

Developing Students' Scientific Literacy Based on Pisa Tasks in An Environmental Context

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Abstract: The development of scientific literacy has become a central objective of contemporary science education because students are increasingly expected to interpret evidence, evaluate scientific claims, and make responsible decisions in situations that connect science with everyday life. Environmental problems provide a particularly productive context for this purpose because they combine scientific knowledge with social relevance, uncertainty, data interpretation, and the need for evidence-based action. This study examines how PISA-type tasks situated in environmental contexts can be used systematically to develop students' scientific literacy. The research employed a qualitative methodological design based on document analysis, comparative framework analysis, and pedagogical task modelling. OECD PISA science frameworks, including the 2018, 2022, and 2025 assessment frameworks, were examined together with peer-reviewed studies on context-based science education, socio-scientific reasoning, argumentation, environmental literacy, and evidence evaluation. The analysis showed that effective environmental PISA tasks should not function merely as assessment questions; they can be transformed into instructional sequences that connect a real-world stimulus, a scientifically meaningful problem, multiple forms of evidence, inquiry-oriented questioning, and a reasoned decision. The findings indicate that such tasks can integrate content, procedural, and epistemic knowledge while developing the abilities to explain phenomena scientifically, evaluate investigations, interpret data critically, assess the reliability of information, and justify environmentally responsible decisions. The study concludes that regular classroom use of environmentally contextualized PISA tasks can provide a practical bridge between curriculum content, scientific reasoning, and education for sustainability.

Keywords: Scientific literacy, PISA, environmental context, science education, evidence-based reasoning, environmental literacy, inquiry, sustainability.

Introduction: Scientific literacy is no longer understood simply as the possession of scientific information. In contemporary education it refers to a learner's capacity to use scientific knowledge and reasoning when interpreting phenomena, examining evidence, evaluating claims, and making decisions in real-life situations. The OECD PISA framework has played an important role in consolidating this applied understanding of science learning. In PISA 2018 and PISA 2022, scientific literacy was organized around the competencies of explaining phenomena scientifically, evaluating and designing scientific enquiry, and interpreting data and evidence scientifically [2; 3].

These competencies depend on content, procedural, and epistemic knowledge and are activated within personal, local or national, and global contexts. Environmental quality, natural resources, hazards, climate-related processes, biodiversity, and sustainability therefore form appropriate contexts for science assessment. The PISA 2025 Assessment and Analytical Framework develops this orientation further by emphasizing critical evaluation of information, decision making, science identity, environmental concern, awareness, and agency [1].

Environmental problems are especially suitable for the development of scientific literacy because they rarely

appear as isolated textbook facts. Students encounter air pollution through local experience, water quality through community concerns, climate change through graphs and competing public claims, and biodiversity through changes in ecosystems. Understanding such issues requires learners to identify relevant scientific principles, distinguish evidence from opinion, interpret numerical and graphical information, evaluate how data were obtained, recognize uncertainty, compare explanations, and decide which conclusions are sufficiently supported. These requirements closely correspond to the cognitive structure of PISA science tasks.

Research has repeatedly shown the value of context-based science education. Fensham argued that the real-world situations used in PISA have direct implications for context-based teaching [5]. Bennett, Lubben, and Hogarth found that context-based and science–technology–society approaches can improve students’ attitudes toward science while maintaining conceptual understanding comparable with conventional instruction [7]. Bybee also linked PISA scientific literacy directly with environmental issues and resource use [6]. These findings indicate that environmental contexts can function as cognitive settings in which scientific knowledge becomes usable rather than remaining decontextualized.

Many environmental topics are also socio-scientific issues because they involve evidence, social choices, uncertainty, and consequences for communities. Research in this field shows that students need opportunities to evaluate evidence and construct justified positions rather than only identify a predetermined answer [9]. Roberts and Gott demonstrated the importance of explicit attention to evidence in evaluating scientific claims [10], while studies of classroom argumentation show that reasoning becomes more sophisticated when students must justify claims and compare competing explanations [11]. UNESCO’s Education for Sustainable Development: A Roadmap likewise emphasizes learning that enables individuals to understand complex challenges and contribute to social and environmental transformation [14].

