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Cultivating Sustainable Practices: Integrating Green Chemistry' in the Course of Chemistry and Laboratories Curriculum

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Abstract:
integrating green chemistry principles into the chemistry and laboratory curriculum is vital for fostering sustainable practices among future chemists. By incorporating these principles, students acquire the knowledge and skills needed to create environmentally friendly solutions, minimize the use of hazardous substances, and mitigate the environmental impact of chemical processes. Educators play a crucial role in implementing green chemistry practices, ensuring that upcoming generations of chemists are equipped with the necessary tools to tackle global challenges in a sustainable manner
This study aimed to potential Integrating and challenges of the 'Green Chemistry' in the Course of Chemistry and Laboratories Curriculum for fostering sustainable practices.
In order to achieve the study goals, a questionnaire was designed and distributed to 66 Chemistry faculty members and laboratories engineering at Islamic Alsmarya University.
The finding highlights the need for increased focus and emphasis on incorporating green chemistry principles into laboratory settings. By providing opportunities for students to work with green chemistry concepts, they can gain firsthand experience and understanding of the principles and practices involved. This exposure can contribute to shaping their perception of green chemistry and its importance in sustainable and environmentally conscious scientific practices.

Keywords: Sustainable Practices, Green chemistry, Chemical Laboratories, Curriculum.

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تعزيز الممارسات المستدامة: دمج الكيمياء الخضراء في مقرر ومعامل الكيمياء

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الملخص
يعد دمج مبادئ الكيمياء الخضراء في مناهج الكيمياء والمختبرات أمراً حيوياً لتعزيز الممارسات المستدامة بين الكيميائيين المستقبليين. ومن خلال دمج هذه المبادئ، يكتسب الطلاب المعرفة والمهارات اللازمة لإنشاء حلول صديقة للبيئة، وتقليل استخدام المواد الخطرة، وتخفيف التأثير البيئي للعمليات الكيميائية. يلعب المعلمون دوراً حاسماً في تنفيذ ممارسات الكيمياء الخضراء، مما يضمن تزويد الأجيال القادمة من الكيميائيين بالأدوات اللازمة لمواجهة التحديات العالمية بطريقة مستدامة

تهدف هذه الدراسة إلى الدمج المحتمل والتحديات التي تواجه "الكيمياء الخضراء" في مقرر الكيمياء والمختبرات الدراسية لتعزيز الممارسات المستدامة.
ولتحقيق أهداف الدراسة تم تصميم استبانة وتوزيعها على 66 عضو هيئة التدريس في قسم الكيمياء وهندسة المختبرات في الجامعة الإسلامية السمرية.
تسلط هذه النتيجة الضوء على الحاجة إلى زيادة التركيز والتأكيد على دمج مبادئ الكيمياء الخضراء في إعدادات المختبر. من خلال توفير الفرص للطلاب للعمل مع مفاهيم الكيمياء الخضراء، يمكنهم اكتساب خبرة مباشرة وفهم للمبادئ والممارسات المعنية. يمكن أن يساهم هذا التعرض في تشكيل تصورهم للكيمياء الخضراء وأهميتها في الممارسات العلمية المستدامة والواعية بيئياً.

الكلمات المفتاحية: الممارسات الاستدامة، الكيمياء الخضراء، معامل العلوم، مقرر الدراسي.

Introduction

Green chemistry, also known as sustainable chemistry, is a scientific methodology that focuses on the development of chemical processes and products with the primary goal of minimizing their negative effects on the environment and human health. It is a proactive and preventative approach that seeks to promote sustainability by reducing or eliminating the use and production of hazardous substances during chemical processes [1]. The concept of green chemistry is a comprehensive framework of twelve principles developed by chemists Paul Anastas and John Warner. These principles serve as the foundation for developing, advancing, and implementing environmentally responsible chemical processes and products [2].

Green chemistry education provides a solution to our current environmental problems by training future scientists and political leaders, thereby helping us move toward a more sustainable society. Green chemistry, while becoming more common in today's curricula, has seen the most widespread adoption in the chemical laboratory. Only recently has the introduction of green chemistry principles into first-year chemistry courses been addressed. This is despite the fact that such education should be consistent throughout a student's chemistry curriculum, beginning with the foundational courses. Successful case studies and examples of incorporating green chemistry into first-year lecture and laboratory sessions will be discussed.

