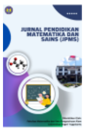
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Evaluation of the Environmental Chemistry Course Using the CIPP Model: Integrating SDGs and Enhancing Students' Environmental Literacy

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Abstract

This study evaluates the alignment of the curriculum with national policies and global environmental challenges, assesses the availability of resources and teaching strategies, and measures students' learning outcomes in cognitive, affective, and behavioral dimensions. Using a mixed-methods approach within the CIPP (Context, Input, Process, and Product) evaluation model, the study involved the program chair, two-course instructors, and 26 students from a public university in Aceh. Research instruments included questionnaires, observation sheets, interview guides, and test items. The findings indicate that the curriculum is relevant to global issues and supports the development of students' critical thinking skills. However, limited laboratory facilities, insufficient funding, and a lack of support for environment-based projects pose significant challenges to optimal curriculum implementation. Additionally, the program effectively enhances students' understanding of global environmental issues and their relevance to the SDGs but requires stronger integration of practical applications and explicit connections to SDG targets. Recommendations include project-based learning innovations, cross-sector collaborations, and improvements in facilities and funding to holistically enhance students' environmental literacy and prepare them as sustainability change agents.

Keywords*: CIPP evaluation model, Environmental chemistry, Environmental literacy, Program evaluation, SDGs.*

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INTRODUCTION

Program evaluation is a systematic process of collecting and analyzing information to assess the effectiveness, relevance, efficiency, and impact of a program or policy. The purpose of program evaluation is to provide information that supports decision-making, clarifies options, identifies areas for improvement, and supplies data within the contextual constraints of time, location, values, and politics (Anglin et al., 2020; Fitzpatrick et al., 2011). As a scientific endeavor, program evaluation serves to measure program performance, guide improvements, and provide actionable insights for decision-makers (Rossi et al., 2004). It plays a critical role in determining whether a program has achieved its intended objectives and in informing decisions about its continuation, modification, or termination.

In the educational context, program evaluation is often used to measure how well a curriculum, teaching methods, and learning activities support the achievement of desired learning outcomes (Luo et al., 2024; Jonathan Michael Spector, 2023). According to Patton (2008), program evaluation aims to provide stakeholders with feedback on program functioning, identify areas for improvement, and assess how well a program meets the needs of its participants or society. This highlights that evaluation focuses not only on the program's outcomes but also on the processes that contribute to achieving these results. In the case of environmental chemistry courses, program evaluation is essential to ensure that the curriculum and learning approaches align with global challenges, particularly the Sustainable Development Goals (SDGs). Established by the United Nations in 2015, the SDGs emphasize environmental sustainability as a key global priority, addressing issues such as climate change, pollution, and sustainable resource management. Evaluating the environmental chemistry program helps determine whether the curriculum equips students with the knowledge and skills needed to contribute to the SDGs. Additionally, it identifies how learning approaches can be adapted to remain relevant in both local and global contexts.

The primary goal of program evaluation is to collect data that informs decisions about a program’s sustainability or improvement. As noted by Weiss (1998), evaluation also serves to clarify policy options, identify areas for development, and assess the effectiveness of implemented strategies. In this way, evaluation not only reveals what works and what doesn’t but also provides insights into how a program can be modified or enhanced to achieve better outcomes. For example, in environmental chemistry courses, evaluation might analyze whether topics such as industrial waste management or water pollution are addressed comprehensively and whether students gain sufficient practical skills to apply these concepts professionally. Stufflebeam & Coryn (2014) emphasize that a comprehensive program evaluation should include assessments of inputs, processes, and outputs while considering the socio-cultural and political contexts in which the program operates.

In higher education, particularly in environmental chemistry courses, program evaluation serves as a critical tool to ensure that educational objectives align with societal needs and global challenges. It also ensures that learning outcomes effectively prepare students to address complex environmental issues. Such evaluations contribute to the broader efforts of universities in supporting the implementation of the SDGs, fostering sustainability, and providing real-world solutions to environmental problems (Bayer et al., 2016; Zeng et al., 2018). Environmental chemistry, as a discipline, focuses on understanding chemical processes in nature and the impact of human activities on environmental balance. It addresses pressing global challenges such as climate change, water pollution, and soil degradation (Awewomom et al., 2024; Sillanpää, 2020). Climate change, for instance, is driven by atmospheric chemical reactions involving greenhouse gas emissions that contribute to global warming. Environmental chemistry provides insights into mitigating these effects through cleaner energy technologies and sustainable waste management. Similarly, water pollution caused by industrial and domestic waste can be addressed using water purification and safe waste management technologies derived from environmental chemistry research.

Program evaluation is integral to ensuring that the curriculum, teaching strategies, and student learning outcomes align with these challenges. A comprehensive evaluation involves assessing the relevance of course materials, ensuring they address current issues like hazardous waste management. Teaching methods must also be interactive and problem-based to bridge the gap between theory and practice. Moreover, evaluations should include assessments of students’ practical skills, as environmental chemistry demands graduates who can monitor and manage environmental impacts while developing sustainable solutions. Surveys and interviews with students and alumni can provide valuable feedback on their readiness to address real-world challenges. Evaluations must also consider local and global contexts, recognizing that while environmental issues are global, solutions often need to be tailored to local conditions.

