

Enhancing Middle School Student's Scientific Literacy through Contextual Science Learning Based on Coastal Environmental Issues

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Abstract [10 Pt., TNR, Bold, Align Text Left]

Keywords:

Coastal environmental issues; Contextual science learning; Junior high school; Science education; Scientific literacy;

Scientific literacy is a key goal of science education, enabling students to understand concepts, interpret evidence, and apply scientific reasoning. However, many middle school students still show limited scientific literacy due to decontextualized instruction. This study examines the effectiveness of contextual science learning based on coastal environmental issues in improving student's scientific literacy. A quasi-experimental pretest–posttest control group design was conducted with 120 eighth-grade students from two public middle schools in a coastal region of northern Java, Indonesia. The experimental group received contextualized instruction, while the control group received conventional teaching. Scientific literacy was assessed across content knowledge, scientific competencies, and context application using a PISA-aligned instrument. Data were analyzed using inferential statistics. Results showed that the experimental group achieved significantly higher gains than the control group ($p < 0.01$). Contextualized learning effectively enhances student's scientific literacy.

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Introduction

Scientific literacy has become a fundamental goal of science education in response to rapid scientific, technological, and environmental change. Scientifically literate individuals are expected to understand core concepts, interpret evidence, and apply scientific reasoning in personal and societal decision-making (Sjöström, 2025; OECD, 2023). Accordingly, scientific literacy is widely regarded as a key indicator of educational quality. However, international assessments such as PISA indicate that many students still demonstrate limited scientific literacy, particularly in applying knowledge to real-world contexts and interpreting evidence (OECD, 2023). In Indonesia, this challenge persists among middle school students, highlighting a gap between curricular expectations and classroom practices (Listiani, 2025). One contributing factor is the dominance of decontextualized instruction, where science is often taught as abstract knowledge detached from student's everyday experiences (Kostøl & Remmen, 2022; Bossér, 2024).

To address this issue, contextual science learning has been proposed as an approach that situates scientific concepts within meaningful real-world contexts. Grounded in constructivist theory, this approach emphasizes the connection between new knowledge

and student's prior experiences (Mercier et al., 2025). Previous studies have shown that contextual and inquiry-based learning can enhance student's scientific literacy and conceptual understanding (Chang et al., 2024). Environmental contexts are particularly relevant for this purpose due to their interdisciplinary and socio-scientific nature (Dragoş & Mih, 2015; Hancock et al., 2019). These issues are especially relevant for students living in coastal areas, as they directly relate to their daily lives and local environment (Mercier et al., 2025; Rahmawati et al., 2023).

Despite this potential, empirical studies integrating coastal environmental contexts into middle school science learning remain limited, particularly in the Indonesian context. In coastal regions such as the northern coast of Java (Pantura), science instruction still tends to rely on textbook-centered approaches, with minimal use of local environmental issues as learning resources (Listiani, 2025). This indicates a clear research gap in exploring how locally grounded, contextualized instruction can support scientific literacy development. Therefore, this study aims to examine the effectiveness of contextual science learning based on coastal environmental issues in enhancing middle school student's scientific literacy. The novelty of this study lies in the integration of authentic local coastal phenomena into classroom instruction as a contextual and place-based learning strategy. The research question guiding this study is: How does contextual science learning based on coastal environmental issues affect middle school student's scientific literacy compared to conventional instruction.

Method

This study employed a quasi-experimental non-equivalent control group pretest–posttest design to examine the impact of coastal-based contextual science learning on student's scientific literacy. Random assignment was not feasible due to existing class structures; therefore, intact classes were used to preserve instructional authenticity. The research was conducted in public junior high schools located in the northern coastal region of Java (Pantura), Indonesia. This region was purposively selected due to its relevant environmental challenges, such as coastal erosion, tidal flooding, and marine pollution, which provide authentic learning contexts. The participants were seventh-grade students, for whom ecosystem-related topics are emphasized in the national curriculum. Schools and classes were selected using purposive sampling to ensure contextual and curricular alignment. Classes were assigned to either an experimental group (contextual instruction) or a control group (conventional instruction).

