

CHEMISTRY EDUCATORS' AWARENESS AND UTILIZATION OF GREEN CHEMISTRY PRINCIPLES IN TERTIARY INSTITUTIONS IN AKWA IBOM STATE: IMPLICATIONS FOR ENVIRONMENTAL SUSTAINABILITY

¹Umanah, F. I.; ²Arop, B. A. and ³Neji, H. A.

¹ Department of Science Education, Akwa Ibom State University, Mkpato Enin, Nigeria.

² Department of Integrated Science, Cross River State College of Education, Akamkpa.

³ Department of Science Education, University of Calabar Cross River State

Corresponding Author: feliciaumanah@aksu.edu.ng

Abstract

This study examined the level of Chemistry educators' awareness and utilization of green chemistry principles in tertiary institutions in Akwa Ibom State and its implications for environmental sustainability. A descriptive survey research design was adopted for the study. The population of the study consisted of 86 Chemistry educators in the 6 public tertiary institutions in Akwa Ibom State. A sample size of 54 Chemistry educators was used for the study. Simple random sampling technique was used to select 3 public tertiary institutions out of the 6 public tertiary institutions in the study area. In each of the selected tertiary institutions, an accidental sampling technique was used. The instrument used for data collection was the Awareness and Utilization of Green Chemistry Principles Questionnaire (AUGCPQ) with a reliability coefficient of .87. Data collected were analyzed using mean, standard deviation and independent t-test statistics. The results indicated a moderate level of chemistry educators' awareness and low level of utilization of green chemistry principles in tertiary institutions in Akwa Ibom State. Also, there was no significant difference in the level of male and female chemistry educators' awareness and utilization of green chemistry principles in tertiary institutions in Akwa Ibom State. Based on the findings, it is concluded that the importance of green chemistry in the curriculum not only supports academic growth but also contributes to raising environmentally responsible future scientists, which is essential for sustainable development and environmental protection in the region and beyond. It is therefore recommended among others that workshops, seminars and continuous professional development programs for chemistry educators focused on the practical application of green

chemistry principles should be organized. Chemistry curriculum in tertiary institutions should be reviewed and revised to include green Chemistry principles as a core component. This will ensure that students are exposed to sustainable practices early in their academic journey, creating a generation that of chemists who prioritize environmental sustainability.

Keywords: Chemistry educators, awareness and utilization, green chemistry principles, environmental sustainability.

Introduction

In an era marked by rapid industrialization and technological advancement, environmental problems such as climate change, pollution, waste generation and depletion of natural resources have triggered global efforts toward sustainability. One area of particular concern is the impact of chemical processes and product on the environment. Chemistry as a central science act as a manufacturer to satisfy human needs of shelter, food, clothing, transportation and good health (Umanah, 2024). From pharmaceuticals to plastics, chemical processes form the backbone of numerous industries, contributing to economic growth and technological innovations. The knowledge of Chemistry serves as a crucial foundation for various professions such as engineering, agriculture, medicine, pharmacy, nursing, biochemistry and several technological-based courses (Umanah & Akpan, 2024). However, traditional chemical practices are often associated with harmful environmental impacts, such as generation of hazardous waste, pollution, depletion of natural resources, and health problems to mention just a few. Most of the pollutants posing threats to man and his environment are chemically produced (Umanah & Udo, 2021). Hence, the need for a paradigm shift from the traditional chemical practices of causing harm to the environment to an eco-friendly and sustainable chemical practice.

The concept of green chemistry has emerged as one of the new advances and scientific developments in the field of Chemistry engineered towards the development of more environmentally friendly products and processes that both reduce waste and prevent toxic substances from entering the environment (Umanah, Udo & Owoyemi, 2019). Green chemistry also known as sustainable Chemistry refers to the design of chemical products and processes that reduce or

eliminate the use and production of substances that are hazardous to human health or the environment (Anastas & Warner, 1998 in Auliah, Muharram & Mulyadi, 2018). It is a fundamentally new approach to environmental protection, transitioning away from managing materials containing toxic chemicals at the end of a product's chemical life cycle, to reducing or eliminating the use of toxic chemicals. Green chemistry is based on 12 principles as advocated by Anastas and Warner, 1998 in Auliah, Muharram & Mulyadi, 2018). The 12 principles of Green chemistry are: Prevention, atom economy, less hazardous chemical syntheses, designing safer chemicals, safer solvents and auxiliaries, design for energy efficiency, use of renewable feedstock, reduce derivatives, catalysis, and design for degradation, real-time analysis for pollution prevention and inherently safer chemistry for accident prevention (Anastas & Warner, 1998 in Owoyemi & Umanah, 2019). Green chemistry is a key to addressing environmental challenges and promoting environmental sustainability. By adhering to these principles, chemists and chemistry educators can contribute to reducing the environmental footprint of chemical processes, enhancing safety and supporting sustainable development.