To guide the evaluation process systematically, the CIPP (Context, Input, Process, Product) model developed by Stufflebeam (1971, 2023) and Stufflebeam & Coryn (2014) provides a decision-oriented framework. This model supports administrators in making informed decisions by assessing four key components: context, input, process, and product. Context evaluation supports planning decisions by identifying the needs a program should address and evaluating existing programs to define their goals. Input evaluation aids structural decisions by helping managers select appropriate strategies and resources for implementation. Process evaluation supports implementation decisions by monitoring program execution and identifying necessary adjustments. Finally, product evaluation assesses program outcomes, determining whether objectives have been met and informing decisions on revising, expanding, or discontinuing the program. The CIPP model emphasizes decision-making, program improvement, and accountability, offering a logical structure for evaluation. The evaluation process begins with determining criteria and relevant policies, collecting qualitative and quantitative data, and organizing this information systematically for accurate analysis. Findings are then reported in formats tailored to stakeholders, ensuring clarity and transparency. Throughout, evaluation administration ensures adherence to policies and resource allocation, ensuring validity and reliability (Dini, 2022; Djuanda, 2020). Over time, the CIPP model has evolved to involve more stakeholders, creating inclusive evaluations that consider political dynamics and emphasize integrity and sustainability.

Through these steps, the CIPP model ensures comprehensive evaluation, identifying areas for revision while remaining aligned with program missions and values. Evaluators begin by assessing program context, such as organizational assets and cultural backgrounds, before moving to input evaluation to review planning, resource allocation, and stakeholder involvement. Process evaluation focuses on continuous improvement, monitoring activities, and identifying challenges. Finally, product evaluation measures program outcomes and their sustainability, addressing questions of impact and effectiveness. By systematically addressing these components, program evaluation not only enhances the quality of environmental chemistry courses but also ensures that higher education institutions contribute to achieving the SDGs, fostering environmental sustainability, and equipping students to tackle global challenges.

Based on the background that has been outlined, the research questions (RQ) are as follows:

- RQ1: To what extent does the alignment of the Environmental Chemistry course curriculum with national policies (SN-Dikti) contribute to the development of students' competencies in addressing global environmental issues and sustainability?
- RQ2: How do limitations in facilities and funding affect the effectiveness of Environmental Chemistry courses aimed at enhancing students' awareness and skills in addressing global environmental issues?
- RQ 3: How do the experience and competence of lecturers, as well as the availability of laboratory facilities, influence the effectiveness of Environmental Chemistry courses in higher education institutions?
- RQ4: What is the impact of integrating project-based practices into Environmental Chemistry education on students' understanding of environmental issues and its contribution to achieving the SDGs?
- RQ5: How does the integration of environmental issues into the curriculum impact the enhancement of students' cognitive, affective, and pro-environmental behavioral dimensions in higher education?
- RQ6: What other factors influence students' environmental literacy beyond the cognitive, affective, and behavioral dimensions, and how do interactions between these factors contribute to increased environmental awareness and pro-environmental actions?

METHOD

The evaluation method used in the Environmental Chemistry course program applies a mixed methods approach, which combines both quantitative and qualitative methods (Creswell & Clark, 2018), using a decision-oriented evaluation approach based on the CIPP model (Context, Input, Process, Product) (Fitzpatrick et al., 2011). Context evaluation is conducted to understand the needs, background, and relevance of the program in relation to student objectives, educational policies, and global environmental issues such as climate change and pollution. This evaluation also ensures that the implemented curriculum aligns with the latest developments in the field of chemistry and supports the SDGs. The primary focus of context evaluation is to identify the program's strengths and weaknesses based on needs, problems, assets, and opportunities, enabling targeted improvements. Subsequently, input evaluation aims to assess the quality and adequacy of the program's resources, including the curriculum, teaching materials, laboratories, supporting facilities, lecturer competencies, and learning technologies. This evaluation ensures the availability of sufficient resources to deliver high-quality teaching and learning processes, allowing students to gain optimal learning experiences.

Process evaluation focuses on assessing the implementation of the program in daily activities, including teaching methods such as discussions, laboratory experiments, and field research. It also evaluates the effectiveness of learning activities and student engagement while identifying obstacles to program implementation, such as resource limitations, lack of interaction between lecturers and students, or challenges in conducting practical sessions. Finally, product evaluation assesses the program's outcomes, including student learning achievements and the impact of the program on their understanding and ability to address environmental issues. This evaluation determines the program's success in achieving its objectives, such as enhancing knowledge about pollution, environmental conservation, and the use of environmentally friendly chemicals. Additionally, product evaluation provides feedback on the program's relevance to labor market needs and its contribution to preparing students to actively participate in solving global environmental problems. Through this evaluation approach, the Environmental Chemistry course program can be comprehensively analyzed to ensure its effectiveness, relevance, and sustainability.

The parameters of the Environmental Chemistry course program evaluated in this study are presented in Table 1**.** The participants in this research include the head of the study program, two lecturers teaching the Environmental Chemistry course, and 26 students who have completed the course at a public university in Aceh Province.

Table 1. Parameters of the Evaluated Environmental Chemistry Course Program

Evaluation stage	**Focus**	**Methods**	**Instruments**
Context Evaluation	Alignment of the curriculum with national policies (SN-Dikti)	Document analysis	Curriculum documents, Semester Learning Plan (SLP) for Environmental Chemistry, Odd Semester, Academic Year 2024/2025
	Suitability of learning with student needs	Document analysis	Semester Learning Plan (SLP) and learning materials for Environmental Chemistry
	Relevance of learning with global environmental issues, including SDGs	Document analysis	Learning materials on air, water, and soil pollution, climate change, waste management, and science- and technology-based solutions
	Identification of the program's key strengths	Interview	Interview guide for the head of the study program and lecturers teaching the course
Input Evaluation	Lecturer experience and competencies	Interview	Interview guide for lecturers teaching the course
	Availability and relevance of learning facilities	Observation, interview	List of learning facilities (classrooms, laboratories, multimedia) and interview guide for lecturers and support staff
	Availability of teaching materials	Document analysis	List of references (textbooks, scientific journals, modules) and available teaching materials
Process Evaluation	Effectiveness of the Environmental Chemistry course	Questionnaire	Student questionnaire to assess the effectiveness of the Environmental Chemistry course
	Relevance of the course to SDGs	Questionnaire	Student questionnaire to assess the relevance of the Environmental Chemistry course to the SDGs
	Program strengths (discussion of environmental issues)	Interview	Interview guide for students on the strengths of discussions on environmental issueS
	Student engagement in learning and discussions	Interview	Interviews with students on their level of engagement in discussions and collaborative learning
Product Evaluation	Assessment of students' environmental literacy (cognitive)	Knowledge test, questionnaire	Test or quiz questions on environmental literacy
	Assessment of students' environmental literacy (affective)	Questionnaire, interview	Questionnaire on attitudes toward environmental issues and interview guide on values and environmental awareness
	Assessment of students' environmental literacy (behavioral)	Observation, questionnaire	Questionnaire on pro-environmental behavior

