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Teachers' perception and attitude toward the integration of green chemistry principles in the school curriculum

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Abstract

As the world is undergoing unprecedented environmental challenges and issues, the application of green chemistry can be considered a major move toward reducing the harmful impacts on the environment. It is essential to include green chemistry in the school curriculum to create a generation, that is aware of sustainable development. This study aims to determine the perception and attitude of teachers in integrating green chemistry principles into the school curriculum. A questionnaire was used to collect information from teachers working in various schools. The collected data was analyzed and interpreted. The study proves that teachers have a positive attitude towards including green chemistry as a part of the curriculum. They prefer getting trained in this arena, as they believe they play a key role in imparting knowledge to children about sustainability practices.

Keywords: Green Chemistry; Curriculum; Sustainability; Attitude

1. Introduction

Green Chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products.

Green Chemistry is also known as "Sustainable Chemistry". It aims at reducing the use of hazardous substances. Green Chemistry represents two components; Effective usage of raw materials and elimination of waste produced during manufacturing processes. According to scientists Green Chemistry allows chemists to create a more sustainable world. The International Pure and Apply Chemistry (IUPAC) defines Green Chemistry as the invention, design, and application of chemical products and processes to reduce or eliminate the use and generation of harmful substances.

1.1. Evolution of Green Chemistry:

Green Chemistry provides a unique forum for the publication of innovative research on the development of alternative green and sustainable technologies[4]. The scope of Green Chemistry is based on scientific advancements that can be made based on the twelve principles of green chemistry (Anastas & Beach, 2007).

In 1998, Paul Anastas and John Warner published the first manual of Green Chemistry, in which they proposed 12 principles for Green Chemistry. The 12 principles for Green Chemistry are;

- Prevention
- Atom Economy
- Less Hazardous Chemical syntheses
- Designing Safer Chemicals

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- Safer Solvents and Auxiliaries
- Design for Energy Efficiency
- Use of Renewable Feedstocks
- Reduce Derivatives
- Catalysis
- Design for Degradation
- Real -Time Analysis for Pollution Prevention
- Inherently Safer Chemistry for Accident Prevention

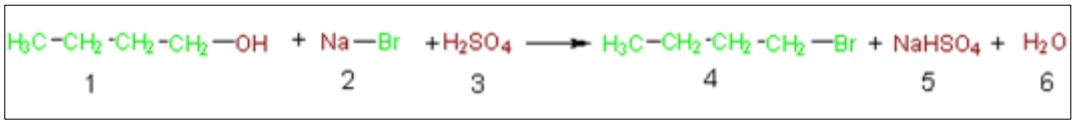
1.2. The 12 Principles of Green Chemistry

1.2.1. Prevention

Prevention of hazardous waste generation through the usage of green chemistry can solve many of the environmental issues. Prevention at the source is better than treatment after the generation of waste.

1.2.2. Atom Economy

Design synthetic methods to maximize the incorporation of all materials used into the final product. To calculate % atom economy we must follow the following steps



% Atom Economy = (FW of atoms utilized/FW of all reactants) X 100

1.2.3. Less Hazardous Chemical Syntheses:

Synthetic methods should be used to generate substances that possess little or no toxicity to the environment.

1.2.4. Designing Safer Chemicals:

The chemical products should be designed in such a way that it is able to preserve the efficacy of function while reducing toxicity.

1.2.5. Safer Solvents and Auxiliaries:

The fifth principle of green chemistry holds that the use of auxiliary substances such as solvents should be made unnecessary wherever possible and innocuous when used.

1.2.6. Design For Energy Efficiency:

Energy requirements should be recognized for their environmental and economic impacts and should be minimized.

1.2.7. Use Of Renewable Feedstocks:

The usage of renewable feedstocks rather than depletable feedstocks should be encouraged. Renewable feedstocks are often agricultural products or wastes formed from other processes.

1.2.8. Reduce Derivatives:

Temporary modification of physical or chemical processes should be avoided because they require additional reagents and can generate waste

1.2.9. Catalysis:

We can minimize waste through catalytic reactions. They are effective in small amounts and carry a single reaction many times.

1.2.10. Design for Degradation:

Chemical products should be designed in such a way that the products degrade after their function so that they break down in such a way forming an innocuous degradation and not accumulate in their environment

1.2.11. Real-Time Analysis for Pollution Prevention:

Analytical methodologies need to be further developed to control the formation of hazardous substances.

1.2.12. Inherently Safer Chemistry for Accident Prevention:

Substances used in chemical processes should be chosen to minimize the potential for chemical accidents and explosions

1.3. Applications of Green Chemistry

Green chemistry is widely used in the chemical, pharmaceutical, paper, polymer, clothes, and colour industries. It is also used in different energy science, and the manufacture of innovative techniques to make solar cells, fuel cells, and batteries for storing energy. In nanoscience and technology, green chemistry is also highly used. The main goal of green chemistry is to minimize or eliminate waste in the chemical industry, hence it has inspired the creation of many green "next-generation" catalysts.

Many entrepreneurs are venturing into Green chemistry as in the case of Mr, Chandrasekar and Mr. Sivaram Pillai as mentioned in Times of India (Fig 1)


Green Chemistry That Delivers

(Left to right) Chandrasekhar B, Sivaram Pillai and Vishwadeep Kuila

NEVER TOO OLD TO START AFRESH

Sindhu.Hariharan@timesgroup.com

Your 50s is a time when you typically start planning how to spend your retired life and mentally prepare to hang up your boots. But for friends and startup co-founders Sivaram Pillai, Bala Chandrasekar, and Vishwadeep Kuila, their 50s couldn't be more different.

As head of a probiotics division in a conglomerate and a leather business owner, Pillai and Chandrashekar had a common goal in their senior phase – to do away with toxic chemicals in industrial applications. Friend and sales and marketing whiz Kuila joined them and biotech startup Proklean Technologies was launched in 2012.

"In our 50s, we were not looking to make a living or create more wealth for our families; we just wanted to lessen the adverse impact of the mass-scale industrialization around us," says Pillai. They realised probiotics could be the green alternative to toxic chemicals in various industrial uses. They came up with some alternatives in the leather and textiles sector. Proklean's patented technology and process converts naturally occurring microbes and other raw material into material that mimic chemical surfactants. In years down the line, Proklean has solutions in the paper and pulp sector; waste water management and is also dabbling in biosurfactants. Primarily a B2B startup, the company also sells household sanitation products.

Their age and industry experience did not make building a business any

Proklean Technologies

LAUNCHED | 2012

FOUNDERS | Sivaram Pillai, Chandrasekar B, Vishwadeep Kuila

WHAT IT DOES: Proklean's proprietary tech uses a consortium of 'good' bacteria to make natural surfactants free of chemicals and other toxic material. Its products reportedly emit 80% lower carbon

Figure 1 Entrepreneurial Ventures in Green Chemistry

1.4. Industrial Usage of Green Chemistry

1.4.1. Pharmaceutical Industry

The Pharmaceutical industry was among the first to recognize the value of green chemistry. The drug industry's is moving towards using organic solvents. Pharmaceutical companies are also developing better catalysts.

