KIU Journal of Education (KJED)

Volume 5 Issue 1
Page 17 - 24

April – May 2025
https://kjed.kiu.ac.ug/

Green Chemistry Education: An Assessment of the Awareness, Knowledge, and Application among Secondary School Students in Southwest Nigeria

Rachael Olatoun Okunuga[1]* & Ikeoluwa Folasade Adeoye[2]

[1] Department of Science Education, University of Lagos, Lagos, Nigeria

[2]Department of Integrated Science Education, Emmanuel Alayande University of Education, Oyo, Nigeria

*Corresponding author: rokunuga@unilag.edu.ng , rookunuga@gmail.com;

Abstract

To help protect the environment, human health and address global climatic challenges, the study assessed secondary chemistry students' awareness, knowledge, sources of awareness, and perception on the application of green chemistry in real life situations. The study adopted a survey research design to draw 475 chemistry students from 12 public secondary schools (SS3) in two states in the Southwest, Nigeria. A self-structured questionnaire of twenty-six (26) statements on a four-point scale was used. The reliability with Cronbach Alpha gave a value of 0.965, indicating high reliability. The responses of the chemistry students were analysed using descriptive statistics and hypotheses tested with correlation analysis. The findings showed that secondary chemistry students have a moderate awareness of green chemistry, though their level of knowledge is low. Further, their perception of the application of green chemistry to real-life situations is strong. There were significant relationships among the students' level of awareness, knowledge and perception on the application of green chemistry and there were no gender biases among the variables. The study recommended the integration of green chemistry at all levels of education in Nigeria and more public enlightenment to promote a green society.

Keywords: Application, Awareness, Knowledge, Green Chemistry (GC), Sustainable environment

Introduction

Green chemistry is a sustainable chemistry designed and developed to manage chemical products and their processes, to reduce or eliminate hazardous substances for safer, efficient chemical practices, and a friendly environment. Green chemistry is imperative to reduce pollution, minimise waste, protect ecosystems, and conserve natural resources and promote human health for sustainable development, economic growth and environmental responsibility.

To have an environmentally friendly and healthy environment, the theory of Green Chemistry (GC) was introduced to cover various areas of an environment of human endeavour. Anastas and Warner (1998) introduced the twelve (12) principles, which are; prevention of wastes, maximising material usage (atom economy), synthesising less hazardous chemical products, designing safer chemicals and solvents, energy efficiency, usage of renewable feed stocks, reducing unnecessary synthesis of chemical products, use of catalysts (instead of stoichiometry reagents) to reduce energy consumption and improve yields and to reduce excess reagents, design for degradation, real-time analysis of chemical products for pollution prevention, safer chemistry processes for accident prevention.

The theoretical framework of GC is based on the theories of Anastas and Warner (1998) principles, Anastas and Zimmerman (2003) green engineering principles, Jonas's (1984) precautionary principle, cradle - to - cradle design of Braungrat and McDonough (2002), life cycle assessment by Stahel (1982) and benign by design by Collins (1995).

The principles of GC by Anastas and Warner (1998) emphasise a safer, and more sustainable design. The green engineering is an extension of green chemistry to engineering, which focuses on designing environmentally sustainable systems and processes. The precautionary principle stresses the imperative responsibility of individuals and industries for a healthy and conducive environment. The life cycle assessment is a systematic approach used to evaluate the environmental impacts of a product, process, or service throughout its life cycle. The cradle-to-cradle approach focuses on designing products that can be technologically or biologically recycled instead of the traditional approach of cradle-to-grave, which leads to waste and pollution at the end of the product's life. The benign design focuses on designing chemical products and processes that are inherently safe and environmentally friendly from the very beginning, rather than managing the risks and hazards after production. The concepts and applications of GC, based on these principles and theories are expected to be applied by industries n the fulfilment of the Sustainable Development Goals (SDGs).

