



INTEGRATING ENVIRONMENTAL POLLUTION ISSUES INTO SCIENCE LEARNING TO ENHANCE STUDENTS' ENVIRONMENTAL LITERACY: A LITERATURE REVIEW

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ABSTRACT

Environmental pollution has become an increasingly important context in science education because it enables students to connect scientific concepts with authentic environmental challenges. Integrating environmental pollution issues into science learning is considered a promising approach to fostering students' environmental literacy and promoting sustainability-oriented education. This study aims to synthesize existing research on the integration of environmental pollution issues into science learning and examine its contribution to the development of students' environmental literacy. A literature review was conducted by analyzing relevant national and international publications focusing on pollution-based science learning, scientific literacy, environmental literacy, and education for sustainable development. The findings indicate that integrating environmental pollution issues into science learning enhances students' environmental literacy, scientific literacy, critical thinking skills, and environmentally responsible behavior. Student-centered instructional approaches, including problem-based learning, inquiry-based learning, socio-scientific issues, and sustainability-oriented learning, consistently provide more meaningful and reflective learning experiences. Furthermore, environmental pollution issues function not only as science content but also as authentic learning contexts that encourage critical reflection, environmental awareness, and sustainability-oriented decision-making. Despite these benefits, challenges remain in teachers' pedagogical readiness, instructional implementation, and the integration of sustainability perspectives into science classrooms. This review highlights the importance of contextualizing environmental pollution issues within science learning as an effective strategy for promoting environmental literacy and advancing sustainability-oriented.

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Keywords: Environmental pollution, Environmental literacy, Science learning, Sustainability education, Literature review

INTRODUCTION

Environmental pollution is no longer viewed solely as an ecological problem but also as an educational challenge that requires the development of environmentally responsible citizens. The increasing complexity of environmental degradation, including air pollution, water contamination, plastic waste accumulation, and ecosystem damage, has strengthened the urgency of integrating sustainability perspectives into science education. Environmental issues currently affect not only ecological systems and human health but also social and economic sustainability. Consequently, education is increasingly expected to contribute to the development of students who are capable of understanding environmental problems critically and participating in sustainable environmental actions (UNESCO, 2017).

In contemporary education, science learning is expected to move beyond the transmission of scientific concepts toward the development of critical, reflective, and sustainability-oriented thinking. Science education plays a strategic role in helping students understand the relationship between human activities, scientific development, and environmental sustainability. Consequently, environmental issues have increasingly become important contexts in science classrooms because they provide opportunities for students to connect scientific understanding with real-world environmental challenges. Through contextual science learning, students are encouraged not only to understand scientific theories but also to develop awareness of environmental responsibility and sustainable living practices (Bybee, 1997).

Among various environmental topics discussed in science education,

environmental pollution represents one of the most relevant and accessible learning contexts because pollution-related problems are closely connected to students' daily experiences. Issues such as waste accumulation, river contamination, air pollution, and improper waste management can easily be observed within students' surrounding environments. This condition allows environmental pollution topics to function as meaningful learning resources that support contextual and student-centered learning experiences. In addition, pollution issues encourage students to analyze the impacts of human activities on environmental sustainability and explore possible solutions to environmental problems.

Environmental literacy is widely recognized as an essential outcome of sustainability-oriented science education because it encompasses not only environmental knowledge but also critical awareness, ecological responsibility, and environmentally responsible behavior (Roth, 1992; Orr, 1992; Hungerford & Volk, 1990). Within this perspective, science learning should not merely focus on conceptual mastery but also encourage students to understand environmental issues critically and develop responsible environmental attitudes. Environmental pollution issues therefore possess strong educational potential because they connect scientific concepts with authentic environmental challenges encountered in everyday life.

Previous studies consistently indicate that pollution-based science learning contributes positively to scientific literacy, critical thinking, environmental awareness, and sustainability-oriented attitudes among students. Student-centered approaches such as problem-based learning, socio-scientific issues, inquiry learning, and integrated

science learning have been widely reported to create more contextual and meaningful environmental learning experiences (Kirana et al., 2022; Marpaung et al., 2021; Tahmid et al., 2023; Widharnati et al., 2022). Furthermore, sustainability-oriented learning has been shown to strengthen students' environmental literacy and encourage reflective understanding regarding the relationship between human activities and environmental sustainability (Susilowati et al., 2018; Lee, 2023). These findings demonstrate that environmental pollution issues possess considerable potential to function not only as science content but also as transformative learning contexts in science education.