Green chemistry principles:

Green chemistry principles provide a comprehensive framework for developing and implementing chemical processes and products that prioritize sustainability. Developed by chemists Paul Anastas and John Warner, these principles serve as valuable guidelines to reduce environmental impact and advance sustainability within the field of chemistry [3].

1. Pollution Prevention: The first principle of green chemistry emphasizes the need to prevent pollution at its source. It encourages the design of chemical processes and products that produce minimal or no waste, reducing the need for treatment or disposal.
2. Atom Economy: The concept of atom economy relates to the efficiency of chemical reactions. It promotes the use of reactions that maximize the incorporation of all starting materials' atoms into the desired products, minimizing waste production.
3. Less Hazardous Chemical Syntheses: The second principle of green chemistry emphasizes the development of synthetic methods that minimize or eliminate the utilization of toxic and hazardous substances. It promotes the adoption of alternative, safer reagents, and reaction conditions.
4. Designing Safer Chemicals: The principle of designing safer chemicals emphasizes the creation of chemicals that exhibit reduced toxicity to both humans and the environment. It encourages the development of substances with lower inherent hazards while still retaining their desired functionality.
5. Safer Solvents and Auxiliaries: The principle of selecting safer solvents and auxiliary substances underscores the significance of choosing environmentally benign options that minimize hazards. It advocates for the utilization of non-toxic, renewable, and sustainable alternatives.
6. Design for Energy Efficiency: Green chemistry principles promote the design of chemical processes that prioritize energy efficiency. This principle encourages the use of energy-efficient reactions, separation techniques, and process conditions to minimize overall energy consumption.
7. Use of Renewable Feedstocks: The utilization of renewable feedstocks is a fundamental principle of green chemistry. It entails integrating renewable, sustainable, and bio-based

materials as substitutes for fossil fuel-based resources, thereby reducing reliance on limited and non-renewable resources.

8. Reduce Derivatives: The principle of minimizing or eliminating unnecessary derivatives in chemical processes advocates for reducing waste generation and mitigating the environmental impact associated with the synthesis and disposal of derivatives. It emphasizes the importance of streamlining chemical reactions and processes to minimize the use of unnecessary intermediate steps.
9. Catalysis: Catalysis plays a crucial role in green chemistry, highlighting the importance of using catalysts to improve the efficiency of chemical reactions. Catalysts enable reactions to take place under gentler conditions, resulting in shorter reaction times and reduced energy and resource consumption.
10. Design for Degradation: In line with the principles of green chemistry, there is a focus on designing chemical products that have the ability to undergo easy degradation after use. This approach aims to reduce the environmental impact by minimizing the presence and persistence of these products in the environment. The emphasis is placed on developing products that can decompose into non-toxic substances, highlighting the significance of sustainability and safety.
11. Real-time Analysis for Pollution Prevention: The principle of real-time monitoring and control emphasizes the significance of integrating advanced analytical technologies to continuously track and regulate processes. This approach underscores the importance of timely and accurate data acquisition, enabling proactive decision-making and optimization of operations techniques to prevent the formation of hazardous substances during chemical processes. It emphasizes the integration of proactive measures to identify and address potential pollution sources, ensuring the continuous improvement of process safety and environmental impact.
12. Inherently Safer Chemistry for Accident Prevention: The principle of inherently safer chemistry prioritizes the development of chemical processes and products that inherently possess safety features, aiming to minimize the potential for accidents and the release of hazardous materials. This principle underscores the early consideration of safety aspects during the design phase, ensuring that safety is integrated throughout the entire lifecycle of the process or product. By incorporating built-in safety features, the risk associated with these chemicals is reduced, promoting a safer and more sustainable approach.
13. Risk Assessment and Reduction: Inherently safer chemistry involves conducting thorough risk assessments to identify potential hazards and risks associated with chemical processes and products. By understanding the risks involved, steps can be taken to reduce or eliminate them through design modifications or alternative approaches. Continuous Improvement: The principle promotes a culture of continuous improvement and learning from incidents and near misses. By conducting thorough investigations and implementing corrective actions, organizations can continually enhance the safety of their chemical processes and products.
14. Training and Education: Inherently safer chemistry emphasizes the importance of training and educating personnel involved in chemical processes. By ensuring that operators and workers are knowledgeable about the hazards, risks, and safety measures, the likelihood of accidents and incidents can be significantly reduced.
15. Continuous Improvement: The principle emphasizes the importance of fostering a culture of continuous improvement and learning from incidents and near misses. By conducting in-depth investigations and taking corrective actions, organizations can consistently enhance the safety of their chemical processes and products. This approach involves actively seeking opportunities to identify and address vulnerabilities, implementing necessary changes, and incorporating lessons learned into future practices. By prioritizing ongoing improvement and proactive measures, organizations can create a safer environment, reduce risks, and promote the well-being of all stakeholders involved.