For the achievement of environmental sustainability, the next generation of chemists and their educators must be properly trained and equipped with the knowledge of the concepts and principles of green chemistry. No nation can rise above its educational system and no educational system can rise above the quality of its teachers (Eze, 2015). In tertiary institutions, chemistry educators play a crucial role in imparting knowledge and fostering awareness of green chemistry principles among students. Their ability to integrate green chemistry principles into the use of chemical products that are innocuous to good health and encourage the use of curriculum is vital for developing future chemists, to-be teachers and researchers who are equipped to address environmental issues (Zuin, Eilks, Elschami & Kummerer, 2021; Chen, Jeronen & Wang, 2020). Despite the importance of green chemistry, the extent to which chemistry educators in tertiary institutions in Akwa Ibom State are aware of and utilize green chemistry principles in their teaching remains uncertain. Hence, this study investigated the level of chemistry educators' awareness and utilization of green chemistry principles in teaching in tertiary institutions in Akwa Ibom State and its implications for environmental sustainability.

Green chemistry however, came as the solution to the problem of waste production and pollution management by encouraging chemical industries to make their reactions and products environmental benign. Many developed nations of the world have seen this as a welcome development. The teaching and learning of Chemistry is rarely connected to the relevant environmental issues. This could be attributed to chemistry educators' lack of awareness and knowledge of the

significance of green chemistry principles. Since the lecturers play a key role in the development and implementation of the curriculum in tertiary institutions, their perceptions, awareness and knowledge of the significance of green chemistry towards the achievement of environmental sustainability is of utmost importance. Hence, it becomes necessary to determine the level of chemistry educators' awareness and utilization of Green Chemistry principles in tertiary institutions in Akwa Ibom State and its implications for environmental sustainability.

The purpose of this study was to investigate the level of chemistry educators' awareness and utilization of green chemistry principles in tertiary institutions in Akwa Ibom State; implications for environmental sustainability. Specifically, the study sought to:

1. Determine the level of chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State.
2. Ascertain the level of chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State.
3. Determine the difference in the level of male and female chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State.
4. Determine the difference in the level of male and female chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State.

Research Questions

1. What is the level of chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State?
2. What is the level of chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State?
3. What is the difference between male and female chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State?
4. What is the difference between male and female chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State?

Hypotheses

1. There is no significant difference in the level of male and female chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State.

2. There is no significant difference in the level of male and female chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State.

Methodology

This study adopted a descriptive survey research design. This study was carried out in Akwa Ibom State. The population of the study consisted of 86 chemistry educators in the 6 public tertiary institutions in Akwa Ibom State. A sample of 54 chemistry educators from 3 public tertiary institutions was used for the study. A simple random sampling technique was used to select 3 public tertiary institutions out of the 6 public tertiary institutions in the study area. In each of the selected tertiary institutions, an accidental sampling technique was used. The instrument tagged: Awareness and Utilization of Green Chemistry Principles Questionnaire (AUGCPQ) was used for data collection. The AUGCPQ consisted of two sections; A and B. Each section consisted of 12 items from the concept of the green chemistry principles. Section A dealt with the level of awareness of green chemistry principles and Section B dealt with the level of utilization of green chemistry principles. The instrument was validated by two experts in Measurement and Evaluation in the Department of Science Education, Akwa Ibom State University. The reliability of the instrument was determined using a sample of 10 chemistry educators selected from a tertiary institution in the study area but not part of the sample for the study. The reliability index of 0.87 was obtained using Cronbach Alpha. The AUGCPQ was administered to chemistry educators in each of the selected tertiary institutions. The data collected were analyzed using mean, standard deviation and independent t-test. Mean and standard deviation were used to answer the research questions while independent t-test was used to test the hypotheses formulated at .05 level of significance. In order to take decisions as regards research questions 1 and 2, any mean score that falls between: 1.00-1.49, 1.50-2.49, 2.50-3.49 and 3.50-4.00 were taken to indicate: Low Level (LL), Moderate Level (ML), High Level (HL), Very High Level (VHL). Also, in order to take decisions as regards research question 3 and 4, any group (either male or female) with the higher mean was regarded to have higher level of awareness and utilization respectively as compared to the one with the lower mean. In terms of the hypotheses, whenever the probability level of significance was less than .05 the null hypotheses were rejected and whenever the probability level of significance greater than .05, the null hypotheses were accepted.