Valderrama et al. (2023) reported an increase in the application of knowledge of green chemistry in different fields on green solvents and education for sustainability. Also, pharmaceutical industry applies a holistic design to the product's life cycle for an eco-friendly environment. In the detergent industry, studies have shown the evidence that bio-based surfactants, like alky polyglucosides and sucrose esters can be used as alternatives to conventional petrochemical

surfactants. The packaging industries also use biodegradable films, a mixture of polycaprolactone diol, cellulose acetate, and bio-based plasticisers to reduce pollution in the environment (Fantoni, Tolomeli & Cabri, 2022; Stubbs, Yousaf & Khan, 2022; and Clark, 2022). These principles are not applied by industries alone, they are incorporated into the chemistry curriculum and taught at different levels of education. Thus, there is a paradigm shift from traditional chemistry to green chemistry in education.

Several investigations exist on the concepts, awareness, and application of green chemistry (Sajeera, 2021; Alwaili, Youssif and Saeed, 2024; Ibrahim et al., 2025). Saadon and Abbood (2022) showed a low extent of the scientific fifth grade in schools of Fallujah Education Directorate in Anbar, Iraq. The study reported no gender difference among the students in the awareness of green chemistry. Alrawili, Youssif, and Saeed (2024) found that the University of Bisha's students in scientific colleges, Saudi Arabia, had weak (33.63%) levels of applications and awareness of the principles of green chemistry. The study also found no differences among students' average scores based on the course of studies. However, there were significant differences between the students' average scores on safer chemicals design, safe solvent usage, designing for energy, and use of catalysis. Sajeera (2021) found an average awareness of 80 % of the concepts of green chemistry and 64 % of average awareness of the application in daily life situations. Ibrahim et al. (2025) found that rural students demonstrated higher knowledge and awareness of green chemistry than urban students. However, there was no significant difference in students' attitudes and values for green chemistry. Teachers, irrespective of their location, showed limited knowledge of principles of green chemistry. The study indicated the interest of science students in incorporating GC education into the school curriculum. In addition, the study found the challenges faced in applying GC to real-life situations to include, inadequate training of teachers and instructors, insufficient resources, and unclear implementation guidelines.

Further, Mulyanti and Kadarohman (2021) investigated students' attitudes towards GC and its applications and found that the students were in agreement with the green chemistry principles. Many of the principles were still unknown to the respondents. It was also found that many of the students did not apply the principles in real-life situations. Gunbatar et al. (2025) reviewed and analysed the students' training orientation to teaching GCSE at the tertiary level through pedagogical content knowledge. The analysis showed that organic chemistry was the most emphasised branch of chemistry in the articles reviewed. The analysis also found that the 'use of renewable feedstocks' was the most emphasised principle in green chemistry, while the least stressed in the curriculum was 'reduce derivatives' and 'real-time pollution prevention'. Grieger and Leontyev (2020) reported an increase in students' awareness of green chemistry principles when chemistry students engaged in discourse with their counterparts while watching generated instructional videos on green chemistry principles using a flip grid platform. Achu (2024) determined the perception and attitude of teachers in integrating green chemistry principles into the school curriculum. The study showed a positive attitude towards including green chemistry into the school chemistry curriculum. The findings recommended training for the teachers as facilitators of the knowledge of green chemistry. The findings from the various studies on GC and its application to real-life situations raise a concern on the level of awareness and knowledge of science students to GC.

Statement of the Problem

Research on the identification of the green chemistry principles of Anastas and Warner (1998) had been intensively carried out. The applications of these principles in designing chemical processes and the production of less hazardous substances, minimising waste production, and biodegradability of substances biologically and technologically have been reported. There were investigations into students' awareness and knowledge of green chemistry among tertiary students in various fields of science. Comparison of the students' awareness and knowledge application among teachers and students at the secondary school level and urban and rural areas were studied (Saadon & Abbood, 2022; Ibrahim et al., 2025). However, few studies exist on chemistry secondary students' awareness, sources of awareness, knowledge, and life applications of green chemistry with students' gender. This study sought to assess senior secondary chemistry students in SS3 awareness, knowledge, and application of green chemistry in southwest, Nigeria.

