

ANALYSIS OF THE NEEDS FOR DEVELOPING GREEN CHEMISTRY-BASED CHEMISTRY TEACHING MATERIALS AT MAN 2 BATUSANGKAR

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Abstract

This study examines the urgent need to develop chemistry teaching materials based on Green Chemistry principles at MAN 2 Batusangkar, Tanah Datar Regency. Despite the madrasah's commitment to environmental education through the Adiwiyata program, chemistry instruction remains conceptually dominated and disconnected from real-world environmental issues. This study aims to analyze the teaching needs by identifying gaps between existing teaching practices and the demands for Green Chemistry integration. Using descriptive qualitative methods, data were collected through in-depth interviews with teachers, students, and administrators; classroom observations; and document analysis of syllabi and lesson plans. Findings indicate that current materials lack contextual content and do not reflect Green Chemistry principles such as waste prevention, safer chemical use, or energy efficiency. Teachers reported difficulties in designing environmentally oriented materials due to limited references and time constraints, while students found the lessons abstract and unengaging. Observations confirmed the dominance of lecture-based methods, and no visible integration of local environmental contexts. Documentation revealed the absence of explicit inclusion of Green Chemistry in the curriculum despite the school's environmental vision. The study concludes that there is a significant gap between the curriculum's environmental objectives and its actual implementation in chemistry teaching. This underscores the need to develop contextual Green Chemistry-based teaching materials to enhance environmental literacy and student engagement. This research offers theoretical insights and practical directions for future educational innovations in sustainable science learning.

Keywords: Green Chemistry, Needs Analysis, Teaching Materials



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INTRODUCTION

The current national curriculum emphasizes the importance of learning that aligns with global issues, one of which is sustainable development (Sulistyowati & Radiana, 2024; Tareze & Astuti, 2022; Vioreza dkk., 2023). In the context of chemistry education, one relevant approach to this issue is Green Chemistry (Anggraeni dkk., 2024; HS dkk., 2025; Pratiwi & Wiyarsi, 2025). However, field observations show that the application of Green Chemistry principles has not been explicitly integrated into chemistry teaching materials, especially at the senior high school level. At MAN 2 Batusangkar, chemistry teachers still rely on conventional teaching materials that focus heavily on theoretical aspects and do not adopt environmentally friendly approaches. This condition results in students' low understanding of the connection between chemical concepts they study and real environmental issues such as water pollution, laboratory waste, and resource sustainability. Furthermore, the lesson plans and syllabi currently used do not contain learning indicators that explicitly reflect the principles of Green Chemistry. Therefore, there is an urgent need for contextualized teaching materials that can foster environmental awareness through the reinforcement of applicable and sustainable chemistry concepts.

Several previous studies have highlighted the importance of integrating environmental issues into chemistry education through the Green Chemistry approach (Widyawati dkk., 2024). Research by Anastas and Warner (1998), for example, emphasizes that chemistry education should evolve from mere knowledge transfer to fostering ecological awareness (Marfiyanto dkk., 2025). However, in practice, various studies note that the development of Green Chemistry-based teaching materials remains limited at the high school level, especially in Indonesia. Most existing materials are still general, not contextual, and fail to address the needs for sustainability-oriented education. This is reinforced by literature reviews showing the scarcity of practical guidelines for teachers to develop teaching materials based on Green Chemistry principles. Thus, a gap exists between practical needs in the field and the theoretical and practical support available in the literature, which strongly justifies the need for a needs analysis study in this context.

This study aims to analyze the needs for developing chemistry teaching materials based on Green Chemistry for students at MAN 2 Batusangkar. The analysis is conducted by identifying the gaps between the current teaching materials and the demands for integrating green chemistry principles into classroom instruction. This objective is pursued through a qualitative descriptive approach by collecting data through in-depth interviews, questionnaires, classroom observations, and document analysis such as lesson plans and syllabi. The study is expected to provide a comprehensive picture of both teacher and student readiness and needs regarding the development of environmentally friendly teaching materials. Moreover, the results are expected to serve as a foundational step in designing chemistry teaching materials that are not only informative but also educative in fostering sustainability values and ecological responsibility among students from an early stage.

