



Integrating STEM and SDGs in Elementary School: Fostering Environmental Awareness Through Practical Chemistry

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Abstract

This study examines the integration of Science, Technology, Engineering, and Mathematics (STEM) with the Sustainable Development Goals (SDGs) in elementary science learning, particularly within environmental chemistry contexts. In response to escalating global environmental challenges, elementary education plays a strategic role in fostering students' environmental awareness and sustainable behavior from an early age. This research employs a systematic literature review (SLR) approach to analyze recent national and international studies published between 2020 and 2025 that investigate STEM-based learning aligned with SDGs. The selected studies include various hands-on and contextual learning activities, such as plastic waste recycling into paving blocks, composting organic waste, and the use of STEM-based digital learning materials. The results reveal that contextualizing chemistry concepts, including polymer properties, biodegradation, and waste management, through practical STEM projects significantly enhances students' scientific literacy, critical thinking skills, and environmental care character. In addition, the integration of SDGs, particularly Goal 4 (Quality Education), Goal 12 (Responsible Consumption and Production), and Goal 13 (Climate Action), into elementary science curricula effectively promotes responsible environmental stewardship. These findings indicate that context-based and project-oriented STEM learning provides meaningful learning experiences that bridge scientific concepts with real-world environmental issues. This study concludes that the integration of STEM and SDGs through hands-on, contextual learning represents an effective pedagogical approach for strengthening environmental awareness in elementary education. Furthermore, this research contributes to the field of science education by offering a systematic synthesis of empirical evidence and proposing an integrated STEM–SDGs framework as a theoretically grounded model for enhancing scientific literacy and socio-environmental responsibility at the primary education level.

How to Cite

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INTRODUCTION

The escalation of global environmental crises, ranging from climate change to waste accumulation, has demanded a transformative response from the education sector. Education is no longer solely about knowledge transfer but must serve as a catalyst for sustainable behavior modification. This alignment is explicitly mandated in the Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education), Goal 12 (Responsible Consumption and Production), and Goal 13 (Climate Action). Recent studies emphasize that without a fundamental “ecological conversion” in our lifestyle and educational paradigms, the relationship between humans and the universe will continue to deteriorate (Santika, 2020). Consequently, there is an urgent need to integrate social-ecological awareness into the elementary school curriculum to foster a generation capable of addressing these planetary challenges (Sánchez & Rojas, 2026).

In the realm of natural science education, the Science, Technology, Engineering, and Mathematics (STEM) approach has emerged as a potent pedagogical solution. Research indicates that students’ attitudes towards STEM are directly correlated with the development of 21st-century skills necessary for future problem-solving (Xu & Zhou, 2022). Furthermore, integrated STEM education has proven effective in teaching socio-scientific issues, bridging the gap between theoretical science concepts and real-world applications in the Indonesian context (Wahono et al., 2021). Specific implementations, such as STEM-based student worksheets (LKPD), have been successfully employed to enhance critical thinking skills, moving students beyond rote memorization toward higher-order cognitive processes (Rosilawati & Abidin, 2025; Simatupang et al., 2020). However, preliminary research suggests that for STEM to be effective at the middle and elementary levels, it must be explicitly designed with an SDGs orientation to ensure teacher and student readiness (Purwaningsih et al., 2025).

To make science learning relevant, particularly in chemistry and environmental science, the curriculum must be contextualized through tangible waste management practices. The concept of 3R (Reduce, Reuse, Recycle) offers a practical framework for this integration (Di Spirito et al 2025). For instance, innovative projects such as converting plastic waste into paving blocks not only mitigate pollution but also serve as a medium to improve scientific literacy by teaching material properties and engineering design

(Satar et al., 2025). Similarly, utilizing organic waste for composting provides a direct biological and chemical learning resource found within the school environment (Dewi & Sapri, 2023). These hands-on activities, supported by STEM-based worksheets utilizing local waste, have been shown to significantly boost scientific literacy by making abstract concepts concrete (Istiani & Malichatin, 2025).