Data collection instruments are divided into two categories, quantitative and qualitative data collection tools. To collect quantitative data, instruments used include environmental literacy test questions (cognitive component) and environmental literacy questionnaires (attitude and behavior components). For collecting qualitative data, instruments used include interview guides for the program head, lecturers, and students, and document analysis sheets.

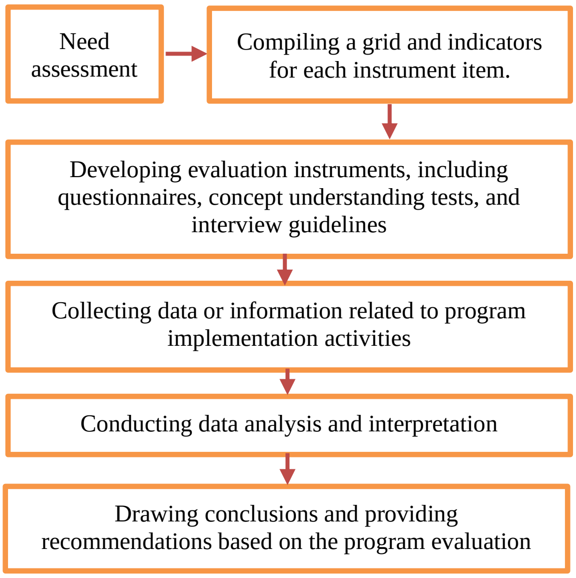

Figure 1. Research procedure

Measurement of students' environmental literacy for cognitive aspects uses test questions related to basic environmental chemistry content. While for affective and behavioral aspects, a questionnaire is given. The questionnaire was designed using a 7-point Likert scale, where a score of 1 indicated "strongly disagree," 2 indicated "moderately disagree" 3 indicated "slightly disagree" 4 indicated "neutral" 5 indicated "slightly agree" 6 indicated " moderately agree" and 7 indicate “very agree”. Data analysis was performed using Microsoft Excel and SPSS application. The criteria for categorizing students' environmental literacy are divided into three categories: high, medium, and low, as shown in Table 1.

Table 1. Criterion for grouping environmental literacy

Score (X)	**Category**
$M + SD \leq X$	High
$M - SD \leq X < M + SD$	Medium
$X < M - SD$	Low

M = Mean; and SD = Standard Deviation.

To examine the influence of affective and behavior (as independent variables) on kognitif (as the dependent variable), multiple linear regression analysis was employed. The data interpretation stage involved the use of Excel and SPSS output presented in graphs or tables, which were further elaborated through narrative analysis to provide deeper insights into the observed behavioral tendencies

RESULT AND DISCUSSION

Context Evaluation

Alignment of the curriculum with national policies (SN-Dikti)

The Environmental Chemistry course is an elective course offered in the fifth semester of the Chemistry Education Study Program, with a credit weight of 2 credits. A document analysis of the Study Program Curriculum Handbook and the Semester Learning Plan for the Environmental Chemistry course in the Odd Semester of the 2024/2025 Academic Year indicates alignment with the National Standards for Higher Education (SN-Dikti). The curriculum has been designed in accordance with the guidelines outlined in the "Guidelines for Higher Education Curriculum Development," ensuring that the course content meets national educational objectives and established quality standards. This alignment ensures that the study program not only complies with regulatory requirements but also effectively addresses current environmental challenges, equipping students with the necessary competencies to contribute to sustainable development.

The suitability of learning to student needs and the relevance of learning to global environmental issues

Document analysis of the Semester Learning Plan (SLP) reveals a significant alignment with students' learning needs. The learning objectives encompass the analysis of critical issues such as air, water, and soil pollution, climate change, as well as science- and technology-based solutions to address these challenges. Approaches such as Problem-Based Learning and the scientific approach foster critical thinking and problem-solving skills, which are essential for students to tackle increasingly complex environmental challenges.

This course is highly relevant to current environmental issues, including climate change, pollution, and waste management, which are also global priorities in sustainability efforts. For instance, students are equipped with knowledge of greenhouse effects, global warming, and the impacts of pollution on health and ecosystems.

Additionally, the integration of topics such as industrial waste management and recycling concepts strengthens students' insights into generating practical and sustainable solutions. This approach not only provides a solid scientific foundation but also encourages students to understand their role in supporting environmental sustainability at both local and global levels.

Research by Gök & Boncukçu, (2023) and Suryawati et al. (2020) demonstrates that problem-based learning enhances students' ability to apply theoretical knowledge to solve real-world environmental problems. Similarly, studies by Jia & Wang (2024), Aikowe & Mazancova, (2023) and Fang (2021) highlight the importance of environmental education integrated with global issues such as climate change and sustainability to increase students' awareness and participation in pro-environmental actions. Furthermore, studies by Leal Filho et al. (2019) and Carracedo et al. (2019) found that curricula incorporating SDGs enrich students' understanding of global challenges and technology-based solutions in achieving sustainability goals.