1.4.2. Green Solvents

Solvents are important in Chemistry as they are used in high compounds and are typically volatile organic compounds, leading to a high risk for air pollution and large amounts of waste. Hence, usage of Green Solvents is recommended. A recent example of a green solvent that is now in commercial use is in fabric dyeing.

1.4.3. Bio-Based Transformations and Materials

Green chemistry has played a key role in the development of a growing number of alternative ways to synthesize chemicals traditionally made from petroleum or other non-renewable resources. The technologies in this field have involved a wide variety of biological materials like such as Algae, Bacteria, Sugar, starch and Yeast. The companies that have developed his technology are Archer Daniels Midland, Cargill, DuPont, Eastman Chemical, Dow, Procter and Gamble, Sherwin-Williams as well as some academic researchers and smaller companies.

1.4.4. Solar Photovoltaics

In recent years clean energy experts have been excited about the emergence of two new chemistry-driven solar technologies, they are Perovskite Solar cells and Quantum dots. The use of solar photovoltaics has been growing at an average of 43% per year since 2000. Perovskite solar cells compare well to older photovoltaic technologies because they offer good power outputs from low-cost materials that are relatively simple to process into working devices. The perovskite appellation is a nod to a long-ago-discovered mineral composed mainly of calcium titanate. As of now, there are 2 companies producing Perovskite cells commercially, they are Oxford Photovoltaics of the U.K. and the Australian firm Dyeso

1.4.5. Quantum Dots

Quantum dots are nanocrystals of semiconductor materials that emit a bright glow of a pure colour by light or an applied voltage. Quantum Dots have a theoretical conversion of 45%. This is possible when a single Photon is absorbed by the Quantum Dot, it produces more than one bound electron-hole pair thereby doubling the normal conversion efficiency number seen in a single-junction silicon cell. And recently, a new class of organometal halide perovskite-based semiconductors has emerged as a viable candidate for quantum-dot solar cells.64 These cells can use methylammonium lead iodide chloride (CH3 NH3 PbI2 Cl) perovskite.

1.5. Green Chemistry Education

Green Chemistry is an essential element of chemistry education as it offers varied opportunities for the sustainable development of a country's three pillars i.e., economic, social, and environmental development. Meanwhile, some of the designed molecules in chemistry have caused environmental damage either in some stages of their regular life cycle or as a result of accidents. Green Chemistry education is a novel method of teaching chemistry that is focused on mitigating risk and is a proactive approach to pollution prevention. Green chemistry education can integrate sustainable concepts and principles into the teaching/learning process and empower the future generation with the required knowledge to tackle complex environmental problems. The interdisciplinary nature of green chemistry can influence the student's awareness and attitude toward sustainability. Many countries have started integrating green chemistry courses into their curriculum. Exposure to green chemistry programs in a formal or informal learning environment has triggered environmental concern among students and a favorable attitude toward sustainability. Including green chemistry in the curriculum increases awareness about environmental issues and raises environmental responsibility standards. It can create awareness about the need to trim down the harm done to the environment by synthetic products and the procedures used to produce them.

Green Chemistry curriculum in China follows a three-fold strategy through Teaching courses, laboratory experiments, and published texts. Green chemistry education can be integrated into the school curriculum through textbooks and classroom teaching, designing green chemistry experiments, and developing teaching cases. The development of new courses should be strongly associated with assessment as well. It is imperative to integrate green Chemistry at different levels of education to create a generation that is well-informed on the importance of sustainable development.

1.6. Statement of problem

Green chemistry has been proposed as a novel approach to teaching chemistry. This novel approach to teaching chemistry emphasizes risk mitigation and keeping dangerous substances out of environment. Incorporating GC into Chemistry curricula at every level, beginning with secondary school, is one approach to equip students with the necessary knowledge to ensure that our environment is sustainable for both the present and future generations. The student's performance and transmission of environmental knowledge to favorable practices and actions are dependent

largely on their experiences and exposure to the principles of GC in school. Teachers play a pivotal role in creating awareness and imparting knowledge. Teachers should have sound knowledge and commitment to equipping students with GC knowledge. In India, there are not many studies conducted on understanding teacher's viewpoints. Hence this study aims to fill this gap and investigate teachers' perceptions and attitude towards the integration of GC into the school curriculum.

1.7. Research Objectives

- To study the teacher's perception of integrating Green Chemistry principles into the school chemistry curriculum
- To study the teacher's attitude toward integrating Green Chemistry principles into secondary school chemistry curriculum

1.8. Scope of the study

Teachers can impart solid green chemistry knowledge to students only when they themselves are knowledgeable and have environmental concerns. Reformation in chemistry education is essential to address environmental issues through teaching and hence teachers need to be trained and made aware of the significance of including green chemistry in the curriculum. Despite the growing outcry for incorporating green Chemistry education in the school curriculum, the Perception and attitude of teachers as the torchbearers in this mission is yet to be explored.

2. Review of Literature

(Wan Yunus & Mat Ali, 2018) in their study "Attitude towards learning chemistry among Secondary school students in Malaysia" found that the world is facing environmental challenges where the future communities are losing interest in science subjects such as chemistry. There are many factors that contribute to students' success. One of the factors is the student's attitude toward learning. The result of this study revealed that a majority of the students have a positive attitude toward learning chemistry when they conduct chemistry experiments in the laboratory. Students also show a positive attitude towards teachers' teaching style

(Karpudewan & Kulandaisamy, 2018) in the study "Malaysian teachers' insights into implementing green chemistry experiments in secondary schools" points out that Laboratory experiences are essential for learning science like chemistry. Learning of abstract concepts occurs more concretely in a laboratory setting. A good pedagogical strategy is essential as the laboratory affects students' learning and what they take away from a laboratory course. The findings of this study suggest green chemistry possesses the potential to be integrated into mainstream chemistry education.

(Sharma & Kanaujia, 2020) in their study proved that Green Schools evolved by a range of stakeholders in India and contributed to environmental awareness activities becoming a movement where schools are adopting a whole school – whole system approach to become sustainable schools. Learnings from various Green School initiatives envisaged and implemented by the government, NGOs, institutions and private companies through CSR in the country provide good insight on opportunities and challenges for the future course of action.

(Zuin et al., 2021) in their research "Education in green chemistry and in sustainable chemistry: perspectives towards sustainability" states that Innovation in green and sustainable technologies requires highly qualified professionals, who have critical, inter/transdisciplinary, and system thinking mindsets. In this context, green chemistry education (GCE) and sustainable chemistry education (SCE) have received increasing attention, especially in recent years. However, gaps remain in further understanding the historical roots of green chemistry (GC) and sustainable chemistry (SC), their differences, similarities, as well the implications of this wider comprehension into curricula.