The purpose of this study is to determine the pedagogical principles through which PISA-type tasks in environmental contexts can be used to develop

students’ scientific literacy. The study focuses on the structure of such tasks, the scientific competencies they activate, the relationship between environmental context and scientific knowledge, and the transformation of assessment-style items into learning activities.

The study used a qualitative design combining document analysis, comparative framework analysis, and pedagogical task modelling. The principal documentary sources were the OECD PISA science frameworks published in the PISA 2018 Assessment and Analytical Framework, the PISA 2022 Assessment and Analytical Framework, and the PISA 2025 Assessment and Analytical Framework [1–3]. These documents were selected because they provide official definitions of the science domain, describe the competencies and knowledge types assessed, establish the role of context, and specify the characteristics of science assessment tasks. Particular attention was given to the 2025 framework because science was the major assessment domain and the framework expanded the emphasis on evaluating scientific information for decision making and on environmental awareness, concern, and agency [1].

The framework analysis was supported by peer-reviewed literature on scientific literacy, real-world contexts in PISA, context-based science education, environmental issues, socio-scientific reasoning, evidence evaluation, and scientific argumentation [4–13; 15]. UNESCO’s Education for Sustainable Development: A Roadmap was included as an international policy source [14]. The literature was used for conceptual triangulation rather than statistical meta-analysis.

Each source was examined in relation to the environmental situation presented, the scientific knowledge needed to interpret it, the type of evidence available, the reasoning process demanded, and the form of conclusion or decision expected. The PISA distinction among content, procedural, and epistemic knowledge provided the principal analytical framework. The resulting relationships were synthesized into a pedagogical structure for classroom task design. No student performance data were generated, and the study therefore does not claim experimental effect sizes.

The analysis indicates that the pedagogical value of an environmental PISA task depends primarily on the relationship between context, evidence, and reasoning. A conventional science exercise often starts from a concept and asks the learner to reproduce a rule or perform a familiar operation. A PISA-type environmental task begins with a situation that can plausibly occur outside school and requires the learner to determine which scientific ideas are relevant. Scientific content thus becomes a tool for interpreting a problem rather than an end in itself, which is consistent with the PISA principle that competence is demonstrated through application in meaningful contexts [1–3].

A productive environmental task therefore begins with a stimulus containing a scientifically interpretable problem. The stimulus may present declining water quality, changes in particulate matter, biodiversity loss, soil salinity, household energy use, or conflicting claims about an environmental intervention. The key feature is not the topic alone but the presence of evidence requiring interpretation. When students must connect a graph with a causal explanation, judge whether a sample is sufficient, identify a variable that should be controlled, or compare the reliability of two sources, the task activates procedural and epistemic knowledge in addition to content knowledge.

One environmental context can also support a progression of reasoning without repeating the same content. In a unit on river-water quality, for example, an initial question may ask students to explain why low dissolved oxygen affects aquatic organisms. A subsequent question may present measurements from several sites and ask students to interpret a pattern. Another may describe a sampling procedure and require evaluation of whether the design supports the stated conclusion. The final stage may present competing explanations for pollution and ask students to recommend an action justified by the available evidence. The topic remains coherent, while cognitive demand develops from explanation toward inquiry evaluation, evidence interpretation, source criticism, and decision making.

This progression mirrors the development of the PISA science framework. Earlier frameworks organized scientific literacy around explanation, enquiry, and evidence interpretation [2–4]. PISA 2025 retains

explanation, merges investigation design with critical interpretation of data and evidence, and adds stronger emphasis on researching, evaluating, and using scientific information for decision making and action [1]. It also gives explicit attention to environmental awareness and agency. Consequently, instructional use of environmental PISA tasks should not end when students obtain the scientifically correct answer. Learners should also consider how the answer is known, how strong the evidence is, what uncertainty remains, and what decisions can reasonably follow.

The analysis also identified the importance of multiple representations. Environmental information commonly appears as graphs, tables, maps, diagrams, measurements, short texts, or claims from different sources. Scientific literacy requires students to move between these forms of representation. A learner may know what greenhouse gases are but still struggle to decide whether a graph supports a causal claim. Lombardi and colleagues found that the quality of students' evaluation of evidence and alternative explanations was associated with their understanding of climate-change science [12]. Arya and Maul similarly reported that structured engagement with scientific evidence supported evidence-based reasoning in climate-change education [13]. These findings support the use of environmental tasks that combine conceptual knowledge with interpretation of realistic data.