The curriculum also presents significant opportunities for integrating SDG-related issues. These include strengthening climate literacy for SDG 13 (Climate Action), technological innovation for clean water in SDG 6 (Clean Water and Sanitation), and sustainable consumption and production management for SDG 12 (Responsible Consumption and Production).

Incorporating discussions on circular economy, environmental data analysis, and national and international environmental policies could further prepare students to understand and address global challenges. By integrating SDGs and additional environmental competencies, this curriculum becomes more effective in preparing students as agents of change. Implementation strategies, such as SDG-based projects, stakeholder collaboration, and local and global case studies, provide relevant practical experiences. Through a holistic and sustainable approach, students can internalize sustainability values and become contributors to global environmental preservation.

Identification of the Program's Key Strengths

Additional information was obtained to understand the program's strategies and approaches through interviews with the head of the study program and the course instructors. The interviews included questions (IQ) and corresponding answers (IA), with IQ1 and IA1 addressing the head of the study program, and IQ2 and IA2 focusing on the course instructors. The questions and summaries of the responses are as follows:

IQ1: *"What do you see as the main strengths of this program in helping students gain a solid understanding of environmental issues?"*

IA1: *"The main strength of this program lies in its curriculum, which is designed to align with global environmental issues, and its problem-based learning approach that encourages students to think critically and develop solutions. In terms of facilities, the general chemistry laboratory and green open spaces are adequate. However, we are continuously working to improve access to modern analytical tools and other resources to support more optimal learning."*

IQ2: *"In your opinion, what are the key strengths of the Environmental Chemistry program, and how do the facilities and teaching materials support the learning activities?"*

IA2: *"The program's strengths lie in the relevance of its topics, particularly those related to environmental issues such as waste management, which is a significant concern today. The Problem-Based Learning approach is effective in training students to solve real-world problems. Furthermore, the program emphasizes the importance of sustainability values to develop students' awareness of environmental issues. However, the program faces challenges, particularly regarding insufficient facilities, such as laboratories that do not fully support the coursework. Additionally, limited funding poses challenges, especially for the implementation of project-based learning. As a result, the learning activities are currently more focused on discussing environmental issues through classroom discussions."*

Based on the interviews with the head of the study program and the course instructors, the main strengths of the Environmental Chemistry program lie in its curriculum, which is highly relevant to global environmental issues, and its Problem-Based Learning approach, which fosters critical and solution-oriented thinking among students. However, limitations in facilities, such as inadequate laboratories, and insufficient funding remain major challenges in implementing the coursework and environmental project-based learning.

Research by Lopes et al. (2020) and Handoyo et al. (2024) shows that problem-based learning is effective in enhancing students' skills, but inadequate facilities can hinder the optimal implementation of such learning methods. Therefore, strengthening facilities and increasing funding are crucial to support more effective learning experiences.

Input Evaluation

Lecturer Experience and Competencies

Two lecturers (Lecturer A and Lecturer B) have been teaching the Environmental Chemistry course in the Chemistry Education Study Program. Lecturer A has been teaching for 9 years, and Lecturer B for 7 years, both with considerable experience in delivering the course. However, Lecturer A does not teach the course every year, nor is Environmental Chemistry a functional or primary course in their teaching portfolio. On the other hand, Lecturer B teaches Environmental Chemistry regularly every year and has conducted research on environmental issues, such as utilizing sugarcane bagasse to produce briquettes, converting plastic waste into flooring materials, and studying the impacts of water pollution on soil quality in coastal areas. The research findings indicate that water pollution significantly reduces soil quality, which adversely affects local agricultural productivity. Conversely, Lecturer A does not focus on environmental issues in their research.

To ensure that the course content remains relevant to the latest developments in the field of Environmental Chemistry, both lecturers regularly update their teaching materials by consulting recent scientific journals and participating in seminars or workshops related to Environmental Chemistry. This demonstrates their commitment to maintaining the quality and relevance of the materials delivered to students.

Availability and Relevance of Learning Facilities

Observations revealed that classroom facilities are highly adequate, including well-maintained, clean, and comfortable spaces equipped with sufficient tools such as projectors and other teaching aids. However, challenges were identified during interviews with the course lecturers regarding the availability of facilities and infrastructure supporting Environmental Chemistry learning activities.

The interviews revealed that while basic learning facilities such as classrooms, laboratories, and teaching media like projectors are available, there are significant challenges in conducting Environmental Chemistry laboratory practicums. The currently available laboratory is a general chemistry laboratory, which is not fully adequate to support environmental chemistry practicums or project-based activities. Limited laboratory equipment and materials hinder the optimal execution of several activities planned by the lecturers.

Although classroom facilities and teaching media are sufficient, the development of laboratories tailored to the needs of Environmental Chemistry practicums is urgently required to enhance the effectiveness of learning. During class sessions, learning activities are primarily conducted through discussions centered on current environmental issues. Students are encouraged to gather information from diverse sources such as articles, books, and online media, including YouTube, which are used as discussion materials. This approach provides flexibility for students to independently explore various environmental topics.

However, Lecturer B noted that although project ideas, such as converting plastic waste into eco-bricks, have been designed, their implementation has not been optimal due to financial and facility constraints. Therefore, to improve the quality of Environmental Chemistry education, further support for laboratory facilities and funding is essential to facilitate more in-depth and effective implementation of environment-based projects.

Process Evaluation

Evaluation of the Effectiveness of Environmental Chemistry Learning

The evaluation of learning activities in the Environmental Chemistry course aims to evaluate the effectiveness of teaching methods, the relevance of the content, and its influence on students' understanding and awareness of environmental issues. The objective of learning Environmental Chemistry extends beyond imparting theoretical knowledge; it also seeks to cultivate critical thinking, practical skills, and a sense of responsibility towards environmental challenges. This evaluation helps identify the strengths and weaknesses of the learning activities, including teaching strategies, interactions between lecturers and students, and supplementary activities like practical sessions and fieldwork. The findings from this evaluation are intended to inform improvements in the quality of education, ensuring it aligns more closely with students' needs and the global environmental challenges they face.