(Armstrong et al., 2018) in their study points out that Green chemistry emerged over the past several decades as an important component of chemical education. Many different types of educational materials have been created to teach students the *12 Principles of Green Chemistry*. However, an international push towards sustainable development challenged green chemistry educators to teach students to weigh the complex factors of green chemistry and consider societal factors of sustainability.

3. Research Methodology

A descriptive study was conducted during the period 16-10-2023 to 10-11-2023. The study was conducted among teachers who are working in different schools. A survey was conducted among school teachers.

3.1. Methods of Data Collection

Both primary and secondary data were used in this study. A questionnaire was formed by adapting the questions in the "Perception and Attitude of Teachers towards Integrating Green Chemistry Principles Questionnaire (PATIGCPQ)". It was circulated via Google Forms among teachers. Data was collected from 33 respondents. The questionnaire has 3 sections and is made up of three sections; the first section contains demographic information like age, gender, and qualification of the participants in the study, the second section is made up of 12 items on the participants while the third section contains 10 items on their attitude towards integration of GC principles into secondary school chemistry curriculum. The response type used was the four Likert scale types of Strongly Disagree (SD), Disagree (D), and Agree (A) Strongly Agree (SA). Data collected from 33 respondents was downloaded from Google Forms and analyzed using Excel. The results were interpreted and findings were reported

4. Data Analysis and Interpretation

The collected data was analyzed using percentage analysis and presented using pie charts and bar graphs.

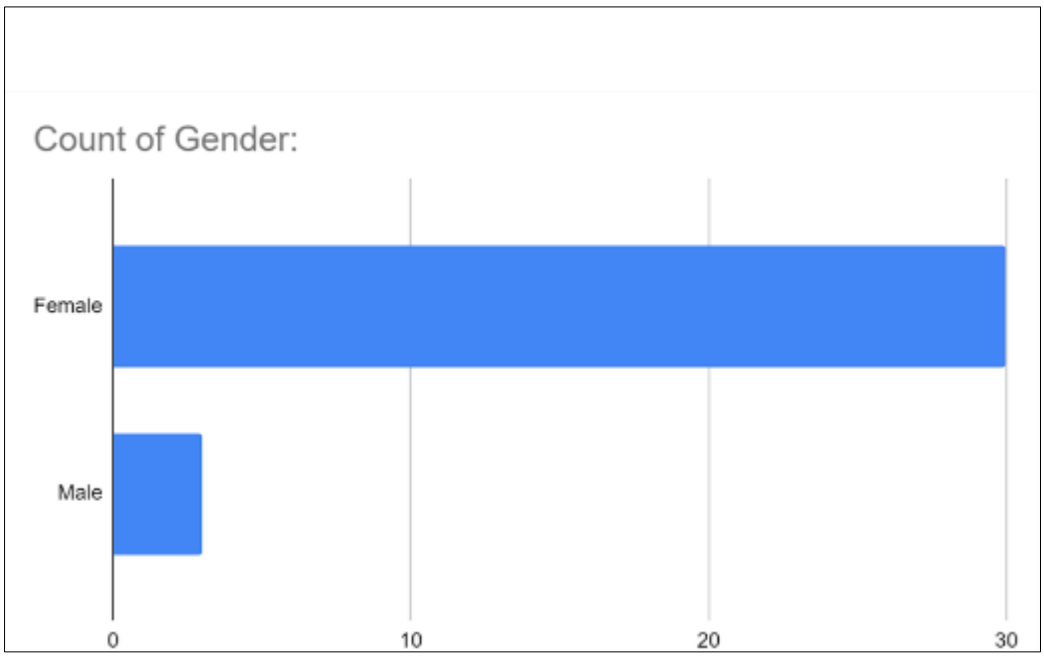


Figure 2 Gender

90.9% of respondents are Female and 9.1%of respondents are Male

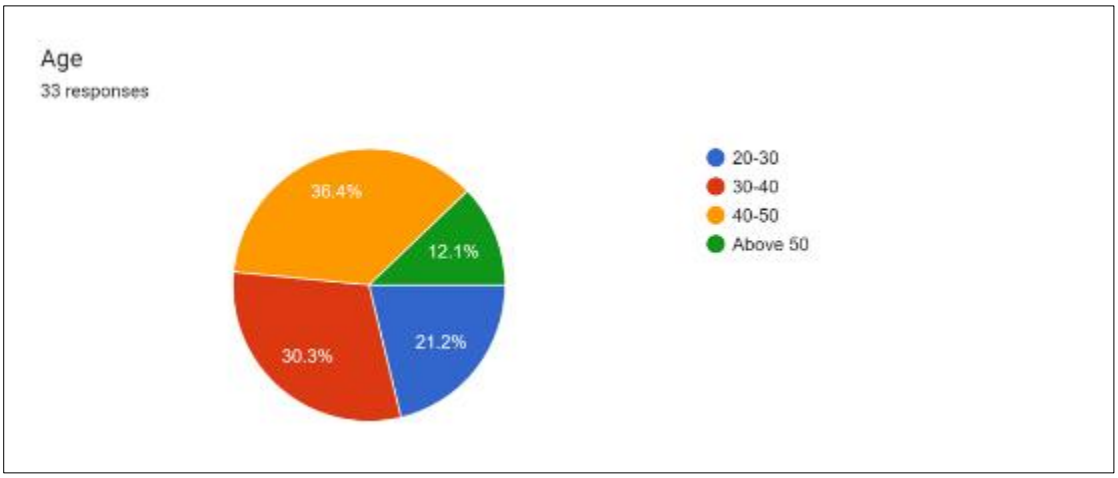


Figure 3 Age

36.4% of respondents are in the age group 40-50 years. 30.3% of respondents are in the age group 30-40 years. 21.2% are in the age group 20-30 years. 12.1% of respondents are in the age group above 50 years.