Despite the growing number of studies discussing environmental pollution in science education, existing research remains largely fragmented and tends to focus on specific instructional models or isolated learning outcomes. Limited attention has been given to how environmental pollution issues are conceptually positioned as contextual learning resources for strengthening environmental literacy within sustainability-oriented science education. In addition, scientific literacy and environmental literacy are often examined separately, despite their strong conceptual interconnectedness. This condition indicates the need for a broader literature-based analysis that synthesizes current educational perspectives regarding the integration of environmental pollution issues into science learning.

Therefore, this study seeks to critically examine the integration of environmental pollution issues into science learning and synthesize their educational contributions toward the development of students' environmental literacy within the

broader framework of sustainability-oriented science education. The findings of this study are expected to provide conceptual and pedagogical insights for developing more contextual, meaningful, and environmentally responsive science learning practices.

This study aims to critically examine the integration of environmental pollution issues into science learning and synthesize their contributions to the development of students' environmental literacy within the framework of sustainability-oriented science education. In addition, this study seeks to identify dominant instructional approaches, emerging educational perspectives, and current research trends related to pollution-based science learning in contemporary science education.

METHOD

This study employed a literature review approach to critically examine the integration of environmental pollution issues into science learning and their contributions to students' environmental literacy within sustainability-oriented science education. The review aimed to synthesize current educational perspectives, instructional approaches, and research trends related to pollution-based science learning.

The literature sources were obtained from reputable academic databases, including Google Scholar, Scopus, and ERIC. The literature search employed several relevant keywords and keyword combinations, such as "environmental pollution," "science learning," "science education," "environmental literacy," "scientific literacy," "sustainability education," and "socio-scientific issues." The reviewed literature primarily consisted of peer-reviewed journal articles published

between 2018 and 2025 to ensure alignment with recent developments in science education research. Several seminal references published prior to 2018 were also included selectively to strengthen the conceptual and theoretical foundation of the study.

The review process consisted of four stages: identification, screening, eligibility assessment, and thematic synthesis. Relevant publications related to environmental pollution and science education were initially identified from selected databases. The screening stage was conducted by evaluating the relevance of titles, abstracts, and study focus to the objectives of the study. Subsequently, eligible studies were reviewed in depth based on their discussions of environmental pollution, environmental literacy, sustainability-oriented learning, and instructional approaches in science education.

The selected literature included empirical and conceptual studies from credible academic sources, while publications unrelated to science education or environmental literacy development were excluded from the analysis. The collected literature was analyzed using thematic analysis by identifying recurring themes, categorizing dominant instructional approaches, comparing major findings, and

synthesizing educational perspectives regarding pollution-based science learning. This analytical process was intended to develop a comprehensive understanding of the educational role of environmental pollution issues in fostering environmentally literate students within contemporary science education.

RESULTS AND DISCUSSION

Results

The reviewed literature (Table 1) consistently demonstrates that environmental pollution has become one of the most relevant contextual issues in contemporary science learning (Akbar et al., 2024; Lee, 2023). Topics such as plastic waste, water contamination, air pollution, and household waste provide authentic environmental contexts that allow students to connect scientific concepts with real environmental problems encountered in everyday life. Within sustainability-oriented science education, contextual learning is increasingly considered important because students are expected not only to understand scientific theories but also to interpret environmental challenges critically and responsibly (Tahmid et al., 2023; UNESCO, 2017).

Table 1. Summary of Reviewed Studies on Pollution-Based Science Learning and Environmental Literacy

Authors	Instructional Approach	Main Findings	Educational Contribution
Susilowati et al. (2018)	Sustainability-based science learning	Improved students' environmental literacy	Strengthened sustainability awareness and responsible behavior
Marpaung et al. (2021)	SETS approach combined with Vee Diagram	Enhanced scientific literacy on pollution topics	Connected science learning with environmental contexts
Kirana et al. (2022)	Socio-scientific issues-based learning	Increased scientific literacy and critical understanding	Encouraged reflective environmental decision-making
Widharnati et al. (2022)	Integrated science learning	Improved contextual scientific literacy	Supported interdisciplinary science learning

Authors	Instructional Approach	Main Findings	Educational Contribution
Tahmid et al. (2023)	ESD-oriented learning	Improved environmental literacy and critical thinking	Promoted sustainability-oriented science learning
Lee (2023)	Environmental awareness-oriented learning	Strengthened environmental awareness in classrooms	Encouraged reflective environmental understanding
Akbar et al. (2024)	Contextual pollution learning	Increased learning relevance	Supported meaningful science learning
Fajarwati et al. (2024)	Environmental literacy and critical thinking integration	Identified relationships among literacy, critical thinking, and self-awareness	Strengthened reflective environmental perspectives
Kuswandi et al. (2025)	Problem-based learning with digital modules	Improved students' scientific literacy	Enhanced active and contextual environmental learning