The analysis of student responses to the survey evaluating the effectiveness of Environmental Chemistry learning reveals several key insights into the teaching and learning processes (Table 2). For instance, in Item 1, 92.3% of respondents agreed or strongly agreed that the employed teaching methods, such as discussions, lectures, and experiments, effectively aid their understanding of Environmental Chemistry concepts. This result aligns with active learning theories, which emphasize that interactive methods foster deeper comprehension (Andraos & Dicks, 2013; Idsardi, 2020; Prince, 2004; Ribeiro-Silva et al., 2022). Similarly, Item 2 showed 92.31% agreement on the clarity of instructor explanations, underscoring the importance of clear communication in facilitating learning, as supported by Biggs et al. (2022) constructive alignment theory.

Table 2. Questionnaire statements for evaluating the effectiveness of course learning

Item	Statements	Percentage			
		SA	A	D	SD
1	The teaching methods employed (such as discussions, lectures, and experiments) aid my understanding of Environmental Chemistry concepts.	46.15	46.15	7.69	0.00
2	The instructor offers clear and comprehensible explanations in every session.	42.31	50.00	7.69	0.00
3	The practical sessions enhance my grasp of the topics covered in lectures.	50.00	42.31	3.85	3.85
4	The materials presented are connected to environmental issues that are relevant to everyday life.	61.54	34.62	0.00	3.85
5	Class or group discussions encourage me to be more active and engaged in the learning process	42.31	53.85	0.00	3.85
6	The lecturer provides valuable feedback following assignments or presentations	46.15	50.00	3.85	0.00
7	The time allocated for each activity (discussion, practice, presentation) is adequate to meet the learning objectives.	15.38	69.23	15.38	0.00
8	The technology or teaching aids used (such as projectors, e-learning tools, etc.) improve my understanding of the material.	34.62	61.54	3.85	0.00
9	The interaction between the lecturer and students in the Environmental Chemistry course is effective	46.15	50.00	3.85	0.00
10	The content presented aligns with the principles of the Sustainable Development Goals (SDGs)	7.69	88.46	3.85	0.00
11	I feel capable of applying the concepts learned in class to real-world issues, particularly environmental ones.	26.92	57.69	11.54	3.85
12	The learning activities encourage me to think critically about global environmental challenges	34.62	53.85	7.69	3.85
13	Fieldwork (if applicable) significantly aids my understanding of environmental conditions firsthand.	23.08	61.54	11.54	3.85
14	The lecture materials are consistently relevant to current developments in the fields of chemistry and the environment	38.46	57.69	3.85	0.00
15	I believe that the learning experience in this course effectively enhances my environmental literacy	38.46	53.85	7.69	0.00

The questionnaire utilized a Likert scale with the following response options: Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD).

Practical sessions, as highlighted in Item 3, were valued by 92.31% of students for enhancing their grasp of lecture topics. This finding resonates with Kolb's experiential learning model, which posits that hands-on experiences are integral to applying theoretical knowledge effectively (Kolb, 2014). Additionally, item 4 indicates that 96.16% of students believe the presented materials are connected to real-life environmental issues, reflecting the effectiveness of context-based learning approaches in promoting relevance and engagement (Huang &

Chiu, 2015; Tutal, 2023). Group discussions (Item 5) and lecturer feedback (Item 6) were also highly appreciated, with over 92% agreement in each, supporting the notion that collaborative and formative feedback methods significantly enhance student engagement and understanding (Deiparine et al., 2023; Oestergaard et al., 2024)

While most students (84.61% in Item 7) felt that the allocated time for activities was adequate, a notable minority (15.38%) expressed dissatisfaction, suggesting a need for reviewing time management strategies in course planning. Teaching aids (Item 8) were deemed helpful by 96.16% of respondents, underscoring the role of technology in modern pedagogical practices, as highlighted by Mayer (2014) multimedia learning principles. Effective lecturer-student interaction (Item 9), supported by 96.15% agreement, indicates the importance of a conducive learning atmosphere for promoting active participation (Vygotsky, 1978).

One notable finding is the high alignment of course content with the Sustainable Development Goals (SDGs) (96.15% agreement in Item 10), demonstrating the course's relevance to global environmental challenges. This is consistent with research suggesting that integrating SDG-focused content enhances student awareness and prepares them to tackle global issues (Leal Filho et al., 2021, 2023). However, fewer students (84.61% in Item 11) felt confident about applying their knowledge to real-world problems, indicating potential areas for improvement in bridging theory and practice. Similarly, while 88.47% of respondents agreed that the course encourages critical thinking about global environmental challenges (Item 12), some students indicated room for further development in this area.

Fieldwork, noted in Item 13, was perceived as beneficial by 84.62% of respondents. However, 15.39% expressed dissatisfaction, highlighting the need for better logistical support or design of fieldwork activities. The relevance of lecture materials to current developments (Item 14) received strong agreement (96.15%), indicating the course's success in staying up-to-date with advancements in chemistry and environmental science. Finally, 92.31% of students felt that the course effectively enhances environmental literacy (Item 15), emphasizing the course's overall success in meeting its educational objectives.

These findings reveal a strong alignment between teaching strategies and effective learning principles but also highlight areas for improvement, such as time allocation for activities and enhanced integration of real-world applications. By addressing these aspects, the course can further strengthen its impact on student learning and preparedness to address environmental challenges.

Relevance to the Sustainable Development Goals (SDGs)

The evaluation of the relevance of the Environmental Chemistry course to the SDGs was conducted by distributing a questionnaire to students. The questionnaire statements are presented in Table 3.