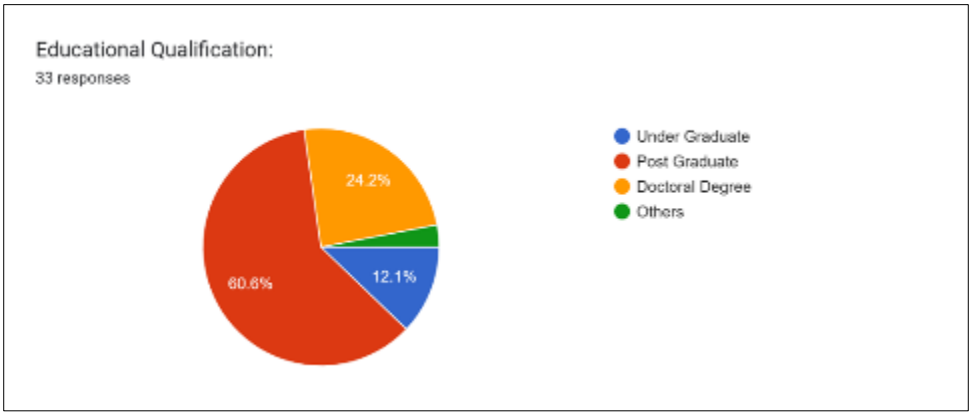


Figure 4 Educational Qualification

60.6% of respondents are post-graduates,24.2% of the respondents have a Doctoral degree, 12.1% of respondents are undergraduates and 3% of respondents fall in the others category.

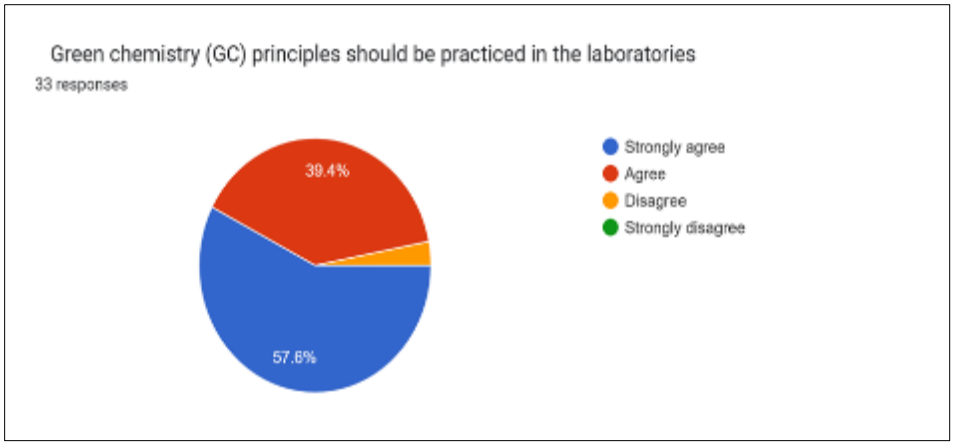


Figure 5 Practice of Green Chemistry Principles in laboratories

57.6% of respondents strongly agree with implementing green chemistry (GC) principles in the laboratories. 39.4% of respondents agree with this statement and 3% of respondents strongly disagree implementing green chemistry (GC) principles should be practiced in the laboratories.

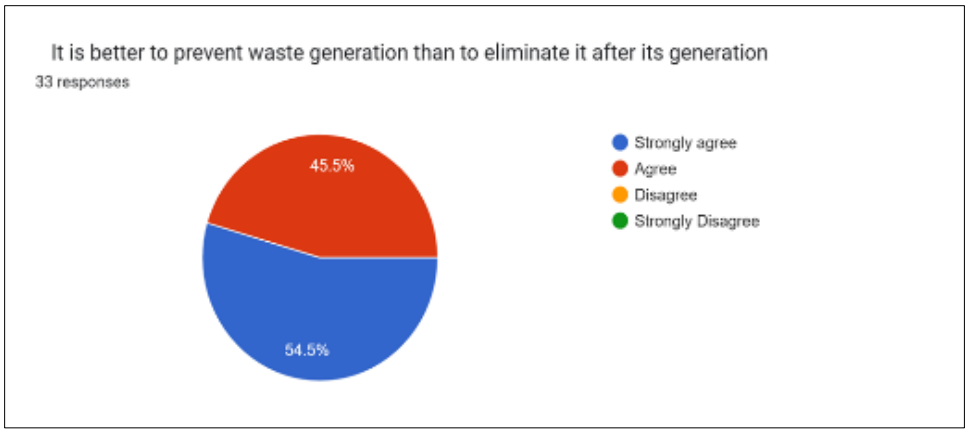


Figure 6 Prevention of waste Generation

54.5% of respondents strongly agree with this statement. 45.5% of respondents agree with this statement.

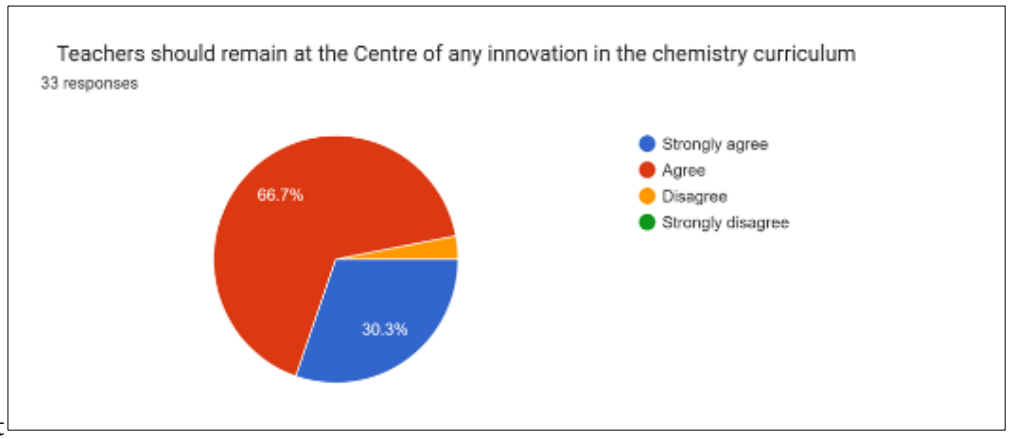


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Figure 7 Centre of Innovation

66.7% of respondents agree with this statement. 30.5% of respondents strongly agree with this statement and 3% of respondents disagree with this statement.

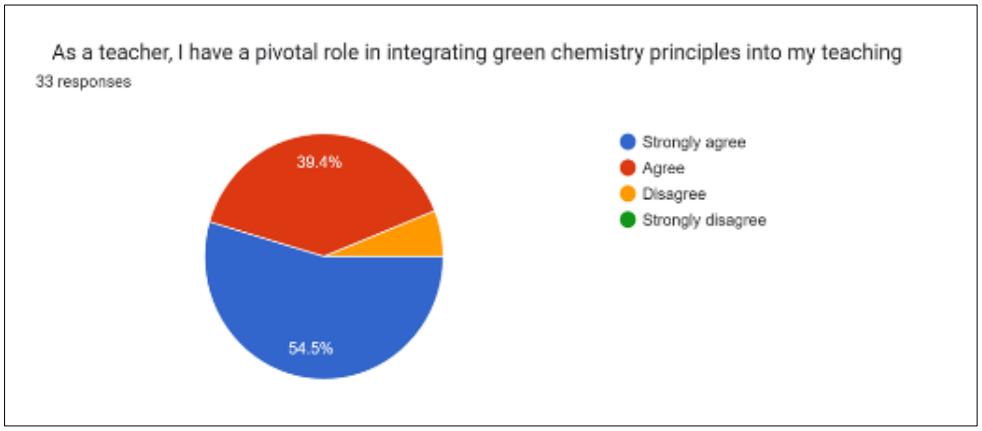

Figure 8 Green Chemistry principles in teaching

54.5% of respondents strongly agree with this statement., and 39.4% of respondents agree with these statements. 6.1% of respondents disagree with this statement.