Enhanced Student Engagement and Learning Outcomes:

Incorporating green chemistry principles in the classroom has a positive impact on student engagement and motivation. By connecting chemical concepts to real-world environmental issues, students develop a deeper understanding of the relevance and practical application of their knowledge. Green chemistry encourages critical thinking and problem-solving skills as students explore eco-friendly alternatives, analyze environmental impacts, and propose sustainable solutions. Studies have shown that students

who learn through green chemistry approaches demonstrate improved learning outcomes and a greater awareness of sustainability issues [10].

Personal and Professional Growth:
The integration of green chemistry principles in teaching also benefits educators themselves. By embracing green chemistry, teachers enhance their professional growth and expand their knowledge base. Engaging with sustainable practices and staying updated on the latest advancements in green chemistry fosters ongoing learning and professional development. Educators who incorporate green chemistry principles often report a sense of fulfillment and personal satisfaction in contributing to a more sustainable future [11].

Material and methods:
This study employed a qualitative research method with a descriptive design [4]. The research utilized a questionnaire comprising 37 questions administered to 66 Faculty members eho teaching Chemistry Courses and Laboratories Engineers across different faculties, namely the Faculty of Science and the Faculty of Education at Alasmarya Islamic University. The questionnaire included 37 questions, with each question corresponding to one of the 15 green chemistry principles and other separated question regarding potential application of green chemistry in chemistry courses and laboratories. Each principle was represented by three questions. The questionnaire was designed as a 5 Likert scale, with three answer choices and scores ranging from 1 to 5, reflecting the participants' perceptions of the application of green chemistry principles in each question. The collected data were analyzed and tabulated using the Statistical Package for Social Science (SPSS), Version 24.

Results and discussion
Green chemistry has been applied in various studies related to chemistry education, serving as an important tool in promoting Education for Sustainable Development (ESD) and achieving the Sustainable Development Goals (SDGs) [5]. The principles of green chemistry [6][7] are being applied across different fields of chemistry, including organic, analytical, biochemical, and others. In the realm of chemistry education, green chemistry has started to find its place in the curriculum of both secondary and higher education levels. As a result, the term "green chemistry" is no longer unfamiliar, although some students may still have limited understanding of its meaning [8].
To assess the application of green chemistry, a questionnaire was developed carefully read each question and select the most appropriate response based on the 15 principles of green chemistry. Each principle was represented by five answers according to the principal application focusing on the application of green chemistry principles in laboratory work and daily activities. The questionnaire provided five answer choices for each question, with scores ranging from 1 to 5. A score of 1 indicated very little application of the green chemistry principle, a score of 2 indicated little application, a score of 3 indicated moderate application, and a score of 4 indicated high application and score of 5 indicated very high application.

Table 1. The Average Number of Respondents from whole score each green chemistry principle.

SN.	Grean Chemistry Principles	Very Little Application	Little Application	Moderate Application	High Application	Very high Application	Average	Rank
1.	Pollution Prevention	10	31	15	2	8	**2.21**	7
2.	Atom Economy	13	29	11	6	7	**2.24**	6
3.	Less Hazardous Chemical Syntheses	4	6	22	8	26	**1.83**	12
4.	Designing Safer Chemicals	27	11	8	6	14	**3.14**	1

5.	Safer Solvents and Auxiliaries	26	15	12	6	7	**2.52**	2
6.	Design for Energy Efficiency	34	14	10	2	6	**1.98**	9
7.	Use of Renewable Feedstocks	21	18	15	8	4	**2.06**	8
8.	Reduce Derivatives	12	30	9	4	11	**1.86**	11
9.	Catalysis	14	29	6	8	9	**2.26**	4
10	Design for Degradation	26	14	18	6	2	**2.38**	3
11	Real-time Analysis for Pollution Prevention	25	18	6	11	6	**1.41**	15
12	Inherently Safer Chemistry for Accident Prevention	23	12	6	11	14	**1.50**	14
13	Risk Assessment and Reduction	31	16	4	7	8	**2.26**	4
14	Training and Education	39	15	5	4	3	**1.94**	10
15	Continuous Improvement	28	13	9	11	5	**1.52**	13
Average							**1.97**	