Table 3. Student responses regarding the evaluation of relevance to the SDGs

Item	Statements	Percentage (%)			
		SA	A	D	SD
Focus: Relevance of Course Material to SDGs					
1	I feel that the course material in Environmental Chemistry is aligned with global environmental issues.	61.54	30.77	3.85	3.85
2	This course helps me understand issues such as climate change, pollution, and conservation	57.69	42.31	0.00	0.00
3	The material presented by the lecturer is directly related to several SDG targets, especially in terms of the environment.	19.23	76.92	3.85	0.00
4	I believe that the topics studied are important for supporting environmental sustainability in the future	42.31	50	7.69	0.00
Focus: Understanding and Application of SDGs in Environmental Chemistry					
5	This course enhances my understanding of how chemistry can support the achievement of the SDGs	34.62	61.54	0.00	3.85
6	I have gained a better understanding of local and global environmental issues after taking this course	38.46	53.85	7.69	0.00
7	The lecturer provides real-life examples related to the role of chemistry in addressing global environmental problems.	57.69	42.31	0.00	0.00

Item	Statements	Percentage (%)			
		SA	A	D	SD
8	After taking this course, I understand my role as a student in supporting the SDGs.	26.92	69.23	3.85	0.00
Focus: Impact of the Program on Environmental Attitudes and Awareness					
9	This course motivates me to be more concerned about environmental issues	50	46.15	3.85	0.00
10	I am encouraged to engage in activities or projects that support environmental sustainability	23.08	61.54	15.38	0.00
11	The material studied helps me consider environmental aspects in my daily life.	46.15	53.85	0.00	0.00
12	I feel that this course has increased my awareness of pollution and the conservation of natural resources.	38.46	61.54	0.00	0.00

The questionnaire utilized a Likert scale with the following response options: Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD).

The Environmental Chemistry course has been shown to be highly relevant to global issues and supports the achievement of the SDGs. Based on the survey results, the majority of students (92.31%) agreed that the course materials align with global environmental issues, such as climate change, pollution, and conservation. Furthermore, all respondents agreed that lecturers provided real-world examples of how chemistry can address environmental challenges. However, only 19.23% of students strongly agreed that the materials explicitly connected to specific SDG targets, such as SDG 6 (Clean Water and Sanitation) or SDG 13 (Climate Action). This highlights the need to enhance the emphasis on direct connections between course content and SDG targets. These findings align with studies by Abera (2023), O'Flaherty & Liddy, (2018) and Bilderback, (2024), which suggest that aligning educational content with SDGs enhances the relevance and impact of education on global issues.

The survey also demonstrated that the course positively impacts students' understanding and application of SDGs in their lives. A total of 96.15% of students stated that the course improved their understanding of chemistry's role in supporting SDGs, and 100% felt that real-world examples provided by lecturers were very helpful. However, only 26.92% strongly agreed that the course helped them understand their roles as students in supporting SDGs. Research by Safitri et al. (2024) and Tampubolon & Sipahutar, (2024) indicates that project-based and case-study approaches can help students better understand their roles practically in addressing global issues. Therefore, integrating projects that involve students directly could be a key step to enhancing the course's impact.

The course's impact on students' environmental awareness and attitudes was also significant. A total of 96.15% of students reported being motivated to care more about environmental issues, and 100% stated that the course materials encouraged them to consider environmental aspects in their daily lives. However, only 23.08% were strongly motivated to participate in sustainability projects. This indicates that, while discussion-based approaches are effective, students need hands-on experiences to internalize sustainability values. Hungerford & Volk, (1990) argue that direct experiences through problem-based projects significantly enhance pro-environmental motivation and behavior. Thus, incorporating practical activities, such as waste management or organic fertilizer production, could deepen students' engagement.

There is an opportunity to enhance the relevance and impact of this course through innovative learning approaches. One of the strategies is integrating practice-based projects that align with specific SDG targets, despite challenges such as limited laboratory facilities and funding constraints. Collaborative efforts between universities, governments, industries, and communities can serve as a solution to overcome these obstacles.

Additionally, developing interactive and contextual teaching materials that explicitly link the content to SDGs will help students understand their critical role as agents of change. By implementing these steps, the Environmental Chemistry course will not only foster students' environmental literacy but also contribute to achieving sustainability goals in the future.

Strengths and Challenges of the Program

Discussions on environmental issues in the Environmental Chemistry course are recognized by students as one of the program's main strengths. Students find the materials engaging because they are highly relevant to daily life, connecting theoretical knowledge to real-world pollution issues and their impacts. This approach not only provides theoretical understanding but also insights into solutions and mitigation efforts. Discussion-based learning enables students to share perspectives and ideas, fostering high enthusiasm and engagement. Studies by Aripin et al., (2024) and Suryawati et al. (2020) highlight that discussion-based learning on environmental issues enhances students' environmental awareness and critical thinking skills. This method allows students to develop deeper understanding of environmental problems and how to apply their knowledge in real life.

Student interviews also revealed specific strengths and areas for improvement. When asked about the program's advantages and its facilitation of in-depth and interactive learning students highlighted that discussion-based exploration of environmental issues is the course's primary strength. For example, students suggested incorporating practical projects, such as producing fertilizer from organic waste or conducting direct experiments focused on waste management to address water and soil pollution. While students acknowledged the importance of theoretical knowledge, they emphasized that hands-on experiences in handling environmental issues would deepen their understanding and skills. This view is supported by research from Azrai et al. (2024) and Zahra et al. (2023), which shows that project-based learning not only enhances theoretical understanding but also strengthens students' commitment to concrete environmental actions.