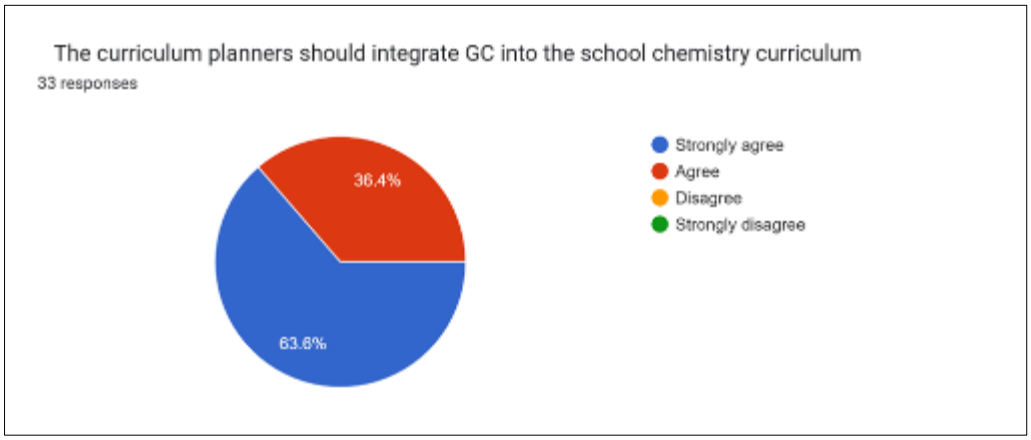

Figure 9 Green Chemistry in School Curriculum

63.6% of respondents strongly agree with this statement, and 36.4% of respondents agree with this statement.

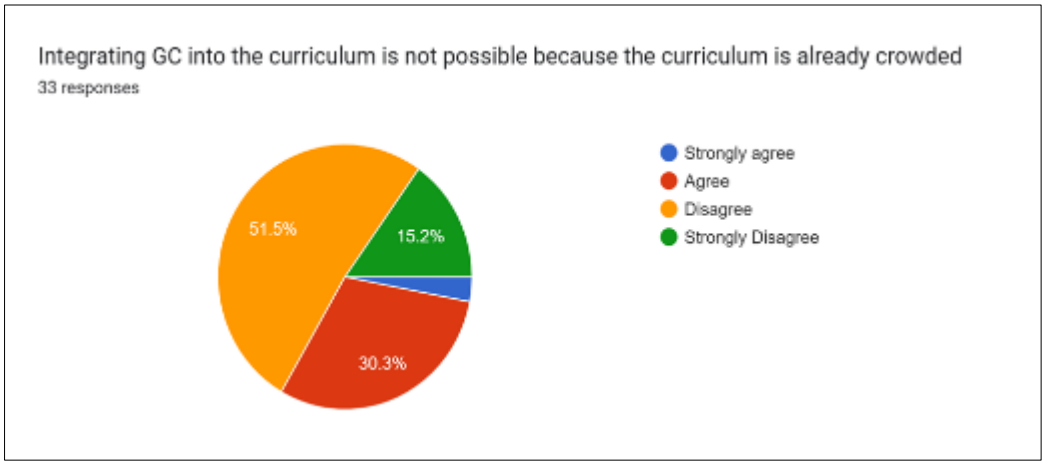

Figure 10 Limitation of curriculum

51.5% of respondents disagree with this statement. 30.3% of respondents agree with this statement. 15.2% of respondents strongly disagree with this statement. 3% of respondents strongly agree.

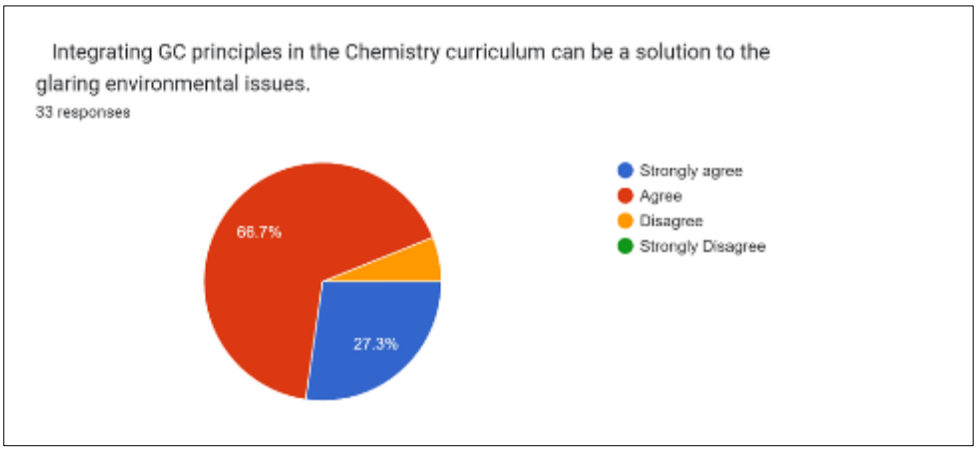

Figure 11 Green Chemistry as a solution for environmental issues

66.7% of respondents agree with this statement. 27.3% of respondents strongly agree with this statement. 6.1% of respondents disagree with this statement.

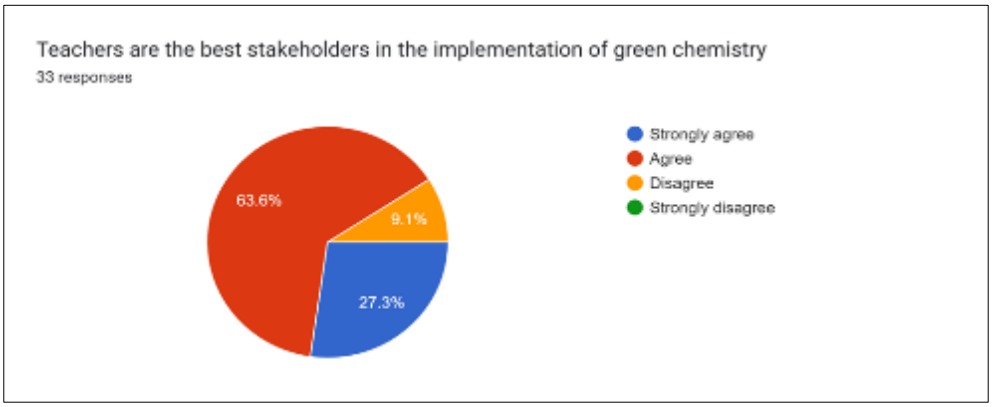

Figure 12 Teachers as stakeholders

63.6% of respondents agree with this statement. 27.3% of respondents strongly agree with this statement. 9.1% of respondents disagree with this statement.