Results

Research Question One What is the level of chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State?

Table 1: Mean and Standard Deviation Scores of the level of Chemistry Educators' Awareness of Green Chemistry Principles in Tertiary Institutions in Akwa Ibom State.

S/N	STATEMENT	\bar{x}	SD	Remarks
1.	Prevention of Waste	2.83	1.15	HL
2.	Atom Economy	2.02	0.90	ML
3.	Less Hazardous Chemical Syntheses	2.57	1.14	HL
4.	Designing Safer Chemicals	2.37	1.15	ML
5.	Safer Solvents and Auxiliaries	2.44	1.09	ML
6.	Design for Energy Efficiency	2.30	1.06	ML
7.	Use of Renewable Feedstocks	2.24	1.06	ML
8.	Reduce Derivatives	2.22	1.02	ML
9.	Catalysis	2.56	1.16	HL
10.	Design for Degradation	2.20	0.94	ML
11.	Real-time analysis for Pollution Prevention	2.44	1.09	ML
12.	Inherently Safer Chemistry for Accident Prevention.	2.43	1.02	ML
Cluster Mean		2.39	1.07	ML

The result in Table 1 showed the mean range for the response of the respondents on the level of chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State for items 1,3 and 9 falls within 2.50-3.49. This means that there is high level of awareness of prevention of waste, less hazardous chemical syntheses and catalysis. The result of the analysis as shown in the Table also revealed the mean range for items 2,4,5,6,7,8,10,11 and 12 which falls within 1.50-2.49. This means that there is moderate level of awareness of atom economy, designing safer chemicals, safer solvents and auxiliaries, design for energy efficiency, use of renewable feed stocks, reduce derivatives, design for degradation, real-time analysis for pollution prevention and inherently safer chemistry for accident prevention. The result in Table 1 also showed standard deviation scores of the respondents which ranged from 0.94 to 1.16. These relatively low values of standard deviation indicate that the variation among the respondents' scores is minimal, meaning the individual scores are closely grouped around the mean. Also, the cluster mean of 2.39 for all the items

indicates that there is moderate level of chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State.

Research Question Two

What is the level of chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State?

Table 2: Mean and Standard Deviation Scores of the level of Chemistry Educators' Utilization of Green Chemistry Principles in Tertiary Institutions in Akwa Ibom State

NO.	STATEMENT	\bar{x}	SD	Remarks
1.	Prevention of Waste	2.00	1.10	ML
2.	Atom Economy	1.44	0.66	LL
3.	Less Hazardous Chemical Syntheses	1.59	0.84	ML
4.	Designing Safer Chemicals	1.46	0.75	LL
5.	Safer Solvents and Auxiliaries	1.41	0.66	LL
6.	Design for Energy Efficiency	1.39	0.69	LL
7.	Use of Renewable Feedstocks	1.37	0.65	LL
8.	Reduce Derivatives	1.33	0.58	LL
9.	Catalysis	1.43	0.74	LL
10.	Design for Degradation	1.33	0.61	LL
11.	Real-time analysis for Pollution Prevention	1.39	0.66	LL
12.	Inherently Safer Chemistry for Accident Prevention.	1.57	0.79	ML
	Cluster Mean	1.48	0.73	LL

The result in Table 2 showed the mean range for the response of the respondents on the level of chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State for items 1,3 and 12 falls within 1.50-2.49. This means that there is moderate level of utilization of prevention of waste, less hazardous chemical syntheses and inherently safer chemistry for accident prevention. The result of the analysis as shown in the Table also revealed the mean range for item 2, 4, 5,6,7,8,9,10 and 11 which falls within 1.00-1.49. This means that there is low level of utilization of atom economy, designing safer chemicals, safer solvents and auxiliaries, design for energy efficiency, use of

renewable feed stocks, reduce derivatives, catalysis, and design for degradation and real-time analysis for pollution prevention. The result in Table 2 also showed standard deviation scores of the respondents which ranged from 0.58 to 1.10. These relatively low values of standard deviation indicate that the variation among the respondents' scores is minimal, meaning the individual scores are closely grouped around the mean. Also, the cluster mean of 1.48 for all the items indicates that there is low level of chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State.

Research Question Three

What is the difference in the level of male and female chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State?

Table 3: Mean and Standard Deviation of the Difference in the level of Male and Female Chemistry Educators' Awareness of Green Chemistry Principles in Tertiary Institutions in Akwa Ibom State

Gender	n	\bar{x}	SD
Male	35	2.41	0.84
Female	19	2.33	1.00

The result as shown in Table 3 reveals that the mean score of 2.41 obtained by male chemistry educators on the level of awareness of green chemistry principles was slightly greater than the mean score of 2.33 obtained by their female counterparts. This result implies that there is no difference in the level of male and female chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State.