The interviews also uncovered key challenges, such as limited facilities, particularly laboratories and modern analytical tools, which hinder project-based learning and direct practical activities. Additionally, funding constraints pose significant barriers to implementing practical projects, such as organic fertilizer production or waste management initiatives. According to Kolmos et al. (2009), project-based learning enhances student engagement with the material, especially when supported by adequate facilities. To address these challenges, the program could collaborate with industries or related institutions to provide necessary resources. Additionally, developing a curriculum that integrates more practical projects can enhance the effectiveness of learning and student involvement in environmental issues. By involving students in waste reduction projects, they gain not only knowledge but also deep practical experience in addressing environmental challenges. These improvements could further strengthen the Environmental Chemistry course as a platform for fostering sustainability literacy and preparing students as agents of change in environmental preservation.

Product Evaluation

Student Environmental Literacy

Environmental literacy is a crucial competency for students as the next generation responsible for sustaining the environment. Environmental literacy encompasses the ability to understand environmental issues (cognitive), to care about the environment (affective), and to engage in pro-environmental behavior in daily life (behavioral). Students who possess strong environmental literacy are expected to make decisions that support sustainability. Therefore, assessing students' environmental literacy is essential to determine the extent of their knowledge, attitudes, and behaviors that contribute to environmental sustainability, as well as to design more effective educational interventions (Aikowe & Mazancova, 2023; Goulgouti et al., 2019).

The environmental literacy of students is measured using indicators developed based on the research of W.-T. Fang et al. (2023), which were adapted from the works of Hungerford & Tomera (1985), Hungerford & Volk (1990), Hungerford et al. (1990), Liu et al. (2015), Liang et al. (2018), and Cherdymova et al. (2018). The percentage of students' environmental literacy across the cognitive, affective, and psychomotor aspects can be seen in Figure 2.

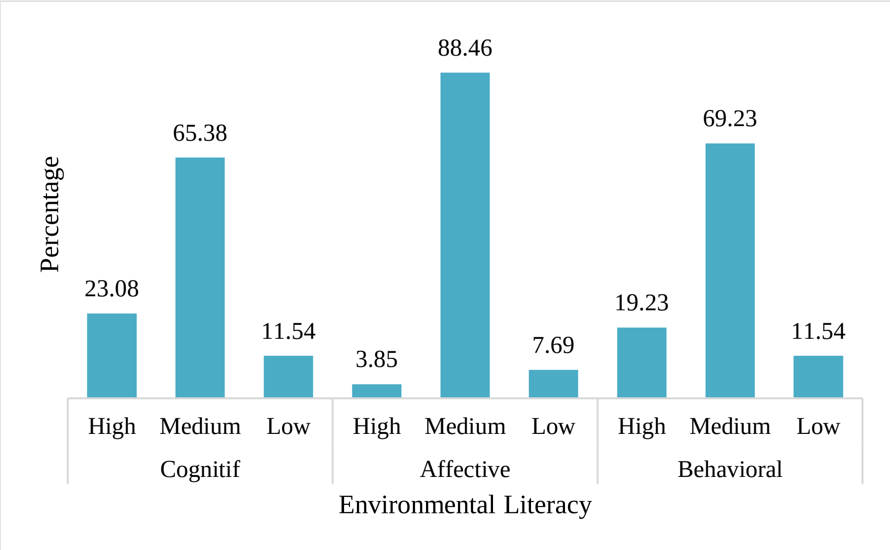

Figure 2. Student environmental literacy percentage

In the cognitive dimension, the majority of students (65.38%) fall into the moderate category, while 23.08% fall into the high category, and 11.54% fall into the low category. This distribution is consistent with the findings of Rachman et al. (2021) and Firmanshah et al. (2023), who found that students' environmental knowledge tends to be at a moderate level due to most of their knowledge being acquired through formal education and media. The learning pattern, which is still dominated by theoretical approaches rather than direct practice, contributes to this condition.

The affective dimension shows the most prominent results, with 88.46% of students in the moderate category, only 3.85% in the high category, and 7.69% in the low category. This finding is consistent with the studies of Müderrisoglu & Altanlar (2011), Berglund et al. (2020) and Kasapoğlu & Turan (2008), which indicate that a positive attitude toward the environment is generally formed among students, though it has not yet reached an optimal level.

In the behavioral dimension, the majority of students (69.23%) fall into the moderate category, with only 19.23% in the high category, and 11.54% in the low category. This data indicates that, although students possess knowledge and concern, this has not fully translated into pro-environmental behavior. According to Ajzen (2020) and the Theory of Planned Behavior, behavior is influenced by intentions, which in turn are influenced by attitudes, subjective norms, and behavioral control. The low implementation of pro-environmental behavior may be due to a lack of external incentives or the absence of facilities that support such behavior, such as recycling bins or sustainability campaigns on campus.

These results show a similar pattern across all three dimensions, with the overall level of student environmental literacy remaining at a moderate level. This condition can be explained by referring to previous studies. Low environmental literacy is often associated with the lack of integration of environmental issues in the curriculum (Arif, 2024), limited hands-on student experience with environmental issues, and insufficient environmental support that encourages pro-environmental behavior.

Based on these results, it is recommended that institutions improve students' environmental literacy through a more holistic approach. The integration of environmental issues into the curriculum should be strengthened to deepen the cognitive aspect. Experience-based programs, such as participation in environmental activities or community projects, can help reinforce the students' affective aspect. Furthermore, universities need to provide supporting facilities, such as recycling stations and green campus programs, to encourage pro-environmental behavior. With these steps, student environmental literacy is expected to improve comprehensively, contributing to the achievement of global sustainability goals.

The Relationship Between Affective and Behavioral Values with Cognitive Values

The analysis begins with a normality test in Table 4 using the Shapiro-Wilk test. This test aims to determine whether the residuals of the regression model are normally distributed, which is an important assumption in linear regression analysis. With a sample size of 26, and an Asymp. Sig. (p-value) of 0.284 > 0.05, it can be concluded that the residuals are normally distributed. This indicates that the normality assumption in the regression analysis has been met, allowing the regression model to be interpreted as valid and the results to be reliable (see Table 4).