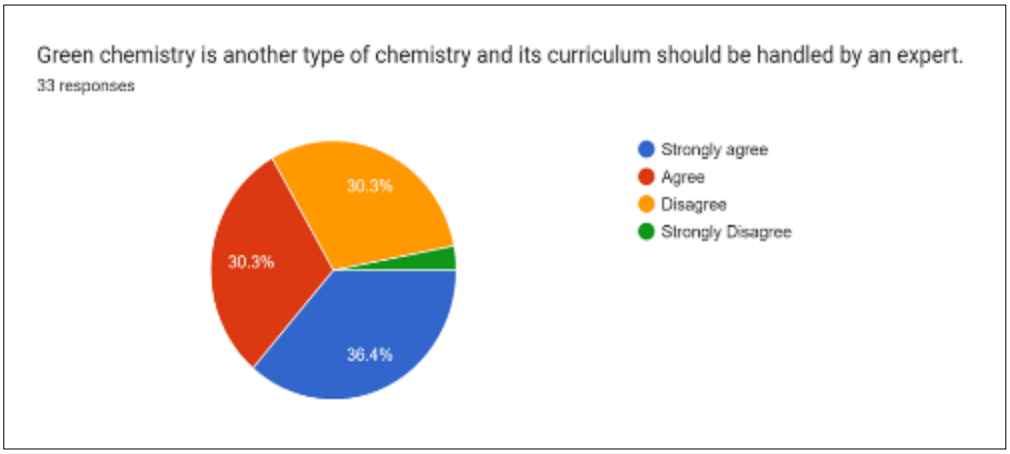

Figure 13 Role of experts

36.4% of respondents strongly agree with this statement. 30.3% of respondents agree with this statement. 30.3% % of respondents disagree with this statement. 3% % of respondents strongly disagree with this statement.

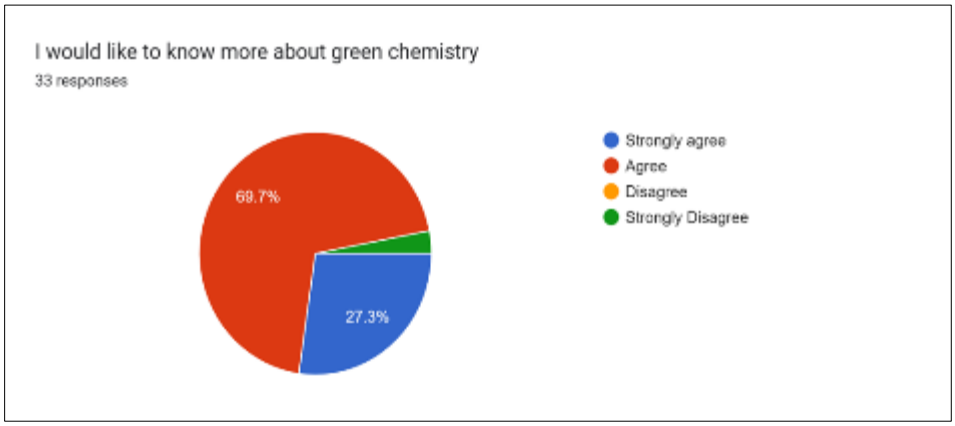

Figure 14 Willingness to know more about Green Chemistry

69.7% of respondents agree with this statement. 27.3% of respondents strongly agree with this statement. 3% of respondents strongly disagree with this statement.

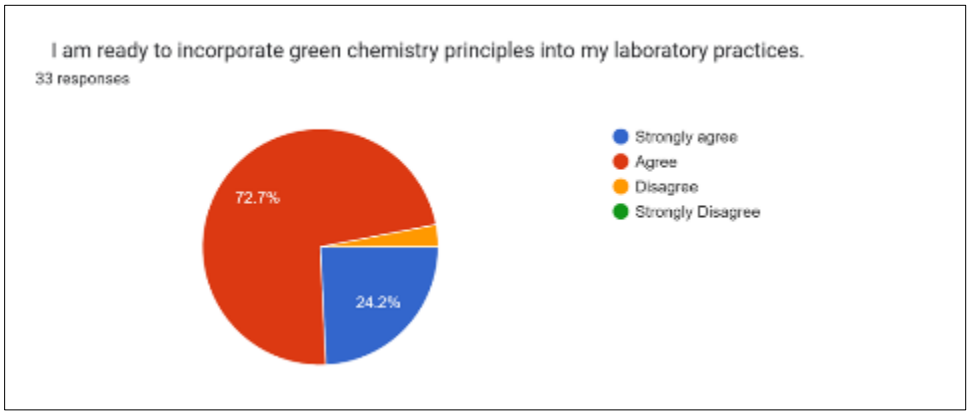

Figure 15 Willingmess to incorporate Green Chemistry in laboratory practices

72.7% of respondents agree with this statement. 24.2% of respondents strongly agree with this statement. 3% of respondents disagree with this statement.

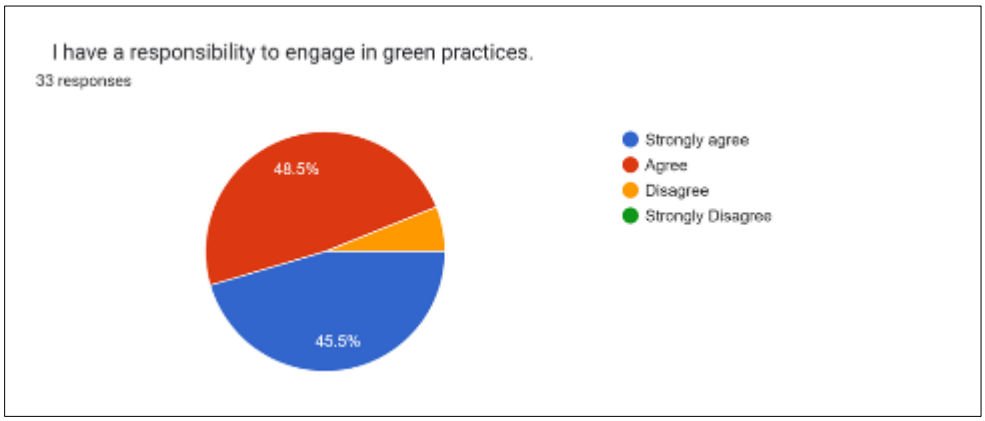

Figure 16 Responsibility to engage in Green Practices

48.8% of respondents agree with this statement. 45.5% of respondents strongly agree with this statement. 6.1% of respondents disagree with this statement.