Beyond technical skills, the integration of local wisdom and religious values plays a pivotal role in character building, especially in the Indonesian educational landscape. The “Ethno-STEM” approach, which combines global SDGs with local cultural practices, has successfully fostered environmental awareness among elementary students (Pada et al., 2025; Sudiartini et al., 2024). In the context of Islamic education (Madrasah), integrating science with religious values, such as the responsibility of a khalifah to protect the earth that has proven effective. Studies show that linking ecosystem balance materials with Islamic values strengthens students’ environmental care attitudes (Putri et al., 2022; Hasibuan & Sapri, 2023). This holistic approach is further exemplified in the Adiwiyata program, where Islamic religious education synergizes with environmental education to create a culture of sustainability (Zulkarnain et al., 2021). Recent findings also highlight that contextual learning based on plastic waste in Madrasah Ibtidaiyah can effectively instill Islamic environmental cleanliness values (Gitmiwati & Indrayuda, 2024).

The delivery of these complex concepts requires appropriate instructional media and teacher competence. The use of technology, such as animation media, has been found to positively influence the environmental character of third-grade students (Nugraha & Rachmawati, 2023). Additionally, the development of electronic worksheets (E-LKPD) based on STEM offers a modern avenue to enhance environmental caring characters (Zain, 2023). Integrated science modules focusing on pollution themes have also demonstrated efficacy in nurturing a love for the environment (Okyanida, 2020). However, the success of these interventions relies heavily on teacher preparation; incorporating zero-waste based learning programs into pre-service teacher education is essential to ensure educators are equipped to lead sustainable development initiatives (Widayanti & Widyawati, 2024).

Despite the abundance of studies on STEM and environmental education separately, there is a need to synthesize how these diverse elements like technical STEM skills, SDGs, re-

ligious values, and digital media, converge specifically in elementary science education. Drawing upon the foundational theories of learning (Rusman, 2017), this article aims to review and elaborate on how integrating STEM with SDGs and local/religious values can effectively foster environmental awareness and scientific literacy in elementary schools. By analyzing recent interventions ranging from composting to plastic recycling, this study provides a comprehensive overview of best practices for “The Thabiea: Journal of Natural Science Teaching.”

However, the implementation of such interdisciplinary approaches is not without challenges. While the theoretical benefits of STEM are well-documented, practical execution in elementary classrooms often faces barriers related to teacher readiness and the availability of contextual resources. Purwaningsih et al. (2025) highlight that while teachers acknowledge the importance of SDGs, many struggle to translate these global goals into specific, age-appropriate STEM activities. There is a tendency for science learning to remain text-book oriented, failing to utilize the surrounding environment as a laboratory. This disconnect highlights the critical need for structured learning materials, such as STEM-based worksheets that utilize local waste, which have been proven to bridge the gap between abstract concepts and practical scientific literacy (Istiani & Malichatin, 2025).

In the specific domain of chemistry and material science at the elementary level, the focus must shift towards tangible environmental solutions. The chemical resistance of polymers, for instance, offers a compelling context for engineering projects like creating paving blocks from plastic waste (Satar et al., 2025). This process does not merely teach the physical properties of matter but also instills the engineering design process (EDP) required to solve the plastic pollution crisis. Simultaneously, on the biological spectrum, the decomposition of organic matter through composting introduces students to biochemical cycles. Utilizing compost as a learning resource transforms the school garden into a dynamic classroom, making science lessons more active and enjoyable while directly addressing waste management issues at the local level (Dewi & Sapri, 2023).

Furthermore, the effectiveness of environmental education in Indonesia is significantly amplified when it resonates with the students' cultural and religious identity. The “Ethno-STEM” approach provides a framework to integrate indigenous knowledge such as Balinese

local wisdom regarding nature conservation that into modern science curricula, thereby increasing engagement and relevance (Sudiartini et al., 2024; Pada et al., 2025). In parallel, for Islamic educational institutions, connecting environmental stewardship with religious values offers a powerful pedagogical strategy. Research by Putri et al. (2022) and Zulkarnain et al. (2021) suggests that when students understand environmental care not just as a scientific necessity but as a religious duty (*amanah*), their commitment to sustainable behavior, such as maintaining ecosystem balance, is profoundly strengthened.