Table 4. Shapiro-Wilk test result

	Unstandardized Residual
N	26
Test Statistic	0.954
Asymp. Sig. (2-tailed)	0.284

Table 5. Correlation regression coefficient

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
	B	Std. Error	Beta		
(Constant)	34.13	17.06		2.00	0.057
Affective	0.763	0.314	0.708	2.43	0.023
Behavioral	-0.311	0.287	-0.315	-1.08	0.290

a. Dependent Variable: Cognitive

Table 5 shows the results of the linear regression coefficients, which indicate the relationship between the affective and behavioral variables with cognitive outcomes. From the data, the multiple linear regression equation can be derived as follows: $Y = 34.13 + 0.763X_1 - 0.311X_2$. The constant value of 34.13 suggests that if there is no contribution from the affective and behavioral variables (i.e., both values are zero), the predicted cognitive value would be 34.13. The coefficient for the affective variable is 0.763, indicating that for each one-unit increase in the affective variable, the cognitive score is expected to increase by 0.763 units, assuming the behavioral variable remains constant. The p-value of 0.023 (< 0.05) indicates that this relationship is statistically significant, suggesting that affective factors such as motivation, interest in learning, and positive emotions play a significant role in enhancing students' cognitive abilities.

On the other hand, the coefficient for the behavioral variable is -0.311, which indicates a negative relationship. For each one-unit increase in the behavioral variable, the cognitive score tends to decrease by 0.311 units. However, the p-value of 0.290 (> 0.05) indicates that this relationship is not statistically significant, meaning that the behavioral influence on cognitive outcomes in this model is not strong enough to be considered reliable.

Table 6. ANOVA test result

Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	1939.91	2	969.954	3.837	.036[b]
Residual	5813.94	23	252.780		
Total	7753.85	25			

a. Dependent Variable: Cognitive
b. Predictors: (Constant), Behavioral, Affective

Table 7. summary of linear regression results

R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
.500[a]	.250	.185	15.899

a. Predictors: (Constant), Behavioral, Affective
b. Dependent Variable: Cognitive

The results of the ANOVA test (Table 6) support the validity of this model, with an F value of 3.837 and a p-value of 0.036 (< 0.05). This indicates that, overall, the affective and behavioral variables have a significant impact on cognitive outcomes, even though the behavioral variable does not have a significant effect individually. In Table 7, the R^2 value of 0.250 indicates that only 25% of the variation in cognitive outcomes can be explained by these two variables, while the remaining variation is influenced by other factors outside of the model. The smaller Adjusted R^2 value of 0.185 suggests that the model can still be improved by adding other relevant variables, such as learning strategies, social support, or the learning environment.

The analysis highlights the importance of strengthening the affective dimension to support environmental literacy in the cognitive aspect. The affective variable, which reflects students' motivation, interest, and emotional attitudes toward environmental issues, significantly influences their cognitive mastery. Therefore, higher education instructors should develop teaching strategies that prioritize enhancing students' affective dimensions. For example, through project-based learning activities that focus on real-world environmental issues or by using a socio-scientific issues-based approach to raise students' emotional awareness of environmental problems. On the other hand, the behavioral variable, which reflects students' concrete actions toward the environment, does not show a significant impact on the cognitive aspect. This suggests that students' environmental behaviors may not directly influence their knowledge acquisition but are rather a reflection of their understanding and attitudes. Therefore, higher education institutions are encouraged to further evaluate how students' behaviors can be encouraged through integrative approaches, such as field-based practical activities, community work, or simulations that combine cognitive, affective, and behavioral aspects.

Moreover, the model used in this study only accounts for 25% of the variation in students' environmental literacy in the cognitive aspect. This suggests that many other factors, such as learning styles, personal experiences, or institutional support, may also influence students' environmental literacy. Therefore, institutions are encouraged to conduct further research that includes additional variables to gain a more comprehensive understanding of students' environmental literacy. Higher education institutions can strengthen the curriculum focused on environmental literacy by providing training for instructors to apply innovative teaching methods. The implementation of these recommendations is expected to support the holistic development of students' environmental literacy, ensuring that they not only possess adequate knowledge but also the attitudes and actions necessary to support environmental sustainability.

CONCLUSIONS

The Environmental Chemistry curriculum in higher education is aligned with national policies (SN-Dikti) and supports the development of students' competencies in addressing global environmental issues and sustainability. However, challenges related to limited facilities and funding impact the effectiveness of the course in enhancing students' awareness and skills regarding global environmental concerns. The experience and competence of lecturers, as well as the availability of laboratory facilities, play a crucial role in the success of the program. The integration of project-based practices into Environmental Chemistry education has been shown to improve students' understanding of environmental issues and contribute to achieving the SDGs. Additionally, the inclusion of environmental issues in the curriculum positively impacts the cognitive, affective, and pro-environmental behavioral dimensions of students. Other factors, such as involvement in environmental projects and cross-sector collaboration, also influence students' environmental literacy and support pro-environmental actions, with interactions between these factors strengthening students' awareness and sustainability actions. Despite these efforts, students' environmental literacy remains at a moderate level, with cognitive, affective, and behavioral aspects interconnected yet not fully optimized. The affective dimension has a significant impact on enhancing students' knowledge of environmental issues, while pro-environmental behavior does not directly influence knowledge. This study recommends integrating hands-on experiences and project-based activities into the curriculum, as well as enhancing the support facilities that foster pro-environmental behavior. Higher education institutions should strengthen the environmental literacy curriculum and involve students in activities that foster awareness and tangible actions related to sustainability.

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