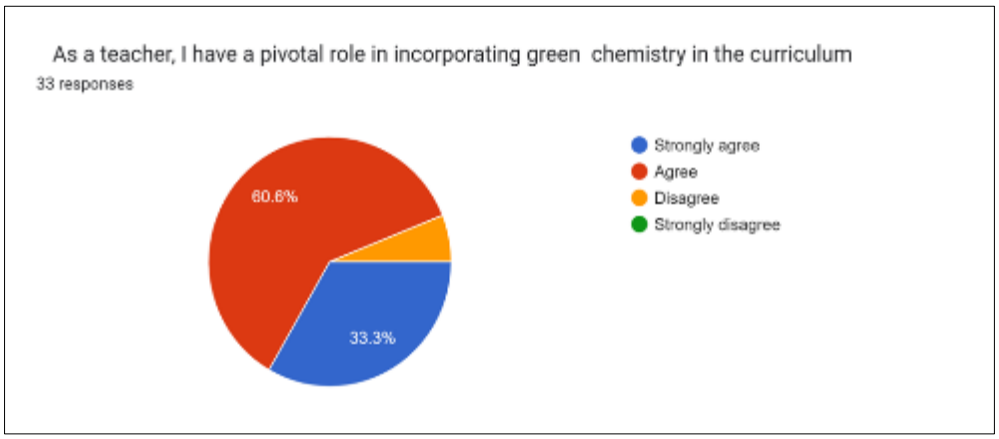

Figure 17 Role of incorporating Green Chemistry in Curriculum

60.6% of respondents agree with this statement. 33.3% of respondents strongly agree with this statement. 6.1% of respondents disagree with this statement.

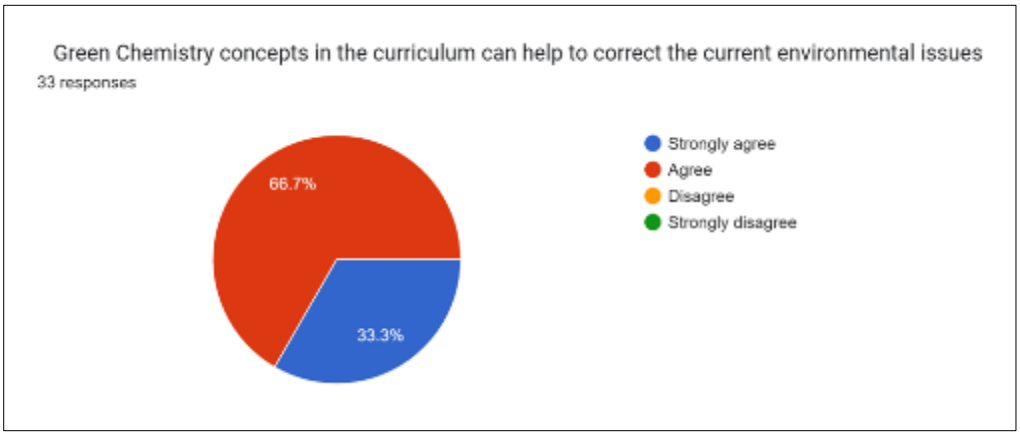

Figure 18 Role of Green Chemistry in correcting environmental issues

66.7% of respondents agree with this statement. 33.3% of respondents strongly agree with this statement.

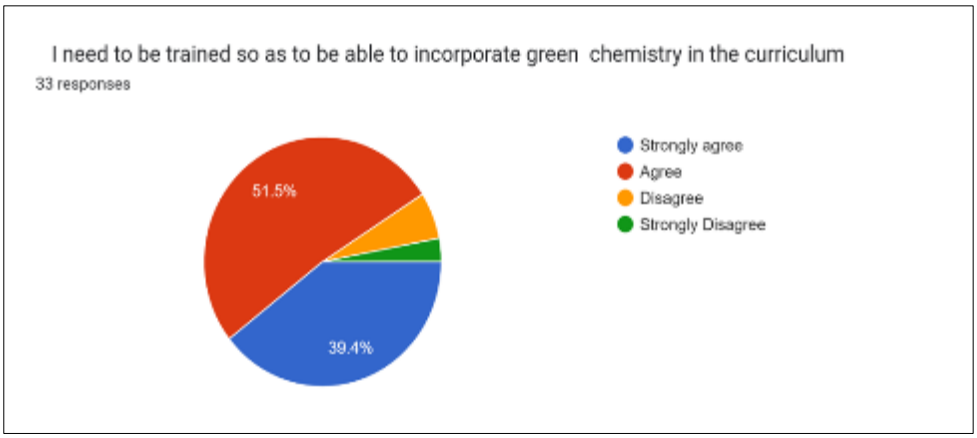

Figure 19 Need for Training

51.5% of respondents agree with this statement. 39.4% of respondents strongly agree with this statement. 6.1% of respondents disagree with this statement. 3% of respondents strongly disagree with this statement.

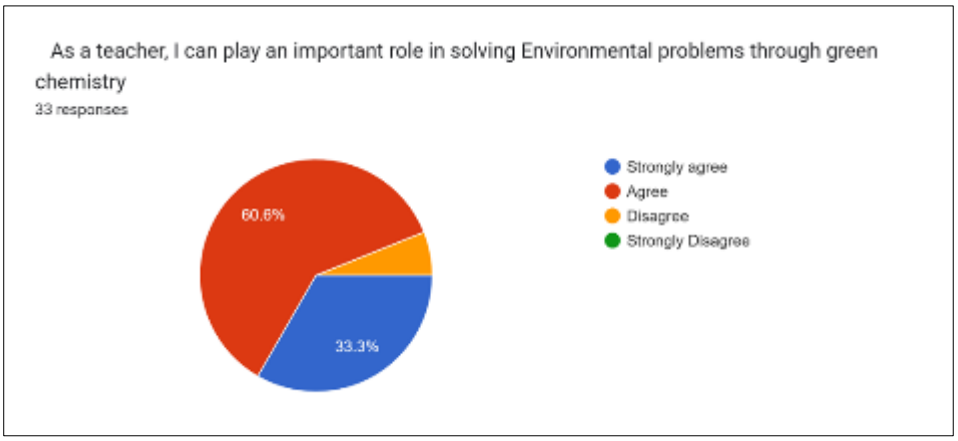

Figure 20 Role in solving environmental problems

60.6% of respondents agree with this statement. 33.3% of respondents strongly agree with this statement. 6.1% of respondents disagree with this statement.