Research Objectives

The purpose of this study was to assess the extent of awareness, and knowledge, as well as the perception on applications of green chemistry among secondary school chemistry students.

The specific objectives were to:

1) Assess senior secondary school chemistry students' level of awareness of green chemistry.
2) Investigate the level of senior secondary school chemistry students' knowledge of green chemistry.
3) Examine senior secondary school chemistry students' sources of awareness and knowledge of green chemistry.
4) Determine the perception of secondary school chemistry students on the perception of green chemistry in real-life situations.
5) Find the relationship between secondary school students level of awareness and knowledge, and their perception of the application of green chemistry to real-life situations
6) Examine the contribution of chemistry students' gender on the level of awareness and knowledge on green chemistry, as well as their perception on the application of green chemistry in real-life situations.

Research Questions

The following research questions were raised for the study.

1) What is the secondary chemistry students' level of awareness of GC?
2) What level of knowledge of GC is possessed by secondary chemistry students?
3) What is the medium of awareness and knowledge of GC among secondary chemistry students?
4) What is the secondary chemistry students' perception of the application of GC in real-life situations?
5) Is there any relationship between the level of awareness and knowledge of chemistry students on GC, and their perception on the application of GC in real-life situations?
6) What is the influence of gender on the level of awareness and knowledge of GC as well as the chemistry students' perception of the application of GC in real-life situations?

Research Hypotheses

The following null hypotheses were formulated and tested for the study at a 0.05 level of significance:

H_{01}: There is no significant relationship between the level of awareness of chemistry students on GC and their perception of the application in real-life situations.

H_{02}: There is no significant relationship between the knowledge level of chemistry students on GC and their perception of the application in real-life situations.

H_{03}: There is no significant difference in the level of awareness on GC of secondary chemistry students by gender.

H_{04}: There is no significant difference in the knowledge of GC of secondary chemistry students by gender.

H_{05}: There is no significant difference in the perception of secondary chemistry students on the application of GC in life situations by gender.

Research Methodology

The study adopted the descriptive survey research design for this study. The participants were drawn from public schools in two states, Lagos and Oyo States in southwest Nigeria. Six schools were randomly sampled from two educational districts of Lagos State and another six schools were sampled from three local government areas of Oyo Town in Oyo State. The total sample of students for the study from the two states was 475. Intact classes of chemistry students in each school were used in both states as the number of Senior Secondary School 3 (SSS3) students varied from 19 to 45 per class. Due to the low number of chemistry students per class, a total of twelve schools were used for the study. Also, to get comprehensive and unbiased responses, it became necessary to use all the SS3 chemistry students in all the sampled schools.

The research instrument was a self-structured questionnaire that had four sections to measure the level of students' awareness of green chemistry, level of knowledge of green chemistry, sources of awareness and knowledge of green chemistry, and perception on the applications of green chemistry to real-life situations. Sections I and III had five statements each on awareness and sources of awareness and knowledge of green chemistry. Section II dealt with knowledge of green chemistry and section IV dealt with students' perception on the application of green chemistry, which had eight statements each. The statements on awareness, knowledge, and source of knowledge of chemistry were on the scale of great extent, moderate extent, low extent, and no extent with scores of 4, 3, 2, and 1, respectively. The eight (8) statements of students' perception on the application of green chemistry were on the scale of strongly agree, agree, disagree, and strongly disagree with scores 4, 3, 2, and 1, respectively. The research instrument was validated for construct and content validity for the appropriateness of the items with what they were to measure. The instrument was found reliable with a Cronbach Alpha reliability of .965 before its administration to the sampled chemistry students.

The responses of the chemistry students to the research instrument were analysed using descriptive statistics and hypotheses tested using correlation.

Data Analysis and Results

Research Question 1

What is the secondary chemistry students' level of awareness of GC?

On a scale of 4 (from 1 to 4), the mean score higher than 2.5 indicates that greater percentage of the respondents had a great or moderate extent of the independent variable.