The instructional intervention was conducted over six weeks. In the experimental group, learning activities were designed based on contextual and place-based learning principles, integrating local coastal issues into classroom instruction. Students engaged in activities such as analyzing real coastal case studies, interpreting environmental data, discussing socio-scientific issues, and solving context-based problems. Instructional materials included locally relevant texts, visual media, and guided inquiry worksheets. In contrast, the control group received conventional instruction focusing on textbook explanations, teacher-led discussions, and routine exercises without explicit contextualization.

Scientific literacy was measured using a test instrument aligned with the OECD PISA framework, covering competencies in explaining phenomena, interpreting data and evidence, and evaluating scientific inquiry. The instrument consisted of multiple-choice and open-ended items contextualized within real-world scenarios. Content validity was established through expert review by science education specialists, while construct validity was examined through item analysis. Reliability testing using Cronbach’s alpha yielded a coefficient of 0.82, indicating acceptable internal consistency.

Data were analyzed using descriptive statistics and inferential statistics, including independent samples t-tests to compare posttest scores between groups. To ensure consistency with the research design and control for initial differences, analysis of covariance (ANCOVA) was also conducted using pretest scores as covariates. Statistical significance was determined at the 0.05 level. Several steps were taken to address validity concerns. Internal validity was supported by the use of pretest–posttest measures, comparable instructional time, and similar curricular content across groups. However, potential selection bias due to non-random assignment remains a limitation. External validity is supported by the use of authentic classroom settings and locally relevant contexts, although generalization may be limited to similar coastal regions and educational settings.

Results and Discussion

Data Acquisition and Scoring Procedures

Student’s scientific literacy data were obtained through a pretest and posttest administered to both experimental and control groups. The test was developed based on the OECD PISA scientific literacy framework, consisting of items measuring three competency domains: explaining scientific phenomena, interpreting data and evidence scientifically, and evaluating scientific inquiry. Scores were converted into percentages, and learning improvement was determined using gain scores (posttest minus pretest). To assess the magnitude of the instructional effect, Cohen’s *d* was calculated using pooled standard deviation.

Baseline Equivalence of Groups

Prior to the intervention, an independent samples t-test was conducted on pretest scores to ensure equivalence between groups. As shown in Table 1, both groups demonstrated comparable initial scientific literacy levels.

Table 1. Pretest Scientific Literacy Scores

Group	N	Mean	SD
Experimental	60	46.32	8.14
Control	58	45.87	8.01

An independent samples t-test on pretest scores indicated no significant difference between the experimental ($M = 46.32$, $SD = 8.14$) and control groups ($M = 45.87$, $SD = 8.01$; $p >$

0.05). This confirms comparable baseline scientific literacy and strengthens the internal validity of the study.

Posttest Performance and Learning Gains

After the instructional intervention, students in both groups showed improvement; however, the magnitude of improvement differed substantially. Table 2 presents the posttest scores and gain scores for both groups.

Table 2. Posttest and Gain Scores of Scientific Literacy

Group	Mean Posttest	SD	Mean Gain
Experimental	78,45	7.62	32.13
Control	63,18	8.54	17.31

Both groups showed improvement; however, the experimental group demonstrated substantially higher gains (Mean Gain = 32.13) compared to the control group (Mean Gain = 17.31). This indicates that contextual science learning based on coastal environmental issues provides a stronger foundation for developing scientific literacy.

Beyond quantitative gains, qualitative evidence from student responses further illustrates this difference. For example, students in the experimental group were able to explain coastal erosion by linking wave dynamics with human activities and proposing mitigation strategies based on data interpretation. In contrast, many control group responses remained descriptive, often limited to recalling definitions without connecting them to real-world contexts. Classroom observations also indicated that experimental group students engaged more actively in discussions, particularly when analyzing local environmental cases. From a constructivist perspective, this result supports the notion that meaningful learning occurs when students actively connect new knowledge with familiar real-world (Ashlan & Firayani, 2025; Zulfana et al., 2025) facilitated student’s understanding of abstract scientific concepts.