Based on Table 1, the literature from 2018 to 2025 reveals a comprehensive shift toward student-centered and context-driven approaches in teaching environmental pollution. The pedagogical interventions vary from localized contextual learning to structured frameworks such as Socio-Scientific Issues (SSI), Environment for Sustainable Development (ESD), and Problem-Based Learning (PBL). While earlier studies primarily focused on establishing basic environmental literacy and awareness (e.g., Susilowati et al., 2018), recent trends show an increase in integrating technology, such as interactive digital modules (e.g., Kuswandi et al., 2025), and examining complex psychological constructs like student self-awareness (e.g., Fajarwati et al., 2024).

1. Environmental Pollution as a Contextual Issue in Science Learning

The analyzed studies indicate that environmental pollution issues possess strong pedagogical value because they encourage students to connect science learning with social and ecological realities (Akbar et al., 2024; Lee, 2023). Pollution-based learning enables students to observe environmental changes directly, identify problems within their surroundings, and

discuss possible environmental solutions. Consequently, environmental pollution functions not only as instructional content but also as a meaningful learning context that strengthens environmental awareness and sustainability-oriented thinking (Orr, 1992; Palmer, 1998).

The reviewed literature also reveals a shift from concept-centered instruction toward more contextual and sustainability-oriented learning approaches (Tilbury, 1995; UNESCO, 2017). Pollution issues increasingly function as interdisciplinary learning contexts connecting scientific understanding with social, ethical, economic, and environmental dimensions. As a result, science learning becomes more relevant and reflective because students are encouraged to understand the relationship between human activities and environmental sustainability.

Collectively, the reviewed studies suggest that environmental pollution issues provide important opportunities for developing more contextual, meaningful, and environmentally responsive science learning practices.

2. Instructional Approaches in Pollution-Based Science Learning

The reviewed literature indicates that pollution-based science learning is

commonly implemented through student-centered and contextual approaches such as problem-based learning, socio-scientific issues, inquiry learning, integrated science learning, and sustainability-oriented instruction (Kirana et al., 2022; Tahmid et al., 2023; Kuswandi et al., 2025). These approaches consistently contributed to the improvement of students' scientific literacy, environmental literacy, and critical thinking skills.

Problem-based and socio-scientific issues-based learning were frequently associated with reflective and participatory learning experiences because students were encouraged to analyze authentic environmental problems, evaluate environmental impacts critically, and discuss possible solutions responsibly (Kuswandi et al., 2025; Zeidler et al., 2005). Similarly, inquiry-oriented and integrated science learning supported more meaningful learning by involving students directly in observation, investigation, and evidence-based reasoning processes (Widharnati et al., 2022).

The reviewed studies also highlight the increasing integration of sustainability-oriented instruction into pollution-based science learning (Susilowati et al., 2018; Tahmid et al., 2023). Through this approach, environmental pollution is understood not only as a scientific issue but also as a sustainability challenge closely related to human behavior and ecological responsibility.

3. Environmental Literacy Development through Pollution-Based Learning

The reviewed literature consistently indicates that pollution-based science learning contributes positively to students' environmental literacy (Susilowati et al., 2018; Husamah et al., 2024). Environmental

literacy extends beyond conceptual understanding and includes environmental awareness, critical reflection, ecological responsibility, and environmentally responsible behavior (Roth, 1992; Orr, 1992).

Contextual environmental learning encourages students to analyze environmental problems critically, evaluate scientific evidence, and reflect on the impacts of human activities on ecological systems (Lee, 2023; Marpaung et al., 2021). Consequently, environmental literacy, scientific literacy, and critical thinking skills appear to function as interconnected competencies within sustainability-oriented science education (Fajarwati et al., 2024).

However, several studies indicate that environmental literacy cannot be developed through short-term conceptual instruction alone. Continuous learning experiences integrating scientific understanding, environmental reflection, and sustainability-oriented practices remain essential for fostering long-term environmental responsibility (Hungerford & Volk, 1990; Palmer, 1998).

Discussion

1. Environmental Pollution as Transformative Science Learning

The synthesis of chronological data from the reviewed studies indicates that the educational contribution of pollution topics has evolved from a passive understanding of ecological degradation into a more proactive, reflective environmental decision-making process. For instance, the integration of SSI and ESD frameworks as observed in Kirana et al. (2022) and Tahmid et al. (2023) highlights that students are no longer just examining the chemical or biological aspects of pollution. Instead, they are prompted to

weigh socio-economic factors, engage in ethical reasoning, and develop actionable sustainability-oriented behaviors, which bridges the long-standing gap between scientific literacy and active environmental citizenship.