Table 1: Descriptive statistics of students' awareness and knowledge of green chemistry

	Awareness			Knowledge		
	Frequency	Percent	Stat	Frequency	Percent	Stat
Great extent	91	19.2		59	12.4	
Moderate extent	188	39.6		196	41.3	
Low extent	124	26.1		120	25.3	
No extent	72	15.2		100	21.1	
Total	475	100		475	100	
Mean			2.6274			2.4505
Std Deviation			0.96023			0.95862

From Table 1, only 19.2% of the chemistry students have awareness of green chemistry to a great extent. However, 39.6% are aware of green chemistry to a moderate extent, while less than 40% of the students are either not aware or have low awareness of green chemistry.

The mean score of 2.6274 shows that secondary school chemistry students have a moderate level of awareness of GC.

Research Question 2

What level of knowledge of GC is possessed by secondary chemistry students?

The results in Table 1 show that about 46.4% of chemistry students have knowledge of GC either to a low extent or without any knowledge of the subject matter. Only 12.4% of them have knowledge of green chemistry to a great extent, while 41.3% with moderate extent of the knowledge. However, it can be inferred that the students have a low knowledge, with a grand mean of 2.45.

Research Question 3

What is the medium of awareness and knowledge of GC among secondary school chemistry students?

Students could get awareness and knowledge of green chemistry from various sources including awareness from their schools when being taught in chemistry class, or through peer discussion or social media or environmental campaign or even at home through family discussion. Hence, respondents gave the extent of how they got the awareness and knowledge of green chemistry and this gave rise to the distribution in Table 2.

On a scale of 4 (from 1 to 4), the mean score higher than 2.5 indicates that greater percentage of the respondents have great or moderate extent of the independent variable.

Table 2: Sources of awareness and knowledge of Green Chemistry

	chemistry classes in school		Social media		Environmental campaign		Peer Discussion		Family Discussion	
	Freq	Percent	Freq	Percent	Freq	Percent	Freq	Percent	Freq	Percent
Great extent	144	30.3	124	26.1	108	22.7	102	21.5	94	19.8
Moderate extent	137	28.8	124	26.1	115	24.2	139	29.3	104	21.9
Low extent	77	16.2	134	28.2	150	31.6	124	26.1	125	26.3
No extent	112	23.6	88	18.5	96	20.2	102	21.5	147	30.9
Total	470	98.9	470	98.9	469	98.7	467	98.3	470	98.9
Missing	5	1.1	5	1.1	6	1.3	8	1.7	5	1.1
Total	475	100	475	100	475	100	475	100	475	100

Table 2 shows that 30.3% of the students had a great extent of their sources of awareness and knowledge of green chemistry from chemistry classes in school, while 28.8% had it to a moderate extent. These two were summed up to give 59.1% that had awareness and knowledge of green chemistry to either a great or moderate extent from the school curriculum taught in classes. Social media also contributed as a source of awareness and knowledge of green chemistry with great extent and moderate extent giving 52.2%. However, the least source of awareness was from family discussion at home, which has only 19.8% for great extent and 21.9% for moderate extent.

On a scale of 4 (from 1 to 4), a mean score higher than 2.5 indicates that a greater percentage of the respondents strongly agreed or agreed with the statement on the application of green chemistry to real-life situations.

Research Question 4

What is the secondary chemistry students' perception of the application of green chemistry in real-life situations?

Table 3: Descriptive statistics of students' perception of the application of green chemistry

	Frequency	Percent	Stat
Strongly Agreed	85	17.9	
Agreed	303	63.8	
Disagreed	70	14.7	
Strongly Disagreed	17	3.6	
Total	475	100	
Mean			2.96
Std Deviation			0.68473

From Table 3, the perception of chemistry students on the application of GC to real-life situations is very high. About 81.7% of the students either agreed or strongly agreed that the application of GC in real-life situations is desirable.

Research Question 5

Is there any relationship between the level of awareness and knowledge of chemistry students on GC and their perception on the application in real-life situations?

The nonparametric correlation statistics between the three variables; awareness, knowledge of GC and perception on its application to real-life situations are shown in Table 4. This was used to test hypotheses 1 and 2.

