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Educating Prospective Science Teachers in Green Chemistry Innovations for Sustainable Development

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Abstract

The integration of Green Chemistry Innovations in Science Teacher Education encourages the use of green alternatives and promotes the development of innovative teachings strategies that emphasize sustainability. This study examines science teachers educators' perception and attitude towards educating prospective science teachers in Green Chemistry innovations for sustainable development in Colleges of Education, South-South Nigeria. The study sample consist of 200 lecturers selected using simple random sampling technique from Schools of Sciences in Colleges of Education in South-South Nigeria. The instrument used in gathering data for the study was "Perception and Attitude of Science Teachers Educator' towards Integrating Green Chemistry Questionnaires (PASTEIGCQ)". Cronbach Alpha reliability formula was used to obtain a reliability coefficient of 0.84 for the instrument. Data obtained were analyzed using mean, standard deviation and t-test Statistics. The findings indicated that science teachers educators have good perception and positive attitude towards educating prospective science teachers in Green Chemistry innovations for sustainable development. Consequently, it was recommended among others that Green Chemistry principles should be integrated into science teacher education program for sustainable development in Nigeria.

Keywords: Science teacher education, Green chemistry, Sustainable development

INTRODUCTION

The composition of the earth's atmosphere is currently undergoing an unprecedented change, largely due to industrial development, human activities and agricultural practices. These activities have resulted in an increase in the atmospheric concentration of pollutants gases such as carbon (iv) oxide and methane that are responsible for the greenhouse effect. The increase in the concentration of these pollutants gases have far reaching consequences on our environment. Agbayewa, Oloruntegbe and Alake (2013) asserted that the scientific estimate of these gases indicates a rise in the global mean temperature of between 1.4°C and 5.8°C over the next 100 years. Oil communities in Nigeria are living with gas stacks that flare gas 24 hours a day at a

temperature range of between 13,000 to 14,000°C. The implications of temperature rise of these magnitude over time would impact negatively on earth's biocapacity. Our water bodies are not equally spared of pollutant from untreated affluent from scientific activities. Besides all these, there are other socio-economic and domestic issues and practices that necessitates the introduction of education for sustainable development into the Nigerian educational system particularly in the Science Teachers Training Institutions.

Sustainable development entails ensuring better quality of life for everyone both now and for generations to come. Although this idea is simple, the task is substantial. The rising interest in environmental literacy and education for sustainability has created expectations that timely, accurate content should be taught at all levels, particularly in science teacher education program (Owoyemi and Moju 2015). There is a need to educate prospective science teachers with the knowledge, skills and appropriate values to ensure sustainability. In recent years, a growing number of publications have emerged discussing how to integrate education for sustainable development into science education. However, in the Nigerian educational sector little is done in this area. In 2015, the United Nations (UN) issued the Agenda 2030 in which it defined seventeen Sustainable Development Goals (SDGs) to be achieved by 2030, among them SDG 4 "Quality Education" in general and education for sustainable development in particular (Linkwitz and Eilks, 2022). Education for sustainable development is a regulatory idea within the 21st century education in which all teachings and learning domains needs to contribute. According to Linkwitz and Eilks (2022), the agenda 2030 states that by 2030, all learners must acquire knowledge and skills needed to promote sustainable development, including and among others through education for sustainable development and sustainable lifestyles, human rights, gender equality and appreciation of cultural diversity and of cultures contribution to sustainable development. An analysis of the United Nations Environmental Program (UNEP), namely the Global Chemical Outlook II (GCO II), was also published recently with focus among other things on chemistry education (UNEP, 2019). The GCO II generally suggests that science is central to many challenges laid down in the SDGs and is connected to almost all of them. Sequel to that fact that science is central to many sustainable challenges today, education for sustainable development needs to become a central focus of science education at all levels.

One of the strategies taken to address education for sustainable development is through the integration of Green Chemistry innovations into the science teacher education curriculum. Curriculum action is necessary to provide learners with a contemporary, balanced view of how science is carried out today and should be in the future. It is also important to learn how changes in chemistry and its associated application affects the environment and society. The concept of Green Chemistry (GC), also known as Sustainable Chemistry (SC) was developed and introduced by Paul V. Anasta and John Warner in 1998 in response to growing adverse effects of science on the environment. According to Anasta and Warner (1998), Green Chemistry is the utilization of a set of principles that reduces or eliminates the use of or generation of hazardous substances in the design, manufacture and application of chemical products. Below are the twelve principles of Green Chemistry as outlined by Anasta and Warner (1998):