Therefore, this article aims to synthesize recent empirical evidence regarding the integration of STEM, SDGs, and local/religious values in elementary science education. Unlike previous studies that may focus on these elements in isolation, this review examines the synergistic effect of combining practical chemistry activities (waste processing) with character-building frameworks. By analyzing various interventions from digital E-LKPD to hands-on composting and Ethno-STEM projects, this study seeks to provide a comprehensive reference for educators and policymakers in designing science curricula that are not only academically rigorous but also socially and ecologically responsible, ultimately contributing to the achievement of the 2030 Sustainable Development Goals.

METHOD

This study employed a Systematic Literature Review (SLR) method to comprehensively analyze and synthesize existing research findings related to the integration of STEM (Science, Technology, Engineering, and Mathematics) and the Sustainable Development Goals (SDGs) in elementary science education. The study applied a qualitative approach that focuses on interpreting the effectiveness, pedagogical strategies, and learning outcomes reported in recent educational research. This research design was selected to provide a broader understanding of how global sustainability goals are implemented in practical learning activities at the elementary school level (Sekolah Dasar/Madrasah Ibtidaiyah).

The data sources were obtained from primary academic documents consisting of articles published in accredited national journals and international conference proceedings between 2020 and 2025. This time range was chosen to ensure that the review reflects the most recent developments in educational curricula, particularly those related to the implementation of the Merdeka

Curriculum and the global SDGs agenda. The documents analyzed included empirical studies on the development of learning materials such as LKPD (Student Worksheets), classroom action research, and experimental studies focusing on environmental character education.

During the data identification stage, literature searches were conducted using several main keywords, including “STEM Education,” “Sustainable Development Goals (SDGs),” “Elementary School Science,” “Environmental Literacy,” “Plastic Waste Management,” and “Ethno-STEM.” The search strategy focused on articles that explicitly connected science learning outcomes (both cognitive and affective) with environmental sustainability issues to ensure alignment with the scope of *Thabiea: Journal of Natural Science Teaching*.

The article selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) procedure. The process consisted of four stages: identification, screening, eligibility assessment, and final inclusion. The PRISMA flow diagram was used to visualize the article selection process systematically, starting from the number of articles identified in the initial search, followed by the screening of titles and abstracts, the exclusion of irrelevant studies, and the final number of articles included in the review.

The inclusion criteria in this study were as follows: (1) articles involving students or teachers at the elementary or junior high school levels (SD/MI or SMP/MTs) as research subjects, (2) studies applying active learning models such as Project-Based Learning (PjBL) or Contextual Teaching and Learning (CTL), and (3) studies addressing specific science or environmental con-

cepts such as waste management (3R). Articles that were purely theoretical without empirical implementation data and those outside the scope of science education were excluded from the analysis.

Data collection was conducted using the documentation technique. Each selected article was analyzed to extract essential information such as the research methodology used in the primary study, the type of learning intervention (for example E-LKPD, animation media, composting activities, eco-bricks, or paving blocks made from plastic waste), the sample size, and the reported statistical or qualitative results. This structured data extraction enabled systematic comparison across the studies included in the review.

Data analysis was conducted using a thematic content analysis approach. The collected data were categorized into several major themes: (1) practical STEM implementation in science learning, (2) integration of character education and environmental values, and (3) utilization of digital technology in science learning. The analysis followed the interactive model of Miles, Huberman, and Saldana, which includes the processes of data reduction, data display, and conclusion drawing.

To ensure the validity and reliability of the findings, data triangulation was applied by comparing research results from various educational contexts, including public schools and Islamic schools (madrasah) that integrate religious values with environmental science learning. By synthesizing findings from diverse demographic and geographical contexts, this study aims to produce more comprehensive conclusions that are relevant for the development of STEM and SDGs-based science education in elementary schools.