Based on the background and objectives described above, it can be argued that the development of Green Chemistry-based teaching materials is a crucial and urgent step to be taken at MAN 2 Batusangkar. This argument is not only based on the factual condition of using conventional teaching materials but also on the demands of contemporary chemistry education theories that emphasize the integration of sustainability principles in teaching. In other words, developing such materials is not only a pedagogical innovation but also a response to global environmental challenges. This study becomes relevant as it generates empirical data supporting the urgency of reformulating more contextual, applicable, and 21st-century-aligned teaching materials. Therefore, this needs analysis serves as an essential initial step in the systematic effort to build chemistry education oriented toward environmental sustainability.

Needs analysis is a systematic process used to identify and evaluate the gap between the current condition and the desired or ideal condition in a learning or training context (Al Giffary, 2021; Amin & Nurhadi, 2020; Tukiran, 2024). In education, needs analysis serves as a crucial first step for designing targeted educational interventions, including teaching material development. According to Kaufman and English (1979), needs analysis aims to determine what learners truly require to achieve intended learning objectives (Herwina, 2021; Marhamah & Zikriati, 2024). This process not only focuses on identifying deficiencies but also maps out existing potentials and available resources. In the context of chemistry learning, needs analysis can reveal limitations in current materials as well as the expectations of both students and teachers for more relevant and applicable content (Abdurahman dkk., 2024; Fitriana & Al Masjid, 2025; Rappéh & Agustin, 2025). Therefore, needs analysis becomes a critical foundation for making informed decisions in planning and improving effective learning strategies.

Needs analysis in education is generally categorized into several types: normative needs, comparative needs, felt needs, and expressed needs (Musfirah dkk., 2025). Normative needs refer to the gap between established standards and actual conditions, such as discrepancies between curriculum competencies and teaching content. Comparative needs are identified by contrasting learning achievements between different groups or institutions. Felt needs arise from the subjective perceptions of individuals—teachers or students—regarding aspects needing improvement. Expressed needs are identified through direct methods such as interviews, observations, and surveys. In this study's context, all these categories are relevant as they reflect the complex realities underpinning the need to develop Green Chemistry-based teaching materials. These manifestations provide a concrete basis for designing teaching resources that are both relevant and effective.

Green Chemistry is an approach in chemical science that focuses on designing chemical products and processes that minimize the use and generation of hazardous substances to humans and the environment (Al Idrus dkk., 2021; Musfirah dkk., 2025). The concept was first introduced by Paul Anastas and John Warner in 1998, who formulated twelve principles of Green Chemistry as its theoretical foundation. These principles include waste prevention, atom economy, safer chemical synthesis, and energy efficiency, among others. In educational settings, Green Chemistry plays a vital role in shaping students' environmental awareness and their understanding of the relationship between chemistry and sustainability (Ardiansyah dkk., 2025). Incorporating Green Chemistry into teaching materials makes the subject more contextual, applicable, and relevant to real-life situations. Hence, integrating Green Chemistry is essential for promoting not only cognitive understanding but also ecological values in learners.

The manifestations of Green Chemistry in education can be observed across various dimensions, from topic selection and eco-friendly laboratory practices to project-based tasks addressing environmental problems (Qulub dkk., 2023). In school chemistry learning, the principles of Green Chemistry can be applied by reducing the use of harmful chemicals, substituting reagents with safer alternatives, and optimizing energy-efficient processes. Additionally, using case studies about environmental issues is part of Green Chemistry application in education. In terms of teaching materials, Green Chemistry is reflected in content that emphasizes sustainability, studies environmental impacts, and introduces green technologies. Applying these principles in the classroom encourages students to think critically and act responsibly in dealing with complex environmental challenges.

Teaching materials refer to any form of content, both printed and digital, used to facilitate the teaching and learning process in achieving educational goals effectively (Hasanah dkk., 2024; Hidayati & Zulandri, 2021; Wijaya dkk., 2021). According to Muslich (2010), teaching materials include modules, textbooks, worksheets, interactive media, and other learning resources systematically designed based on basic competencies and learning objectives (Dianita & Romadhon, 2024). Teaching materials not only serve as sources of information but also as structured guides for teachers and students to engage in planned learning activities. In chemistry education, teaching materials are crucial in bridging students' understanding of abstract concepts through visualization, experiments, and contextual studies that relate science to real life. Therefore, good teaching materials must integrate cognitive, affective, and psychomotor aspects while being aligned with technological advancements and students' learning needs.

