistent motivational support or supplementary instruction, further restricts students' initiative to engage in independent inquiry and apply scientific knowledge to everyday life [33].

Consequently, low scientific literacy among students arises from a combination of insufficient internal factors such as diminished interest, motivation, and learning habits and suboptimal external conditions, including non-contextualized teaching practices, inadequate facilities, and limited parental support. Addressing these challenges necessitates integrative instructional strategies that promote active, experiential learning, incorporate interactive media and technologies, and engage parents as active participants, thereby fostering both conceptual understanding and the application of scientific knowledge in authentic contexts[34][35].

4 Conclusion

Based on the findings of this study, it can be concluded that the scientific literacy competence of tenth-grade students on the topic of climate change is still in the very low category, particularly in the aspects of interpreting data and using scientific evidence for decision-making. Although internal and external supporting factors such as motivation, teacher support, and learning environment were at moderate levels, they have not effectively contributed to students' cognitive development and inquiry abilities. The dominance of teacher-centered learning and the limited use of contextual and inquiry-based methods are identified as key obstacles. Therefore, there is an urgent need for a pedagogical shift toward student-centered learning approaches that emphasize scientific investigation, contextual relevance, and critical thinking, in line with the competencies outlined in the PISA 2025 framework, to improve students' ability to apply scientific knowledge in real-world situations and become literate, reflective citizens.

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