Table 1. Summary of Article Selection Process Using PRISMA

Stage	Description	Number of Articles
Identification	Articles identified through database searching using keywords related to STEM Education, SDGs, Elementary Science Education, Environmental Literacy, Plastic Waste Management, and Ethno-STEM (2020–2025).	85
Screening	Articles screened based on title and abstract relevance to STEM integration and SDGs in science education.	60
Eligibility	Full-text articles assessed according to inclusion criteria such as empirical research, STEM-based learning implementation, and elementary or junior high school context.	35
Exclusion	Articles excluded because they were theoretical studies, unrelated to science education, or lacked complete empirical data.	15
Included	Final articles included in the systematic literature review analysis.	20

RESULT AND DISCUSSION

STEM and Plastic Waste Management

One of the most pressing environmental issues is plastic waste. A recent development in science education involves using STEM-based worksheets (Lembar Kerja Peserta Didik/LKPD) to guide students in converting plastic waste into paving blocks. This activity integrates multiple STEM disciplines. In science, students learn about the properties of plastic (polymers), its resistance to degradation, and the environmental impact of its accumulation. In engineering, students use tools to melt and mold plastic, understanding the design process of creating durable construction materials. Research by Satar et al. (2025) demonstrated that this specific STEM activity was highly valid and effective in improving students' scientific literacy. By engaging in the physical transformation of matter, students grasp abstract chemistry concepts while contributing to SDG 12.

Recent studies published in the Unnes Science Education Journal further strengthen this finding by emphasizing the role of STEM-based learning in improving higher-order thinking skills. Yazid and Marwoto (2025) found that STEM-based digital applications significantly enhance students' analytical thinking abilities, indicating that technology integration can deepen conceptual understanding. In addition, Ajibudiarta et al. (2025) highlighted that the integration of STEAM with SDGs provides a holistic framework that connects scientific knowledge with real-world sustainability challenges. These findings confirm that STEM-based plastic waste projects not only improve scientific literacy but also foster analytical and interdisciplinary thinking aligned with sustainable development.

Ethno-STEM and Cultural Contextualization

Integrating local culture with STEM (Ethno-STEM) has proven effective in increasing relevance for elementary students. A study in Makassar utilized an SDGs-oriented Ethno-STEM approach, incorporating activities like "Eco-brick" making and "Zero Plastic Week" challenges. Eco-bricks, which involve packing plastic waste into bottles to create building blocks, serve as a practical introduction to material density and waste volume reduction. The study found a statistically significant improvement in students' environmental awareness scores after the intervention ($p=0.001$). This suggests that when science concepts are grounded in local cultural practices, students demonstrate higher behavioral engage-

ment. Additionally, the implementation of Balinese local wisdom, such as Tri Hita Karana, has been successfully inserted into learning to teach environmental preservation.

This approach is supported by recent research highlighting the importance of integrating environmental literacy with sustainability frameworks. Savitri et al. (2025) emphasized that sustainable environmental literacy requires the alignment of knowledge, skills, and values within real-world contexts linked to SDGs. Ethno-STEM, therefore, serves as an effective bridge between local wisdom and global sustainability agendas, enabling students to understand environmental issues not only cognitively but also culturally and ethically. Such integration strengthens students' holistic understanding of environmental responsibility.

Organic Chemistry in the Garden

Beyond plastics, organic waste management offers a rich context for learning biology and chemistry. Utilizing the school environment as a learning resource, specifically through composting, allows students to observe decomposition directly. A study at a Madrasah Ibtidaiyah showed that using compost as a learning source made science lessons more enjoyable and active. In this context, students learn about chemical changes as organic matter breaks down into simpler substances.

The effectiveness of such contextual learning can be further enhanced through the integration of innovative educational technologies. Ibrahim et al. (2025) demonstrated that augmented reality-based learning media significantly improve elementary students' understanding of ecosystem concepts by providing interactive and visual representations. This suggests that combining hands-on activities such as composting with technology-enhanced learning can deepen students' conceptual understanding of organic decomposition processes and ecological systems.

Character Building and Challenges

The integration of values is crucial. Research indicates that integrating Islamic values with environmental education (e.g., in the Adiwiyata program) strengthens students' commitment to protecting nature. However, challenges remain. A preliminary study on teachers revealed that while many implicitly apply STEM, there is a lack of familiarity with specific SDGs terminology and a need for specialized teaching materials.

In addition, conceptual understanding plays a key role in shaping students' environ-

mental attitudes. Maknun et al. (2025) found that elementary students often experience misconceptions in science learning due to limitations in instructional materials. This indicates that integrating STEM and SDGs should not only focus on values and activities but also ensure conceptual accuracy through well-designed learning resources. Addressing these challenges is essential to achieving both cognitive and affective learning outcomes in environmental education.