Teaching materials can be categorized into several types, such as printed materials, visual materials, audio materials, audiovisual materials, and technology-based materials. Printed materials include textbooks, modules, and handouts commonly used in classrooms. Visual materials comprise images, diagrams, or concept maps that aid in visualization. Audiovisual resources, such as videos and animations, enhance student engagement and understanding. In chemistry education, practical experiment materials are also crucial as they allow students to explore and apply concepts directly. In the digital era, technology-based materials like e-modules, interactive apps, and virtual simulations are becoming increasingly relevant. Given the diversity of teaching materials, their development must align with students' characteristics, learning objectives, and the values intended to be conveyed—especially those of Green Chemistry.

RESEARCH METHOD

The object of this study is rooted in the observed educational context in which the current curriculum emphasizes learning oriented toward sustainable development. However, the principles of Green Chemistry have not yet been explicitly integrated into existing chemistry teaching materials. At MAN 2 Batusangkar, chemistry teachers continue to use conventional instructional materials that emphasize theoretical content and lack environmentally conscious approaches. As a result, students struggle to connect the chemical concepts they learn with real-world environmental issues such as pollution, chemical waste, and ecological sustainability. Additionally, an analysis of lesson plans (RPP) and syllabi shows that there are no indicators or learning objectives that reflect the principles of Green Chemistry. These findings indicate a critical gap in aligning chemistry education with sustainability values. Therefore, there is a clear need for the development of contextualized teaching materials that can enhance students' environmental awareness through the application of chemical concepts relevant to ecological challenges.

This study adopts a qualitative descriptive approach, which seeks to explore and portray phenomena as they occur naturally without manipulating variables or establishing causal relationships. The primary focus is to provide a comprehensive depiction of the current condition regarding the integration of Green Chemistry in chemistry education. The primary data in this research were collected through in-depth interviews with key informants, including teachers and students, who described their experiences and perceptions regarding the existing chemistry curriculum, the use of conventional teaching materials, and the absence of environmentally oriented content. Secondary data were obtained from literature relevant to the key concepts of this study, including needs analysis, Green Chemistry, and instructional material development. This combination of data sources enables a deeper understanding of the issues and supports the objective of identifying the gap between current practices and ideal instructional strategies.

The participants in this study consisted of key stakeholders involved in chemistry education at MAN 2 Batusangkar. They included two chemistry teachers who currently teach in grades XI and XII, serving as informants to provide insights into the instructional materials and curriculum implementation. In addition, thirty students from the XI MIPA class were selected as questionnaire respondents, with several participating in follow-up interviews to gain deeper qualitative data. The Vice Principal for Curriculum Affairs was also interviewed to provide institutional perspectives on the development of learning tools. Document analysis was conducted on existing learning resources, including chemistry textbooks, syllabi, and lesson plans used in the school. This diverse range of participants and data sources ensured that the study captured various viewpoints and experiences relevant to the need for developing Green Chemistry-based instructional materials.

The data collection process in this study was carried out using three main techniques: interviews, observations, and document analysis. In-depth interviews were conducted with chemistry teachers, the vice principal, and selected students to gather detailed information about their experiences and perceptions regarding the existing teaching materials and the integration of environmental issues in chemistry learning. Classroom observations were also performed to gain insight into the learning process and assess whether teaching practices aligned with sustainable education principles. Document analysis focused on reviewing the content of syllabi, lesson plans, and textbooks to identify the presence or absence of Green Chemistry principles. These data collection methods were designed to complement one another and provide a holistic view of the current state of chemistry instruction at MAN 2 Batusangkar.

The data obtained in this research were analyzed using the interactive model of Miles and Huberman, which includes data reduction, data display, conclusion drawing, and verification. Data reduction involved selecting, focusing, and simplifying the raw data obtained from interviews and observations. Next, the data were organized and presented in descriptive form to identify patterns, themes, and relationships. Conclusions were drawn based on the recurring themes and supported by the triangulated data. To ensure the validity of the findings, source triangulation was employed by comparing and cross-verifying data from multiple sources, including teacher interviews, student responses, classroom observations, and document analysis. This triangulation process enhanced the objectivity and credibility of the research results, allowing for a more accurate depiction of the needs for developing Green Chemistry-based teaching materials in the school.