Table 1 shows that the highest number of respondents who do moderate application of Green Chemistry is the fourth principle (Designing Safer Chemicals) with an average (3.14). The next higher number of respondents shows who do little Application of Green Chemistry the fifth principle (Safer Solvents and Auxiliaries) with average (2.52), the third higher number of respondents shows who do little application of Green Chemistry is the tenth principle (Design for Degradation) with average (2.38). The lowest number of respondents shows who do very little Application of Green Chemistry is the eleventh principle (Real-time Analysis for Pollution Prevention) with an average (1.41).

The responses to the questionnaire revealed that, in general, the respondents had a negative perception of the low application of green chemistry in their daily lives and laboratory work with an average (1.98).

Potential application of green chemistry and daily activities:

1. **How familiar are you with the concept of green chemistry?**

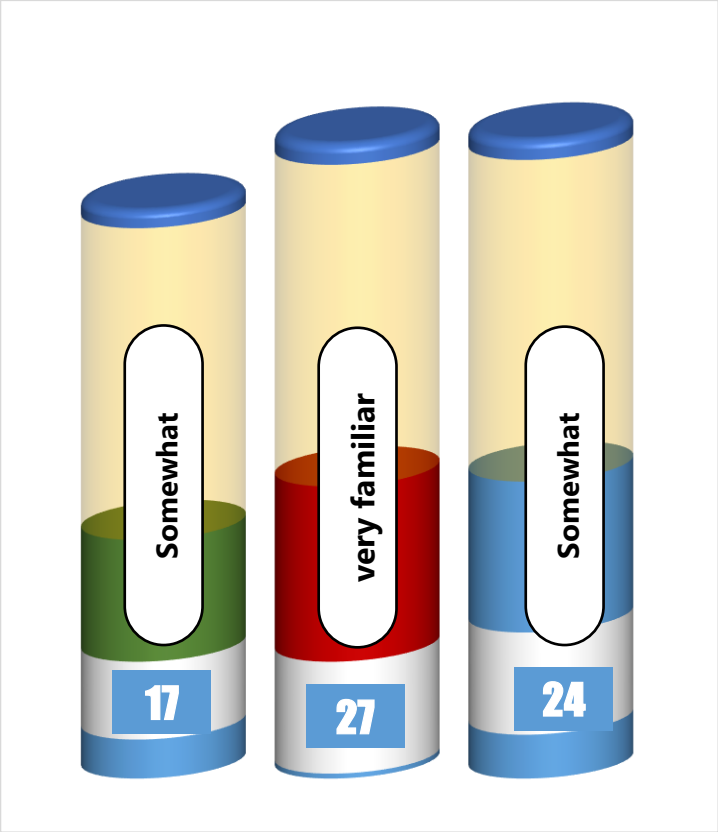

Figure1. Familiarity with the concept of green chemistry.

Figure 1 shows that the majority of the respondents (48%) are somewhat familiar with the concept of green chemistry, 35% of the respondents are very familiar, and only 17% of them are not familiar.

2. **In your opinion, what are the key benefits of integrating green chemistry principles in teaching and laboratory practices? (Select all that apply)?**