Implementation of 3R (Reduce, Reuse, Recycle) in Science and Social Contexts

Beyond complex engineering projects, the fundamental concept of 3R remains a cornerstone of environmental chemistry education at the elementary level. Integrating 3R into the curriculum requires a multidisciplinary approach. Research by Di Spirito et al. (2025) highlights that waste management concepts, such as Reduce (minimizing paper use via digital assignments), Reuse (utilizing refillable bottles), and Recycle (processing organic and inorganic waste), can be effectively embedded in Social Studies (IPS) and Science (IPA) to foster an environmental care character. In the context of science, this is further operationalized through specific projects like the “Zero Waste” program. Widayanti and Widyawati (2024) developed a Zero-Waste-Based Learning Program for pre-service teachers, emphasizing that teachers must first possess deep environmental literacy to effectively transfer these values to students. This implies that successful STEM-SDGs implementation in schools relies heavily on the teacher’s competency in sustainable waste management practices.

Furthermore, recent studies indicate that integrating STEM, sustainability, and digital learning can significantly enhance students’ environmental literacy and higher-order thinking skills. Yazid and Marwoto (2025) and Savitri et al. (2025) emphasize that meaningful learning occurs when students are actively engaged in solving real-world environmental problems through interdisciplinary approaches. Therefore, the implementation of 3R should be viewed not only as behavioral training but also as a scientific learning process that develops critical, analytical, and environmentally responsible thinking.

Contextual Learning and Integration of Islamic Values

A unique finding in the literature is the effectiveness of integrating religious values with environmental science, particularly in Madrasah Ibtidaiyah (MI). Putri (2025) demonstrates that

Contextual Teaching and Learning (CTL) based on plastic waste management becomes more impactful when linked to Islamic values of cleanliness (*taharah*) and stewardship (*khalifah*). By connecting the chemical concept of non-biodegradable plastics with the religious obligation to protect the earth, students develop a stronger intrinsic motivation. This aligns with findings from Zulkarnain et al. (2021) in the Adiwiyata program, where the integration of Islamic Religious Education (PAI) with environmental education created a school culture where “caring for the environment” is seen as an act of worship. This holistic approach bridges the gap between scientific understanding of ecosystems and moral responsibility.

Digital Innovation: E-LKPD and Animation Media

The modernization of learning materials plays a crucial role in engaging the “Alpha Generation” of elementary students. Recent studies indicate a shift from traditional worksheets to digital platforms. Zain (2023) explored the development of STEM-based Electronic Student Worksheets (E-LKPD) to enhance environmental care character. Although initially targeted at higher levels, the principles of using interactive digital media are highly transferable to elementary education. Similarly, Nugraha and Rachmawati (2023) found that using animation media to explain waste issues significantly influenced the environmental character of 3rd-grade students ($t_{count} > t_{table}$). Digital tools visualize abstract processes such as the long-term decomposition of plastics or the chemical reactions in the ozone layer making them accessible and impactful for young learners.

Effectiveness of STEM on Social-Ecological Awareness

The ultimate goal of these interventions is to cultivate high social-ecological awareness. Setiawan et al. (2025) employed a mixed-methods approach to validate that STEM interventions grounded in SDGs significantly improve students’ environmental literacy. The study confirmed that when students engage in problem-solving activities that mirror real-world challenges (e.g., filtering dirty water or designing waste-free packaging), they develop not just cognitive skills but also empathy towards the environment. This supports the notion that STEM in elementary schools should not be limited to robotics or coding but must be deeply rooted in solving ecological problems surrounding the students’ lives.

CONCLUSION

The integration of STEM and SDGs in elementary science education provides a robust framework for addressing environmental challenges. By focusing on practical chemistry and environmental science topics such as plastic recycling and composting educators can make abstract concepts concrete and relevant. The evidence reviewed suggests that these approaches not only enhance scientific literacy and critical thinking but also foster a deep-seated character of environmental care. Future research should focus on developing accessible STEM-SDGs teaching materials and professional development for teachers to explicitly link science curricula with global sustainability goals.

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