RESULTS AND DISCUSSION

The findings from the needs analysis indicate that the current implementation of chemistry teaching at MAN 2 Batusangkar has not yet integrated the principles of Green Chemistry in its instructional materials or pedagogical practices. This conclusion is based on interviews with chemistry teachers, students, and the vice principal, as well as direct classroom observations and document reviews. Chemistry teachers reported that they have never received specific training or workshops on integrating Green Chemistry into teaching. They also expressed that the existing teaching materials are still theoretical in nature and lack contextual practices that relate to environmental issues. Observational data from learning sessions revealed that instruction is still predominantly lecture-based, and the use of instructional media reflecting environmentally friendly principles is absent. Meanwhile, documents such as syllabi and lesson plans do not explicitly include learning objectives or indicators that align with Green Chemistry. Additionally, the current chemistry textbooks and modules in use do not contain references to waste prevention, safe chemical usage, or energy-efficient practices. Despite the school's stated commitment to environmental education as outlined in its vision, mission, and program documents, the chemistry curriculum has yet to reflect this orientation effectively in practice.

The qualitative data collected through interviews, observations, and documentation review further emphasize the absence of concrete steps toward incorporating environmental awareness in chemistry learning. Teachers voiced a strong desire to provide students with learning resources that are environmentally conscious, but they struggle due to limited access to relevant literature and the demands of time and curriculum coverage. Students expressed similar sentiments, describing the learning of chemistry as abstract and disconnected from real-life issues. Many students were unaware of the link between the chemical concepts they study and the environmental problems they encounter daily, such as pollution, chemical waste, or sustainable practices. During observations, students appeared passive and disengaged, and they rarely participated in discussions involving environmental contexts. The lack of practical examples or demonstrations related to green chemical applications contributes to students' limited understanding and appreciation of environmentally responsible science. The teaching and learning process, therefore, remains heavily content-driven, neglecting the need to contextualize chemistry learning within the framework of environmental sustainability.

The findings from the field indicate a strong alignment between the identified problems and the rationale for conducting this research. The absence of Green Chemistry integration in both instructional materials and classroom practice reflects a significant gap in achieving the educational goals of sustainability. This issue not only affects the relevance and engagement of the subject matter for students but also fails to support broader educational policies that promote environmental awareness. Chemistry teachers, while aware of the importance of such integration, lack the resources and pedagogical frameworks to do so effectively. Furthermore, the student learning experience, as observed and described, remains disconnected from pressing real-world issues, which diminishes the transformative potential of science education. The school's environmental commitments, as reflected in policy documents, have not been operationalized at the level of classroom instruction, particularly in the field of chemistry. This dissonance highlights the need for the development of contextual teaching materials that incorporate the principles of Green Chemistry to support both curriculum implementation and environmental education goals.

Findings related to the understanding and application of Green Chemistry principles show that these concepts have not been meaningfully adopted in the chemistry curriculum at MAN 2 Batusangkar. Interviews with chemistry teachers revealed that they are unfamiliar with specific strategies to implement Green Chemistry in their teaching. They also acknowledged the lack of examples and content in textbooks or learning modules that encourage environmental responsibility in chemical practices. The vice principal expressed support for

incorporating environmentally focused learning materials, especially those aligned with the school's Adiwiyata (eco-school) program. Observations during chemistry lessons found that there were no discussions or activities that linked chemical reactions or laboratory practices to eco-friendly approaches. Additionally, students were not exposed to practices such as reducing hazardous chemicals or exploring sustainable chemical processes. Supporting documents, including lesson plans, syllabi, and textbooks, confirmed that no references to the 12 principles of Green Chemistry or similar guidelines exist in the current instructional content. This indicates a disconnection between national curriculum goals for sustainable education and their realization in classroom practice.

Further analysis of the qualitative data reveals that the lack of Green Chemistry content results in missed opportunities for students to understand how chemistry can contribute to solving environmental problems. Teachers admitted they were unfamiliar with core Green Chemistry principles, such as waste prevention, the use of renewable resources, or design for energy efficiency, and thus were unable to guide students in applying these ideas. Although the school's policy promotes environmental care, this policy has not been reflected in the chemistry curriculum or classroom practices. The students' learning experience remains limited to theoretical concepts, and they are not encouraged to critically engage with issues such as pollution control, chemical safety, or ecological sustainability. Observation data showed no presence of green-oriented laboratory activities or discussions, and the available teaching materials lack practical examples or case studies related to environmentally friendly practices in chemistry. Consequently, students' environmental literacy, particularly in the context of scientific learning, remains underdeveloped. This further strengthens the need to design instructional materials that introduce and reinforce Green Chemistry principles in a meaningful and accessible way.