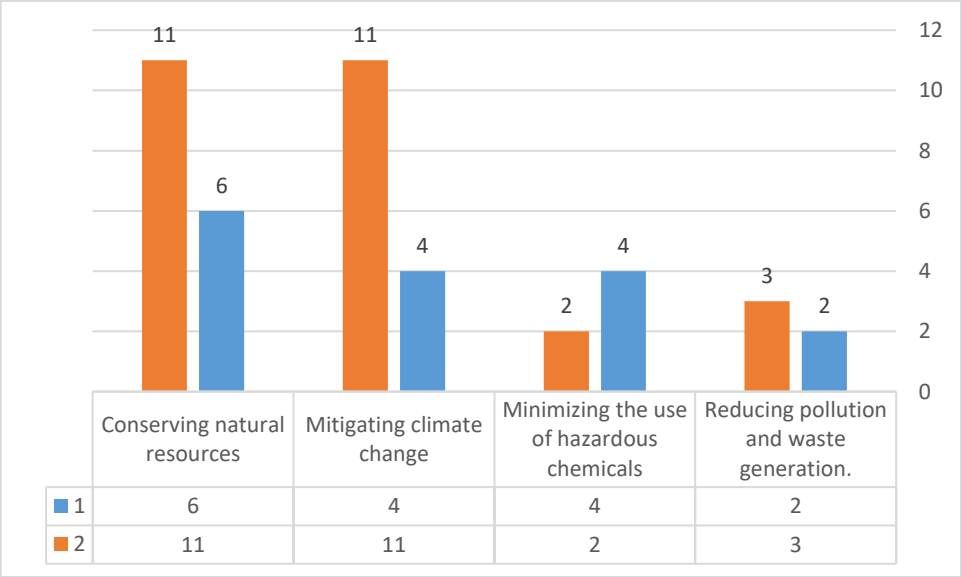

Figure 2. Benefits of integrating green chemistry principles in teaching and laboratory practices.

As seen in figure 2, 24% of respondents said that the benefits of integrating green chemistry principles is reduced environmental impact, 27% of respondents said Safer and healthier learning environment, 11% of the respondents said Enhanced student engagement and critical thinking, and 32% of the respondents said is the cost savings.

3. How do you involve students in the decision-making process when it comes to implementing green chemistry practices in the classroom or laboratory?

Table 2. students' involvement in the decision-making process when it comes to implementing green chemistry practices in the classroom or laboratory.

No	Item	Very Little Application	Little Application	Moderate Application	High Application	Very High Application	Average	Rank
1.	Encouraging students to suggest and explore green alternatives to traditional lab procedures.	1	2	3	4	5	2.56	2
2.	Incorporating student input in the selection of eco-friendly materials and chemicals.	18	14	19	9	6	2.20	4
3.	Involving students in discussions and decision-making related to waste reduction and recycling.	23	19	15	6	3	2.42	3
4.	Allowing students to propose and implement sustainable practices in the classroom	21	15	17	7	6	2.92	1
Average							**2.53**	

Table 2 indicated that Allowing students to propose and implement sustainable practices in the classroom was the higher score with an average (2.92), next Encouraging students to suggest and explore green alternatives to traditional lab procedures.
with an average (2.56), the third higher score was for the application (Involving students in discussions and decision-making related to waste reduction and recycling.) with an average (2.42), the lowest score

according to the respondents was for (Incorporating student input in the selection of eco-friendly materials and chemicals.) with an average (2.20).
in general, the over average score to all student's involvement in the decision-making process when it comes to implementing green chemistry practices in the classroom or laboratory was low application with an overall average (2.53).

4. Have you previously been exposed to or worked with green chemistry concepts in a laboratory setting?

Table 3. previously been exposed to or worked with green chemistry concepts in a laboratory setting.

No	Item	Very Little Application	Little Application	Moderate Application	High Application	Very High Application	Average	Rank
1.	Yes, I have conducted green chemistry experiments or projects.	22	29	8	3	4	2.06	1
2.	I have heard about green chemistry but have not had the opportunity to work with it in a laboratory.	23	28	9	2	4	2.03	2
3.	I have not been exposed to green chemistry in a laboratory setting.	37	14	8	7	0	1.77	3
Average							**1.95**	

Table 3 indicated that the item (Yes, I have conducted green chemistry experiments or projects) was the higher score with an average (2.06), next item was for (I have heard about green chemistry but have

not had the opportunity to work with it in a laboratory) with an average score (2.03), the lowest score for the item (I have not been exposed to green chemistry in a laboratory setting) with an average (1.77). in general, the average score to previously been exposed to or worked with green chemistry concepts in a laboratory setting was low application with an average (1.95).

5. How do you think the implementation and integration of green chemistry in the course of chemistry can enhance your learning experience?

Table 4. The implementation and integration of green chemistry in the course of chemistry can enhance your learning experience.

No.	Item	Very Little Application	Little Application	Moderate Application	High Application	Very High Application	Average	Rank
1.	It can provide a more sustainable and environmentally friendly approach to chemistry.	26	24	8	3	5	2.05	1
2.	It can help me understand the impact of chemical processes on the environment.	36	19	4	5	1	1.68	3
3.	I am not sure how green chemistry can enhance my learning experience.	33	27	1	2	3	1.71	2
Average							**1.81**	

Table 4 indicated that the item (It can provide a more sustainable and environmentally friendly approach to chemistry) was the higher score with an average (2.06), next item was for (I am not sure how green chemistry can enhance my learning experience) with an average score (1.71), the lowest score for the item (It can help me understand the impact of chemical processes on the environment) with an average

(1.68). in general, the average score to implementation and integration of green chemistry in the course of chemistry can enhance your learning experience was low application with an average (1.81).