Table 4: Nonparametric Correlations using the Spearman's rho

Variable	Statistics	Students' awareness of green chemistry	Students' knowledge of green chemistry	Students' perception on the application of green chemistry
Students' awareness of green chemistry	Correlation Coefficient	1	0.771	0.458
	Sig. (2-tailed)	.	0	0
	N	475	475	475
Students' knowledge of green chemistry	Correlation Coefficient	.771**	1.000**	.490**
	Sig. (2-tailed)	0	.	0
	N	475	475	475
Students' perception on the application of green chemistry	Correlation Coefficient	.458**	.490**	1.000**
	Sig. (2-tailed)	0	0	.
	N	475	475	475

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis 1

H_{01}: There is no significant relationship between the level of awareness of chemistry students on GC and their perception of the application in real-life situations.

The nonparametric correlation, Table 5 described the relationship between students' awareness of GC and students' perception on the application in real-life situations has a significant value of p = 0.00. This indicated that there was a significant relationship between students' awareness of GC and their perception of the application of GC to real-life situations with a correlation coefficient, R=0.458. Hence, the null hypothesis is rejected and the alternative hypothesis is accepted.

Hypothesis 2

H_{02}: There is no significant relationship between the knowledge level of chemistry students on GC and their perception of the application in real-life situations.

Similarly, from Table 5, there was a significant relationship between the students' knowledge of GC and students' perception of the application to real-life situations with a significant p value of 0.00. Thus, the hypothesis was rejected and concluded that the knowledge of the students is related to their perception of the application of GC to real-life situations with a correlation coefficient of 0.490.

Research Question 6

What is the influence of gender on the level of awareness and knowledge of GC as well as the chemistry students' perception of the application in real-life situations?

Students' awareness, knowledge of GC and perception on the application were further analysed to determine if the students' gender had contribution to the awareness, knowledge and perception in their decisions. Hence, we examine if male or female have better awareness and knowledge of green chemistry than the other sex. A gender may be said to have a better degree of position than the opposite sex if the percentage difference between them is more than 5%.

Table 5: Distribution on Awareness, Knowledge and Perception of Green Chemistry * Gender Crosstabulation

		Awareness			Knowledge			Perception		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
Great extent	Count	46	45	91	28	31	59	36	49	85
	%	19.20%	19.10%	19.20%	11.70%	13.20%	12.40%	15.00%	20.90%	17.90%
Moderate extent	Count	102	86	188	105	91	196	160	143	303
	%	42.50%	36.60%	39.60%	43.80%	38.70%	41.30%	66.70%	60.90%	63.80%
Low extent	Count	59	65	124	59	61	120	36	34	70
	%	24.60%	27.70%	26.10%	24.60%	26.00%	25.30%	15.00%	14.50%	14.70%
No extent	Count	33	39	72	48	52	100	8	9	17
	%	13.80%	16.60%	15.20%	20.00%	22.10%	21.10%	3.30%	3.80%	3.60%
Total	Count	240	235	475	240	235	475	240	235	475

	% within Gender	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 5 shows the cross tabulation of gender distribution on awareness, knowledge and perception of green chemistry. Male students had 42.5% awareness of green chemistry to a moderate extent while the female students had 36.6%. Furthermore, the number of female students with low awareness is 6.2% more than that of the male students. This indicated that the level of awareness of female students was slightly lower than that of their male counterparts.

This slight difference is further tested to determine if this percentage difference is significant or not.

Awareness and Gender

Hypothesis 3

H03: There is no significant difference in the level of awareness of GC of secondary chemistry students by gender. An independent sample test using Mann Whitney U test was conducted and Table 6 confirmed that there is no significant difference in the awareness of GC across the categories of gender, given a non-significant value of 0.316. The students' awareness of green chemistry is therefore not gender biased.

Table 6: Nonparametric Tests - Independent- Samples Mann-Whitney U Test

Null Hypothesis	Sig.	Decision
The distribution of students' awareness of green chemistry is the same across categories of Gender	.316	Retain the null hypothesis
The distribution of students' knowledge of green chemistry is the same across categories of Gender	.620	Retain the null hypothesis.
The distribution of students' perception on application of green chemistry is the same across categories of Gender	.298	Retain the null hypothesis.