Inferential Analysis and Effect Size

The independent samples t-test on posttest scores revealed a statistically significant difference favoring the experimental group ($p < 0.001$). The calculated Cohen’s *d* value of 1.02 indicates a large effect size, suggesting that the intervention had substantial educational significance. This finding suggests that contextualization is not only beneficial but critical for fostering deeper engagement with scientific concepts. The large effect size reflects the combined influence of authentic contexts, inquiry-based activities, and opportunities for evidence-based reasoning embedded within the instructional design. According to Roy et al. (2025), large effect sizes in scientific literacy studies are typically associated with instructional approaches that emphasize contextualization, inquiry, and application elements that characterized the coastal-based learning design used in this study.

Scientific Literacy Performance by Competency Domain

To provide a more detailed understanding of learning outcomes, student's posttest scores were analyzed across the three scientific literacy competency domains. The results are presented in Table 3.

Table 3. Posttest Scientific Literacy Scores by Competency Domain

Competency Domain	Experimental	Control	Mean Difference
Explaining scientific phenomena	80.12	65.47	14.65
Interpreting data and evidence	77.68	61.23	16.45
Evaluating scientific inquiry	77.54	62.84	14.70

Analysis across competency domains revealed that the greatest improvement occurred in interpreting data and evidence, followed by explaining scientific phenomena and evaluating scientific inquiry. This pattern suggests that contextual learning environments are particularly effective in supporting evidence-based reasoning.

The prominence of data interpretation skills can be attributed to student's direct engagement with authentic coastal data, such as visual representations of erosion patterns and pollution levels. These activities required students to analyze, interpret, and justify conclusions, thereby strengthening higher-order thinking skills. Compared to traditional instruction, which often emphasizes factual recall, this approach provides more opportunities for students to practice scientific reasoning in meaningful contexts.

Integration with Prior Theory and Research

The findings support constructivist and place-based learning theories, demonstrating that knowledge construction is enhanced when students interact with meaningful, context-rich environments. Coastal environmental issues served as authentic socio-scientific contexts, enabling students to connect scientific concepts with real-world challenges. Importantly, the results also highlight that the effectiveness of contextual learning lies not only in the context itself but in how it is structured. Guided inquiry, discussion, and data-based tasks played a key role in facilitating learning. This aligns with prior research emphasizing that contextual and inquiry-based instruction must be carefully designed to support higher-order competencies.

Practical Implications

These findings have important implications for teaching practice and curriculum development. First, teachers should integrate local environmental issues into science instruction through structured learning modules that include real data, case studies, and problem-solving tasks. Second, instructional practices should emphasize guided inquiry and discussion to support student's reasoning and interpretation skills. Third, curriculum developers should incorporate place-based contexts into science curricula, particularly in regions where environmental issues are directly relevant to student's lives. Additionally, professional development programs are needed to support teachers in designing and

implementing contextual learning. This includes training in using local data sources, facilitating classroom discussions, and assessing scientific literacy beyond factual knowledge.

Limitations and Future Directions

Several limitations should be considered. First, the quasi-experimental design limits causal inference due to the absence of random assignment. Second, the study was conducted within a specific coastal region, which may limit generalizability to other contexts. Third, the sample size, while adequate, may not fully capture variability across diverse student populations. Future research should address these limitations by employing larger and more diverse samples, exploring different environmental contexts, and conducting longitudinal studies to examine the long-term impact of contextual science learning. Further investigation into teacher implementation and classroom dynamics would also provide deeper insights into how contextual approaches influence learning outcomes.

Conclusion

This study shows that contextual science learning based on coastal environmental issues significantly improves junior high school students' scientific literacy compared to conventional, decontextualized instruction, particularly in interpreting data, using evidence, and explaining scientific phenomena. The findings support constructivist, contextual, and place-based learning theories by demonstrating that local coastal environments can function as effective learning resources, while also highlighting their potential as an underutilized context in science education. Practically, the results suggest that curricula should integrate local environmental modules, especially coastal issues, and that teachers need professional development to design inquiry-based, context-rich learning supported by appropriate materials such as worksheets, case studies, and data tasks. Future research should examine long-term impacts, effectiveness across different contexts and educational levels, and the role of teacher readiness and instructional quality. Overall, the study reinforces the value of contextual, place-based science learning for improving scientific literacy.

Credit Authorship Contribution Statement

Henry Setya Budhi: Conceptualization, Methodology, Software, Visualization, Formal analysis, original draft writer, Writing review & editing. **Laviola Fiorentina:** Formal analysis, Supervision and Resources.

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