The disconnection between curriculum goals and instructional practice concerning Green Chemistry illustrates the urgency of this study. The findings show that although the school is committed to environmental education, as seen in its Adiwiyata program, these commitments are not being translated into classroom learning. The chemistry subject, which has significant potential to support sustainability education, is currently failing to serve this role. Teachers' limited knowledge, students' disengagement, and the absence of instructional resources aligned with Green Chemistry all contribute to a missed opportunity in cultivating environmental awareness through science education. These conditions reflect a systemic issue in educational implementation, where policies are not sufficiently supported by concrete teaching tools or teacher training. Addressing this gap by developing Green Chemistry-based teaching materials is thus essential for realizing the full potential of chemistry education in promoting environmentally responsible behavior among students.

Data gathered from interviews, observations, and document analysis reveal significant shortcomings in the availability and quality of instructional materials used in teaching chemistry. Teachers confirmed that the modules and textbooks in use are outdated and largely focused on theory without integrating real-world applications. There is no inclusion of content that emphasizes sustainability, waste management, or environmentally safe chemical use. Observations in the classroom supported these claims, with no evidence of instructional media or student activities promoting environmentally friendly practices. The vice principal also highlighted the gap between the school's environmental policy and its instructional execution. Documents reviewed, including syllabi, lesson plans, and textbooks, show no alignment with Green Chemistry principles. The absence of visual aids, contextual examples, and problem-based learning activities in the available teaching materials further hampers the delivery of effective environmental education through chemistry. These findings illustrate the need for instructional resources that are not only scientifically accurate but also relevant to students' environmental context and responsibilities.

The instructional materials currently used in MAN 2 Batusangkar do not support the integration of Green Chemistry into classroom practice. Teachers explained that they rely heavily on traditional textbooks, which do not address the environmental dimension of chemical education. The materials lack visual illustrations, local case studies, and practical projects that could engage students in meaningful learning about sustainability. Additionally, the available lesson plans and modules do not include goals or indicators related to environmentally conscious chemical practices. The lack of guidance and relevant resources limits teachers' ability to innovate in their instructional design. Classroom observations confirmed that students are primarily exposed to theoretical content with minimal interaction or contextual discussion. The result is a static learning environment where chemistry is presented as a detached academic subject rather than a powerful tool for understanding and addressing environmental challenges. These conditions point to the pressing need for developing teaching materials that embed Green Chemistry concepts and support active, contextual, and sustainability-oriented learning.

The findings regarding instructional materials confirm and reinforce the central problem addressed in this study. Despite the potential for chemistry education to promote environmental responsibility, the lack of relevant, engaging, and context-based teaching resources has hindered this goal at MAN 2 Batusangkar. Teachers are limited by outdated and incomplete materials that do not reflect current educational priorities, particularly those related to sustainability. Students, in turn, experience chemistry as abstract and irrelevant to their daily lives and environmental realities. The school's vision of becoming environmentally responsible remains unfulfilled in the actual teaching of science subjects. These conditions align directly with the research's core objective: to develop chemistry teaching materials based on Green Chemistry principles that are relevant, contextual, and capable of fostering both scientific understanding and environmental awareness. This stage of research highlights the essential groundwork for such development by illustrating the gaps and needs within the current instructional framework.

Table 1. Research Findings

Aspect	Existing Condition	Green Chemistry Integration Demands	Identified Gap
Curriculum Documents	Syllabus and lesson plans do not include specific goals or competencies related to Green Chemistry.	Curriculum should explicitly include environmental sustainability competencies, especially aligned with the 12 Green Chemistry principles.	Absence of Green Chemistry-related objectives in official documents.
Teaching Materials	Textbooks and modules are focused on conceptual content; no contextual environmental issues are included.	Teaching materials should incorporate real-world environmental problems (e.g., waste reduction, eco-friendly reactions).	Lack of contextual and relevant content that connects chemistry concepts to environmental applications.
Teaching Practices	Predominantly lecture-based; no evidence of practical applications involving green experiments or materials.	Active, inquiry-based approaches are needed that involve eco-friendly laboratory practices and student engagement.	Mismatch between instructional method and environmentally responsible chemistry learning.
Teacher Readiness	Teachers have not received training on Green Chemistry; lack	Teachers should be equipped with pedagogical and content knowledge related to	Limited capacity to innovate due to lack of

	of references and time to develop new materials.	sustainable chemistry.	professional development and resources.
Student Engagement	Students find chemistry abstract and disconnected from real-life issues.	Lessons should foster critical thinking, relevance, and motivation through contextual environmental issues.	Low student engagement due to absence of meaningful, environmentally oriented content.