Research Question Four

What is the difference in the level of male and female chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State?

Table 4: Mean and standard deviation of the difference in the level of male and female chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State

Gender	n	\bar{x}	SD
Male	35	1.55	0.58
Female	19	1.34	0.50

The result as shown in Table 4 reveals that the mean score of 1.55 obtained by male chemistry educators on the level of utilization of green chemistry principles

was slightly greater than the mean score of 1.34 obtained by their female counterparts. This result implies that there is no difference in the level of male and female chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State.

Hypothesis One

There is no significant difference in the level of male and female chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State?

Table 5: Independent t-test Analysis of the Difference in the level of Male and Female Chemistry Educators' Awareness of Green Chemistry Principles in Tertiary Institutions in Akwa Ibom State.

Gender	n	\bar{x}	SD	t-value	Sig	Remarks
Male	35	2.41	0.84	0.32	0.75	Not significant
Female	19	2.33	1.00			

The result in Table 5 shows the t-value of 0.32 and the corresponding probability level of significance of 0.75 alpha at 52 degrees of freedom. This level of significance is greater than .05 in which the decision is based. With this result, the null hypothesis was retained. This implies there is no significant difference in the level of male and female chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State.

Hypothesis Two

There is no significant difference in the level of male and female chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State?

Table 6: Independent t-test Analysis of the Difference in the level of Male and Female Chemistry Educators' Utilization of Green Chemistry Principles in Tertiary Institutions in Akwa Ibom State.

Gender	n	\bar{x}	SD	t-value	Sig	Remarks
Male	35	1.55	0.58	1.31	0.20	Not significant
Female	19	1.34	0.50			

The result in Table 6 shows the t-value of 1.31 and the corresponding probability level of significance of 0.20 alpha at 52 degrees of freedom. This level of significance is greater than .05 in which the decision is based. With this result, the null hypothesis was retained. This implies there is no significant difference in the

level of male and female chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State.

Discussion of Findings

The finding on the level of chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State showed a moderate level of awareness of green chemistry principles among chemistry educators. The finding lend credence to that of Moju (2021) who found that a moderate number of in-service chemistry teachers had better understanding in terms of knowledge of the concept of green chemistry compared to the pre-service chemistry teachers. The finding contradicts that of Owoyemi and Adesina (2020), Umanah and Owoyemi (2019) and Auliah, Muharram and Mulyadi (2018) who reported that chemistry teachers had low level of awareness of green chemistry principles.

The finding on the level of chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State indicated that there was low level of chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State. The finding on the difference in the level of male and female chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State indicated that there was no significant difference in the level of male and female chemistry educators' awareness of green chemistry principles in tertiary institutions in Akwa Ibom State. This result lend credence to that of Hussein and Ahmed (2021) who reported that gender had no significant difference in chemistry teachers' awareness on the principle of green chemistry. However, the finding contradicts that of Owoyemi and Adesina (2021) who reported that male chemistry teachers had more content knowledge than their female counterparts.

The finding on the difference in the level of male and female chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State revealed that there is no significant difference in the level of male and female chemistry educators' utilization of green chemistry principles in tertiary institutions in Akwa Ibom State.

Conclusion

Based on the findings of this study, it is concluded that Chemistry educators in tertiary institutions in Akwa Ibom State possess a moderate level of awareness and low level of utilization of green chemistry principles and low level of utilization. The low level of utilization of green chemistry principles in tertiary

institutions means that students graduate without the necessary knowledge and skills to incorporate sustainable practices in their careers and contribute toward achievement of environmental sustainability. These findings underscore the urgent need for a more comprehensive approach to integrating green chemistry into tertiary education to raise a generation of environmentally conscious scientists who can contribute to sustainable development.

Recommendations

Based on the conclusion of this study, the following recommendations are made:

1. Tertiary institutions should review and revise their chemistry curricula to incorporate green chemistry principles as a core component.
2. Regular workshops, seminars, and professional development programs should be organized for chemistry educators to enhance their practical knowledge and skills in green chemistry.
3. Institutions should engage in public awareness campaigns that highlight the importance of green chemistry for environmental sustainability.
4. A system for monitoring and evaluating the integration of green chemistry in educational practices should be established.
5. Government and tertiary institutions should provide incentives such as research grants, awards, and recognition for educators and students who conduct research in green chemistry.

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