The environmental context should, however, be cognitively relevant rather than merely persuasive. A question that asks students to agree that environmental protection is important may address attitudes but does not necessarily reveal scientific reasoning. A waste-management task becomes scientifically meaningful when students compare decomposition data, material properties, energy costs, or disposal consequences. A biodiversity task becomes meaningful when students interpret population trends, evaluate a field survey, or judge whether evidence supports a proposed explanation. The environmental conclusion should therefore emerge from reasoning with evidence rather than from moral instruction alone.

The final result concerns the transformation of assessment tasks into instructional tasks. In classroom use, students can predict outcomes, identify missing

information, compare interpretations, discuss evidence quality, and revise explanations before producing an individual answer. This dialogic use of tasks is consistent with evidence that explicit argumentation can improve the quality of students' scientific reasoning [11]. The instructional architecture derived from the analysis is therefore a sequence in which the learner encounters an environmental situation, identifies the scientific problem, activates relevant knowledge, examines data and methods, evaluates claims, formulates an evidence-proportional conclusion, and applies it to a reasoned decision.

The findings support the view that environmental PISA tasks can serve both assessment and instructional functions. If teachers use PISA materials only for test preparation, students may become familiar with item formats without developing the underlying habits of reasoning. A more productive approach is to use the structure of PISA tasks as a model for learning activities in which scientific knowledge is repeatedly applied to unfamiliar but understandable situations.

Environmental contexts are valuable because they make the relationship between science and citizenship visible. Bybee showed that environmental and resource issues provide direct opportunities for examining scientific literacy [6], while Fensham emphasized the educational significance of PISA's real-world contexts [5]. The present analysis suggests that contextualization is strongest when the context changes what the student must do intellectually. A short story about air pollution does not create genuine contextualization if it can be removed without changing the question. In contrast, interpreting air-quality data, examining the placement of monitoring stations, or deciding whether a public claim is justified makes the environmental context essential to the reasoning process.

This approach also clarifies the relationship between scientific and environmental literacy. Environmental literacy involves knowledge, concern, and action, but responsible action depends on the ability to distinguish reliable evidence from unsupported assertion. Recent research therefore links critical scientific and environmental literacies through evidence evaluation, systems thinking, uncertainty, and informed judgment [15]. The PISA 2025 framework makes this relationship more explicit through environmental awareness,

concern, agency, and the evaluation of scientific information for decision making [1].

For classroom assessment, the findings imply that tasks should vary in both knowledge and reasoning demand. If assessment is dominated by recall, teachers obtain little evidence about students' ability to interpret data or evaluate enquiry. At the same time, complex open-ended problems require sufficient conceptual preparation. Effective task systems therefore need a deliberate balance between scientific concepts and their use in evidence-rich contexts. Local environmental problems such as drinking-water quality, urban air pollution, soil degradation, waste separation, heat exposure, or biodiversity change can provide suitable contexts, provided that the data are accurate, sources are identifiable, and questions do not imply conclusions stronger than the evidence supports.

The study is limited by its methodological and conceptual character. It does not quantify learning gains from a specific classroom intervention. The effectiveness of the proposed structure may vary with age, prior knowledge, teacher expertise, language demands, and the complexity of environmental data. Future research should test sequences of PISA-type environmental tasks using pre- and post-assessment of explanation, enquiry evaluation, data interpretation, and evidence-based decision making.

PISA-type tasks situated in environmental contexts provide a strong methodological basis for developing students' scientific literacy because they connect scientific knowledge with evidence, inquiry, critical evaluation, and decision making. Their educational value is greatest when the environmental context functions as a genuine problem space in which students must explain phenomena, interpret data, examine methods, compare claims, and justify conclusions. Analysis of OECD frameworks and science-education research shows that such tasks can integrate content, procedural, and epistemic knowledge within a coherent learning process.

The evolution of the PISA science framework, especially the 2025 emphasis on critical information evaluation, informed decision making, and environmental agency, strengthens the relevance of this approach. Environmentally contextualized tasks can help students move from knowing scientific facts to using science as

a disciplined way of reasoning about problems affecting individuals, communities, and ecosystems. Used regularly in this form, PISA-type tasks can become not only instruments for measuring scientific literacy but practical tools for developing it.

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