Asymptotic significance displayed. The significance level is .05

Knowledge and Gender

The extent of students' knowledge of green chemistry across categories of gender was examined. We observed from table 4 above that there is no wide difference in the percentage of gender across the categories except in moderate extent where it's just a difference of about 5%. Furthermore, an independent sample test was carried out on the students' knowledge on green chemistry by gender with the following hypothesis.

Hypothesis 4

H_{04}: There is no significant difference in the knowledge of GC of secondary chemistry students by gender

Table 6 results show a non-significant value p = 0.620. Hence, the extent of students' knowledge on green chemistry by secondary school students is the same across the categories of gender. Hence, the null hypothesis was accepted.

Perception on real-life application of green chemistry and Gender

Hypothesis 5

H_{05}: There is no significant difference in the perception of senior secondary chemistry students on the application of green chemistry in real-life situations by gender

From the independent samples test using Mann Whitney in Table 6, the results show a non-significant value p = 0.298. Hence, it was concluded that students' perception of the application of GC in real-life situations is the same across the categories of gender and it is not gender biased. Hence, the null hypothesis was accepted.

Discussion of Findings

The findings revealed that chemistry students have a moderate level of awareness of green chemistry, however, they have a low level of knowledge. This is in line with the findings of Alwaili, Youssif and Saeed (2024) and Saadon and Abbood (2022), who found science students to have a low percentage of the knowledge of GC. The implication of this is that if science students have a low level of awareness and knowledge of GC, then, the expectation from non-science-based students would be extremely low. The low knowledge of the students in GC is an indication that they do not have sufficient knowledge of designing chemical processes and products to reduce or eliminate hazardous substances in the environment, minimising wastage to enhance efficiency in chemical industries, design processes that use or generate substances with minimal toxicity to improve safety at work places and reducing environmental harms. The students' knowledge of pollution prevention, the use of renewable feed stocks to reduce dependence on fossil fuels, and the use of catalysts to increase efficiency and reduce wastes were limited. This low knowledge of the students would negatively influence their attitude and ethical considerations towards promoting a safer and hazard-free environment that affect human health, ecosystems and climatic changes. Mulyanti and Kadarohman (2021) reported that weak knowledge of GC would reduce its applications.

The main source of students' awareness of GC was from the school chemistry curriculum, even though GC is not taught as a specific topic but it is taught in topics related to the environment. Social media also contributed to the students' source of awareness. The study found awareness and knowledge from peers and family discussions to be low. Green chemistry should be discussed more among students' peers and in families to harness the importance of green chemistry. Loste et al. (2020) indicated that education was a means of promoting green chemistry in a chemical and nonchemical

environment. The study proposed that the Massive Open Online Courses (MOOCs) model could be used to promote green chemistry and environmental sustainability. This supported the finding that the sources of awareness and knowledge of green chemistry came majorly from chemistry classes and curriculum. However, Grieger and Leontyeve (2020) reported in their study that the awareness and knowledge of students could be increased through peer interactions. That is, engaging the students in the use of peer instructional strategy in teaching chemistry and also encouraging students to discuss environmental issues at home would assist in combating environmental challenges.

The finding also revealed that gender does not have any bias on the level of awareness, knowledge, and the perception of the application of green chemistry in real-life situations. Principles of green chemistry education could promote gender equity in awareness and application. Green chemistry fosters equity by integrating ethical and scientific advancements to ensure sustainability benefits everyone in respective of their gender.

Recommendations

The study recommended the following

1) Inclusion of GC in science curricula at all levels of education because the knowledge of this field of chemistry can grant job opportunities to students in agriculture, pharmaceutical, and manufacturing industries.
2) The government should strengthen the environmental campaign to sensitize the entire populace on the awareness of green chemistry and its benefit to the society at large.
3) Public enlightenment on the principles, applications, benefits, and consequences of not complying with the principles of green chemistry
4) The government should implement environmental regulations and ensure compliance by industries and the public.