6. In which specific areas of chemistry do you believe green chemistry principles should be integrated?

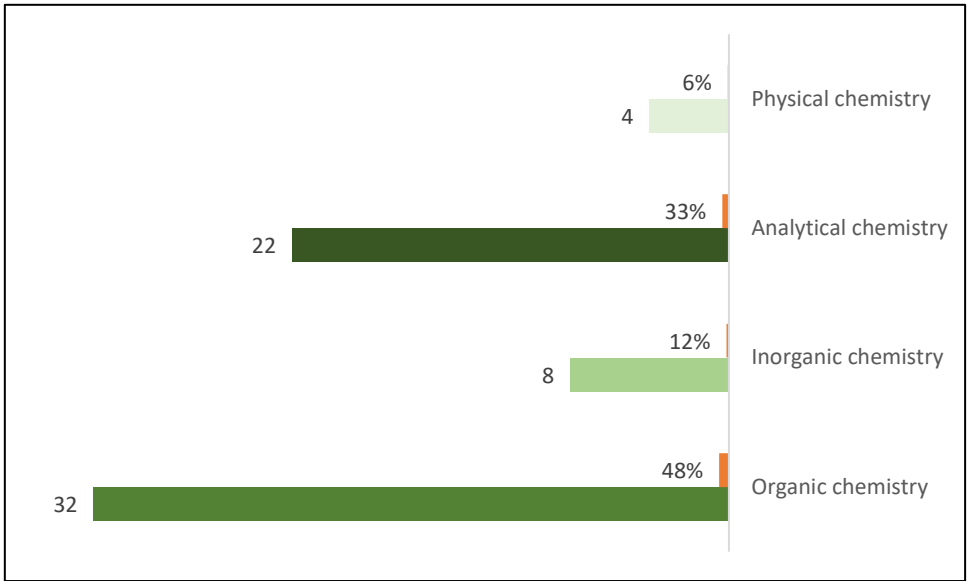

Figure 3. Specific areas of green chemistry principles should integrate.

Figure 3 shows that 48% of the respondents said that Organic Chemistry was the most specific areas of chemistry do you believe green chemistry principles should be integrated, 33% said Analytical Chemistry, while 12% of the respondents said Inorganic Chemistry, and only 6% of the respondent said Physical Chemistry is the specific areas of green chemistry principles should integrate.

7. What challenges or concerns do you foresee in implementing and integrating green chemistry principles in the laboratory and course?

Table 5. The challenges or concerns do you foresee in implementing and integrating green chemistry principles in the laboratory and course.

No.	Item	Very Little Application	Little Application	Moderate Application	High Application	Very High Application	Average	Rank
1.	Limited availability of green chemistry resources and materials	4	2	12	19	29	4.02	2
2.	Resistance to change from traditional chemistry approaches	8	10	8	12	28	3.64	3
3.	Lack of knowledge and training on green chemistry principles	4	2	1	26	33	4.24	1
Average							**3.96**	

Table 5 illustrated that the Lack of knowledge and training on green chemistry principles was the most important challenges or concerns do the respondents foresee in implementing and integrating green

chemistry principles in the laboratory and course with the higher score of (4.24), the next higher challenges was for Limited availability of green chemistry resources and materials waith an average (4.02), the lowest expected challenges is the Resistance to change from traditional chemistry approaches with score of (3.64).
In general, the overall average of the challenges or concerns do the respondents foresee in implementing and integrating green chemistry principles in the laboratory and course was (3.96).

8. In your opinion, what are the key environmental challenges that can be addressed through the application of green chemistry principles?

Table 6. The key environmental challenges that can be addressed through the application of green chemistry principles.