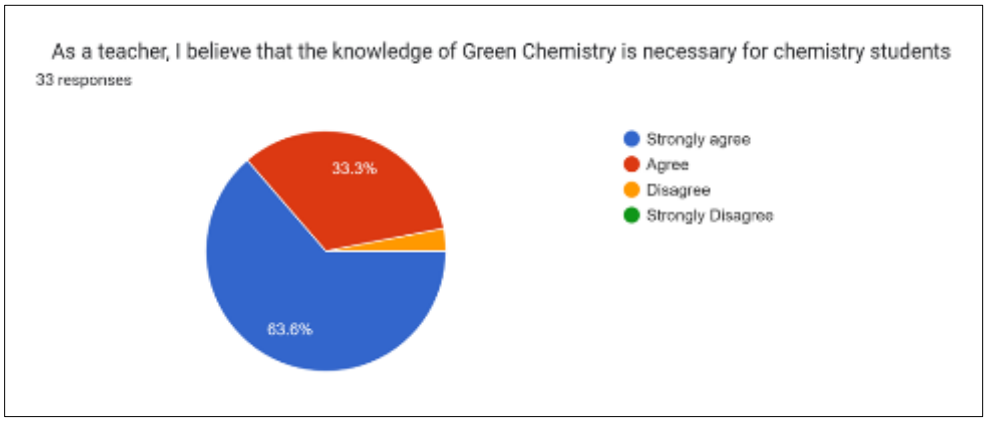

Figure 21 Knowledge of Green Chemistry for Chemistry students

63.6% of respondents strongly agree with this statement. 33.3% of respondents agree with this statement. 3% of respondents disagree with this statement

The analysed data can be summarized as mentioned in Table 1

Table 1 Data Summary

No	ITEMS	Mean
1	Green chemistry (GC) principles should be practiced in the laboratories	3.55
2	It is better to prevent waste generation than to eliminate it after its generation	3.55
3	Teachers are in the best place to promote green chemistry activities during teaching/learning process	3.70
4	Teachers should remain at the centre of any innovation in the chemistry curriculum	3.27
5	As a teacher, I have a pivotal role in integrating green chemistry principles into my teaching	3.48
6	The curriculum planners should integrate GC into the school chemistry curriculum	3.64
7	Integrating GC into the curriculum is not possible because the curriculum is already crowded	2.21
8	Integrating GC principles in the Chemistry curriculum can be a solution to the glaring environmental issues.	3.21
9	Teachers are the best stakeholders in the implementation of green chemistry	3.18
10	Green chemistry is another type of chemistry and its curriculum should be handled by an expert.	3.00
11	I would like to know more about green chemistry	3.21
12	I am ready to incorporate green chemistry principles into my laboratory practices.	3.21
13	I have a responsibility to engage in green practices.	3.39
14	As a teacher, I have a pivotal role in incorporating green chemistry in the curriculum	3.27
15	Green Chemistry concepts in the curriculum can help to correct the current environmental issues	3.33
16	I need to be trained so as to be able to incorporate green chemistry in the curriculum	3.27
17	As a teacher, I can play an important role in solving Environmental problems through green chemistry	3.27
18	As a teacher, I believe that the knowledge of Green Chemistry is necessary for chemistry students	3.61

5. Results

The findings of the study can be summarized as follows

- The study's findings demonstrate that teachers believed GC should be included in the chemistry curriculum, as evidenced by the high degree of agreement they showed in their ratings regarding this belief and their positive attitude toward doing so.
- The willingness of teachers to incorporate GC concepts into the curriculum, as shown in the corresponding high-level agreement to the various statements addressing their perception, is an eye-opener for policymakers.
- The findings reflect the level of teachers' readiness to integrate the principles of GC in their future classroom and laboratory practices
- The study proves that the prevention of waste generation through green practices is better than its elimination
- Implementation of GC practices requires highlighting its importance in achieving environmental sustainability in the classroom
- While the participants acknowledged the importance of incorporating GC into the curriculum, they also felt that the chemistry curriculum was already
- overcrowded.
- Though most of the teachers are aware of GC practices, they expressed the need for further training in this arena.
- Teachers acknowledged the fact that they play a pivotal role in sharing knowledge about green chemistry and adopting GC methods can reduce the glaring environmental issues to an extent.
- The study brings to notice that teachers think that curriculum planners should consider the incorporation of green practices in school curricula to create awareness about environmental issues.
- Training students about green chemistry practices is integral in developing a generation that works towards sustainability

6. Conclusion

The study throws light to the fact that the teachers are of the view that GC should be integrated into the curriculum and this opinion was supported by positive attitudes indicated by the teachers regardless of their genders. This is evidence that teachers are willing to see green chemistry integrated into the curriculum. This calls for a necessary review of the chemistry curriculum to accommodate the Green Chemistry principles to address the issue of environmental sustainability. It is therefore recommended that GC principles should be integrated into the curriculum at all levels, starting from secondary school. By so doing, the concept of environmental sustainability will gradually be acculturated into the youngsters who are the leaders/decision makers of tomorrow. Also, training should be provided for teachers to improve their expertise in this field. So, it is necessary to incorporate GC into teacher training curricula to prepare the teachers for future teaching with environmental sustainability consciousness.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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Appendix

QUESTIONNAIRE

1.Gender: Male ☐ Female ☐ Others ☐

2. Age :

3. Educational Qualification:

Under Graduate ☐ Post Graduate ☐ Doctoral Degree ☐ Others ☐

4. Profession

Teaching ☐ Others ☐

Directions: Please indicate your level of agreement or disagreement with each of these statements. Strongly Agree : 4, Agree :3, Disagree :2, Strongly Disagree 1

		Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**
	Question	**4**	**3**	**2**	**1**
1	Green chemistry (GC) principles should be practiced in the laboratories				
2	It is better to prevent waste generation than to eliminate it after its generation				
3	Teachers are in the best place to promote green chemistry activities during teaching/learning process				
4	Teachers should remain at the centre of any innovation in the chemistry curriculum				
5	As a teacher, I have a pivotal role in integrating green chemistry principles into my teaching				
6	The curriculum planners should integrate GC into the school chemistry curriculum				
7	Integrating GC into the curriculum is not possible because the curriculum is already crowded				
8	Integrating GC principles in the Chemistry curriculum can be a solution to the glaring environmental issues.				
9	Teachers are the best stakeholders in the implementation of green chemistry				

10	Green chemistry is another type of chemistry and its curriculum should be handled by an expert.				
11	I would like to know more about green chemistry				
12	I am ready to incorporate green chemistry principles into my laboratory practices.				
13	I have a responsibility to engage in green practices.				
14	As a teacher, I have a pivotal role in incorporating green chemistry in the curriculum				
15	Green Chemistry concepts in the curriculum can help to correct the current environmental issues				
16	I need to be trained so as to be able to incorporate green chemistry in the curriculum				
17	As a teacher, I can play an important role in solving Environmental problems through green chemistry				
18	As a teacher, I believe that the knowledge of Green Chemistry is necessary for chemistry students				