Conclusions

Education is an important means of promoting green chemistry, which will help in addressing some of the environmental challenges faced globally. There is, therefore the need to include green chemistry in the basic science curriculum at elementary levels and science subjects curricula in secondary schools. The awareness of GC in school curricula should also be strengthened, which will improve and affect directly or indirectly the awareness and knowledge of green chemistry through peer discussion.

References

1) Achu, S. K. (2024). Teachers' perception and attitude toward the integration of green chemistry principles in the school curriculum. International Journal of Science and Research Archive, 12(01), 2489-2504.
2) Alrawili, K. S. R., Youssif, A. E, & Saeed, A. M. (2024). The awareness degree of the principles and applications of green chemistry among students of scientific Colleges at University of Bisha. *Journal of Ecohumanism*, 3(4), 335-350.
3) Anastas, P. T. & Warner, J. C. (1998). *Principles of green chemistry. Green chemistry theory and practice*. Oxford University Press, New York.
4) Anastas, P. T. & Zimmerman, J. (2003). Design through the twelve principles of green engineering. Environmental Science & Technology, 37, 94A-101A.
5) Braungrat, M. & McDonough, W. (2002). *Remaking the way we make things.* North Point Press.
6) Clark, J. H. (2022). Using green chemistry to progress a circular fashion industry. Curr. Opin. Green Sustain. Chem., 38, 100685.
7) Collin, T. J. (1995). Introducing green chemistry in teaching and research. Journal of Chem. Educ., 72(11), 965-966.
8) Fantoni, T., Tolomelli, A. & Cabri (2022). A translation of the twelve principles of green chemistry to guide the development of cross-coupling reactions. Catal. Today, 397-399, 265-271.
9) Grieger, K. & Leontyev, A. (2020). Promoting student awareness of green chemistry principles via student-generated presentation videos. *Journal of Chemical Education,* 97(9), 2657-2663.
10) Gunbatar, S. A., Kiran, B. E., Boz, Y. &Oztay, E. S. (2025). A systematic review of green and sustainable chemistry training research with pedagogical content knowledge framework: current trends and future directions. *Chem. Educ. Res. Pract.,* 26, 34-52.
11) Ibrahim, M. M., Abas, A. Yahaya, A., Taha, H. Che Ahmad, C. N., & Yahaya, R. (2025). Exploring environmental sustainability awareness: perspectives of rural and urban school students and teachers on green chemistry and strategies for achieving sustainable development goals. *Journal of Lifestyle &SDS's Review*, 5(3), e04946. https://www.doi.org/10.47172/2965-730x.SDGsReview.v5.no3.pe04946.
12) Jonas, H. (1984). *The imperative of responsibility: In search of an ethics for the technological age*. University of Chicago Press.
13) Loste, N., Chinarro, D., Gomez, M., Roldan, E., & Giner, B. (2020). Assessing awareness of green chemistry teaching for sustainability. Journal of Chemical Education, Quimica Nova, 43(10), 1510-1521.
14) Mulyaanti, S. & Kadarohman, A. (2021). Students attitude towards green chemistry and its application. Journal of Physics: Conference Series, 1806, 012181. DOI 10.1088/1742-6596/1806/1/012181.
15) Saadon, S. Q. & Abbood, S. A. A. (2022). Awareness of green chemistry concepts among secondary school students. International Journal of Health Sciences, 6(S5), 9914-9931. https://doi.org/10.53730/ijhs.v6nS5.12100
16) Sajeena, S. (2021). A study on the role of green chemistry in daily of secondary school students. International Journal of Engineering Applied Sciences and Technology, 6(3), 340-345.

17) Stahel, W. R. (1982). The product-life factor: https://www.product-life/org/en/major-publications/the-product-life-factor.

18) Stubbs, S., Yousaf, S., & Khan, I. (2022). A review on the synthesis of bio-based surfactants using green chemistry principles. *DARU J. Pharm Sci.,* 30, 407-426.