No.	Item	Very Little Application	Little Application	Moderate Application	High Application	Very High Application	Average	Rank
1.	Reducing pollution and waste generation.	2	3	9	21	31	4.15	3
2.	Minimizing the use of hazardous chemicals	4	2	1	23	36	4.29	1
3.	Mitigating climate change	4	11	8	16	25	3.62	5
4.	Conserving natural resources	6	11	8	16	25	3.65	4
5.	Promoting sustainable energy production.	4	2	1	26	33	4.24	2
Average							**4.02**	

As seen in table 6 illustrated that the highest score of the key environmental challenges that can be addressed through the application of green chemistry principles was for the minimizing the use of hazardous chemicals with an average (4.29), next was for Promoting sustainable energy production with an average (4.24), the third higher score was for reducing pollution and waste generation with an average (4.15), the forth higher score was for the Conserving natural resources with an average of (3.65), and the lowest score was for mitigating climate change with an average (3.62). in general, the key environmental challenges that can be addressed through the application of green chemistry principles was high with an average score of (4.02). This high average score suggests that respondents acknowledged the potential of green chemistry to contribute to environmental sustainability and mitigate environmental issues.

Conclusion:
Integrating green chemistry principles in the course of chemistry and laboratory curriculum is essential for cultivating sustainable practices among future chemists. By incorporating these principles, students gain the knowledge and skills necessary to develop environmentally friendly solutions, minimize the use of hazardous substances, and reduce the environmental impact of chemical processes. Educators

play a crucial role in implementing green chemistry practices, ensuring that future generations of chemists are equipped with the tools to address global challenges sustainably.

1. The study findings indicated a prevalent negative perception among respondents regarding the limited application of green chemistry in their daily lives and laboratory work, with an average score of 1.98.
2. The average score for students' involvement in the decision-making process regarding the implementation of green chemistry practices in the classroom or laboratory was relatively low, with an average of 2.53.
3. 48% identified Organic Chemistry as the most specific area of chemistry where green chemistry principles should be integrated. Analytical Chemistry was mentioned by 33% of the respondents, while 12% believed Inorganic Chemistry should incorporate green chemistry principles. Interestingly, only 6% of the respondents indicated Physical Chemistry as the specific area where green chemistry principles should be integrated. These findings suggest that Organic Chemistry and Analytical Chemistry are perceived as the most suitable areas for the application of green chemistry principles, while Inorganic Chemistry and Physical Chemistry are considered less relevant. The results emphasize the importance of integrating green chemistry principles in organic and analytical chemistry curricula to cultivate sustainable practices among future chemists. Further research and initiatives are needed to explore effective strategies for integrating green chemistry principles into these specific areas of chemistry.
4. The average score of 3.96 indicates that respondents have significant concerns and foresee challenges in implementing and integrating green chemistry principles in the laboratory and course. These concerns likely reflect the complexities and obstacles associated with adopting sustainable practices in chemistry education.
5. The average score of 4.02 indicates that respondents recognized the importance of addressing key environmental challenges through the application of green chemistry principles.

References:

[1] Warner J Benny, (2020), Green chemistry Environ. Journal of Sustainable Development, 7–8 p. 675–699.

[2] Josephson P Nykvist V Qasim W Blomkvist B and DInér P, 2019 Student-Driven Development of Greener Chemistry in Undergraduate Teaching: Synthesis of Lidocaine Revisited J. Chem. Educ. 96 p. 1389–1394.

[3] Anastas, P. T., & Warner, J. C. (2021). Green chemistry: theory and practice. 3rd edition, Oxford University Press.

[4] Creswell J W, 2012 Educational research: Planning, conducting, and evaluating quantitative and qualitative research 4 New York: Pearson.

[5] UNESCO, 2017 UNESCO moving forward the 2030 Agenda for Sustainable Development United Nations Educ. Sci. Cult. Organ. p. 22.

[6] Shri Dikshanya K N, Priadharshni P, Karthikeyan N S, Karthikeyan S, Kumar M & Ravichandran C, 2016 Pricniples & Trends in Green Chemistry p. 209–221.

[7] Eilks I, 2015 Science education and education for sustainable development - justifications, models, practices and perspectives Eurasia J. Math. Sci. Technol. Educ. 11, 1 p. 149–158.

[8] Welton T, 2015 Solvents and sustainable chemistry Proc. R. Soc. A Math. Phys. Eng. Sci. 471, 2183.

[9] Sharma S R, 2015 Green Chemistry, Green Solvents and Alternative Techniques in Organic Synthesis SONALI R. SHARMA Green Chemistry, Green Solvents and Alternative Techniques in Organic Synthesis Int. J. Chem. Phys. Sci. 4 p. 2319–6602. [23] Kale A, 2015 Green Synthesis of Benzoin Derivatives Using Coenzyme Catalyzed Benzion Condensation April p. 62–64.