The findings of this study indicate a significant discrepancy between the current chemistry teaching practices at MAN 2 Batusangkar and the principles of Green Chemistry. Chemistry learning remains largely theoretical and lacks contextual relevance, especially concerning environmental issues. Teachers are aware of the importance of integrating environmental awareness into their teaching but face practical constraints, including limited resources and time. While the school is committed to environmentally based education, this commitment is not yet reflected in the existing teaching materials or lesson plans, which fail to incorporate Green Chemistry indicators.

This study aligns with and expands upon prior research by highlighting the urgent necessity of contextualized instructional materials in chemistry education. Previous studies have demonstrated that the integration of Green Chemistry principles enhances students' awareness of environmental issues and encourages more meaningful learning (Zoller, 2010; Mahaffy et al., 2017). However, unlike many earlier studies that focused on experimental interventions or curriculum proposals, this research emphasizes a critical preliminary phase: the needs analysis. This step enables the development of teaching materials that are not only scientifically valid but also pedagogically necessary within the local educational context.

The outcomes of this study reflect the real and present need to bridge the gap between environmental education discourse and actual classroom practice. The identification of these needs suggests that any efforts toward material development must begin by listening to teachers, understanding student perceptions, and reviewing the institutional readiness for innovation. This realization reinforces the importance of integrating sustainability into science education not merely as an abstract ideal but as an achievable, grounded instructional goal.

The implications of this research are twofold. First, it provides foundational data for developing Green Chemistry-based teaching materials tailored to the needs of students and teachers at MAN 2 Batusangkar. Second, it presents a model for conducting needs analysis that can be adopted in similar educational settings to inform the development of environmentally oriented curricula. The study advocates for a bottom-up approach in instructional design, wherein the actual conditions of classroom practice are central to innovation.

The findings also raise an essential question: why has the integration of Green Chemistry remained absent despite institutional support for environmental values? One plausible explanation lies in the disconnect between institutional policy and pedagogical practice. School-level programs such as *Adiwiyata* are often managed administratively and not sufficiently translated into instructional strategies. Furthermore, the lack of teacher training and reference materials on Green Chemistry limits the ability to design effective and relevant lesson content.

In light of these findings, several actions are recommended. Educational stakeholders should prioritize the development of contextually relevant teaching materials that embody the principles of Green Chemistry. This includes organizing teacher training programs, revising lesson plans to include sustainability indicators, and involving teachers in the co-creation of instructional resources. Through these measures, it is possible to align curriculum content with

environmental commitments and provide students with the scientific literacy required to address contemporary ecological challenges.

CONCLUSION

Unexpectedly, the study revealed a significant disconnect between the school's declared environmental vision and the actual practices of chemistry instruction at MAN 2 Batusangkar. Despite institutional support for sustainability through programs like Adiwiyata, chemistry learning remains dominantly theoretical, devoid of practical contextualization, and fails to incorporate the principles of Green Chemistry. Both teachers and students acknowledge the importance of environmentally conscious education, yet the absence of suitable instructional resources, limited training, and a lack of curricular integration leave this potential unrealized.

This research contributes meaningfully to both theoretical discourse and practical innovation in science education. Theoretically, it enriches the understanding of how needs analysis can serve as a foundational step in aligning curriculum content with sustainability goals. Practically, the study offers a roadmap for educators, curriculum developers, and policymakers to identify specific gaps in teaching materials and take data-driven steps toward designing chemistry resources that reflect contemporary environmental challenges. It demonstrates the critical role of local contextualization in educational reform, especially in embedding Green Chemistry in secondary school instruction.

While this study provides valuable insights, it is bound by its focus on a single educational setting and a qualitative approach. These are not limitations in the sense of methodological flaws but rather boundaries that shape the scope of the research. Future studies are encouraged to expand this investigation across diverse schools with varied environmental programs, utilize mixed-method approaches, and explore the implementation phase of Green Chemistry-based instructional materials. Such extensions will strengthen the generalizability of findings and support the creation of a more holistic framework for sustainable science education.

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