The findings of this review indicate that environmental pollution issues should not merely be positioned as science content but as transformative learning contexts within sustainability-oriented science education. The consistent integration of contextual environmental problems across the reviewed studies demonstrates a shift from memorization-oriented instruction toward more reflective and socially relevant science learning (Tilbury, 1995; Stevenson, 2007).

Pollution-based science learning allows students to connect scientific understanding with environmental realities, making science education more meaningful and applicable to everyday life. This finding supports the view that science learning becomes more effective when students are actively involved in analyzing authentic environmental problems rather than passively receiving conceptual information (Bybee, 1997).

Furthermore, the analyzed literature indicates that pollution-based science learning contributes to transformative educational experiences because students are encouraged not only to understand environmental degradation scientifically but also to reflect critically on human behavior, environmental ethics, and ecological responsibility. This condition aligns with sustainability-oriented education perspectives emphasizing the importance of developing environmentally responsible citizens capable of responding critically to contemporary environmental challenges.

2. Challenges in Implementing Pollution-Based Science Learning

Despite the positive educational contributions identified in the reviewed literature, several challenges remain in implementing pollution-based science learning effectively. One of the most significant challenges is the persistence of conventional instructional practices that still prioritize conceptual mastery and examination-oriented learning (Stevenson, 2007). In many educational contexts, environmental pollution is taught primarily as theoretical content without sufficient opportunities for contextual investigation and reflective learning.

Another important challenge concerns teacher preparedness and instructional competence. Pollution-based science learning requires teachers to facilitate critical discussions, integrate environmental issues into science instruction, and manage contextual learning activities effectively. However, not all teachers possess adequate pedagogical preparation or instructional resources to implement sustainability-oriented learning consistently.

The reviewed literature also indicates that instructional resources and learning environments significantly influence the effectiveness of pollution-based science learning. Contextual environmental learning often requires field observations, environmental projects, interactive learning media, and collaborative activities that support authentic learning experiences.

In addition, several studies reveal that scientific literacy and environmental literacy are still frequently separated within science learning practices. Science instruction often emphasizes cognitive achievement without adequately integrating environmental ethics, sustainability values, and environmentally

responsible behavior. This fragmentation may reduce the transformative potential of pollution-based science learning.

3. Educational Implications and Future Directions

The reviewed literature highlights several important implications for the future development of science education. Environmental pollution issues possess strong potential to become integrative learning contexts capable of connecting scientific understanding, sustainability awareness, and environmental responsibility simultaneously. Science learning should therefore move beyond the transmission of scientific concepts toward more transformative and environmentally responsive educational practices.

The consistent effectiveness of student-centered instructional approaches across the reviewed studies suggests that contextual and participatory learning strategies should be strengthened within science classrooms (Kirana et al., 2022; Tahmid et al., 2023). Approaches such as problem-based learning, socio-scientific issues, inquiry learning, and sustainability-oriented instruction provide opportunities for students to engage actively with environmental problems and develop reflective understanding regarding environmental sustainability.

Finally, future science education should increasingly emphasize the integration of scientific literacy and environmental literacy within sustainability-oriented learning frameworks. Future research is also needed to explore innovative and contextual approaches in pollution-based science learning, particularly those integrating local environmental issues, digital

learning technologies, and long-term sustainability-oriented educational practices.

CONCLUSION

This literature review demonstrates that the integration of environmental pollution issues into science learning possesses strong potential to support sustainability-oriented science education. Pollution-based learning not only strengthens students' scientific literacy and environmental literacy but also encourages critical reflection, environmental awareness, and environmentally responsible behavior. Through contextual and student-centered instructional approaches, environmental pollution issues increasingly function as transformative learning contexts that connect scientific understanding with real environmental challenges.

The reviewed studies also indicate that approaches such as problem-based learning, socio-scientific issues, inquiry learning, and sustainability-oriented instruction contribute positively to more meaningful and reflective science learning experiences. However, the effective implementation of pollution-based science learning still requires adequate teacher preparedness, contextual instructional strategies, and stronger integration of sustainability perspectives within science education practices.

Ultimately, environmental pollution issues should not merely be positioned as science content but as an important educational pathway for developing scientifically literate and environmentally responsible citizens capable of responding critically to contemporary environmental challenges and sustainability issues.

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