- (i) Prevention: It is better to prevent waste than to treat or clean up waste after it has been created.
- (ii) Atom Economy: Synthetic method should be designed to maximize incorporation of all materials used in the process into the final product.
- (iii) Less Hazardous Chemical Synthesis: Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
- (iv) Designing Safer Chemicals: Chemical product should be designed to effect their desired function while minimizing their toxicity.
- (v) Safer Solvent and Auxiliaries: The use of auxiliary substances (e.g solvent separation agent) should be made unnecessary where ever possible and innocuous when used.
- (vi) Design for Energy Efficiency: Energy requirements of chemical processes should be recognized for their environmental and economic impact and should be minimized if possible, synthetic methods should be conducted at ambient temperature and pressure.
- (vii) Use of Renewable Feedstocks: A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
- (viii) Reduce Derivatives: Unnecessary derivatives (use of blocking group, protection/deprotection, temporary modifications of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagent and can generate waste.
- (ix) Catalyst: Catalyst reagent (as selective as possible) are superior to stoichiometric reagents.
- (x) Design for Degradation: Chemical products should be designed so that at the end of their function, they break down into innocuous degradation products and do not persist in the environment.
- (xi) Real-Time Analysis of Pollution Prevention: Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substance.
- (xii) Inherently Safer Chemistry for Accident Prevention: Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accident, including releases, explosion and fires.

Green Chemistry is a student centered active learning approach of teaching science content in an eco-friendly way. According to Umanah and Udo (2021), Green Chemistry is the

practice of chemical science and manufacturing in a manner that is sustainable, safe and non-polluting and that consumes minimum amount of materials and energy while producing little or no waste materials. It is a science of creating safe, energy efficient and non-toxic products and processes and provides a concrete path towards solving the environmental problems that we are facing in our society. The adoption of Green Chemistry begins with recognizing that production, processing, use and eventually disposal of chemical products may be disastrous if not done in the proper way. Basically, Green Chemistry harnesses a vast body of scientific knowledge and applies it in the production, use and ultimate disposal of chemicals in a way that minimizes consumption of materials, exposure of living organisms, including humans to toxic substances and damage to the environment. This practice must be done in a way that is economically feasible and cost effective. Owoyemi and Moju (2020) asserted that with the knowledge of Green Chemistry, scientists can manipulate the molecular characteristics of substances so that it possesses a reduced hazard or no hazard at all. Karpudewan, Ismail and Mohamed (2011) opined that, Green Chemistry is interdisciplinary in nature and involves exploration of the environment. Hence, it can serve as a theme to facilitate integrative and interdisciplinary learning experiences where the students use their critical thinking and communication skills to address complex problems facing the scientific enterprise. Through the application of Green Chemistry principles, Green Chemistry innovation can contribute to sustainable development. According to Eze (2015), in the United Kingdom (UK), the Green Chemistry Network (GCN) was established as far back as 1998 to help promote and encourage the application of Green Chemistry in all area where Chemistry plays a significance role. In 1990s the Green Chemistry Institute (CGI) was established in USA which is now part of the American Chemical Society. There is also a presidential award instituted for Green Chemistry innovations in USA.

In Nigeria these principles are not considered with seriousness on the part of the educational stakeholders. As Nigeria hopes to join the league of industrialized nations and move the frontiers of development beyond 2030, there is a need for prospective science teachers to be armed with good knowledge of Green Chemistry principles. Teacher training institutions have an important role to play due to the impact that they have on the curricula and policy for the implementation of these curricula to bring about systematic economically efficient changes. One of the objectives of teacher education in Nigeria as enunciated by the National Policy on Education (2013) among others is to provide teachers with the intellectual and professional background adequate for their assignment and make them adaptable to changing situations. The emerging world order requires that Green Chemistry principles be internationalized and put into practice. This task falls squarely on science teachers, hence, the need to educate prospective science teachers on Green Chemistry innovations for sustainable development. The curriculum used for science teacher education program need to be enriched with these cutting edge principles as the country strives to position herself among the developed countries of the world. It is imperative that science must turn away emphasis on the exploitation of limited resources and the production of increasing amount of products that ultimately end up as waste. The way forward is the application of science in avenues that provide for human needs without damaging

its support system upon which all living things depend. Industries should churn out products that are innocuous to good health, environmental friendliness and resource sustainability.

The practice of science in a manner that maximizes its benefits while eliminating or at least reducing its adverse effect is a good justification for educating prospective science teachers on Green Chemistry principles for sustainable development. Auliah, Muharram and Mulydi (2018) asserted that the concept of sustainability, which is born by Green Chemistry should be socialized and introduced at all levels of education. Sameena and Gowda (2015) and Hessein and Ahmed (2021) opined that Green Chemistry is a tool for inspiring students to pursue scientific careers that is often abstract and preparing the student for future sustainability challenges. In the opinion of Caruana (2015), Owoyemi and Umanah (2019) and Chhangani (2023), the concept of green chemistry, when properly harnessed, has the ability to shape future sustainability and development. Green Chemistry should be introduced into the curriculum so that the academia and the industry will work towards curbing the effect of the dangerous chemicals in the environment through teaching. Hence, this study is intended to investigate the science teachers educators' perception and attitude towards educating prospective science teachers in Green chemistry innovations for sustainable development.

Gender is considered as one of the variables that may likely affect the perception and attitude of science teachers educators towards educating prospective science teachers in Green Chemistry innovations for sustainable development. Gender is an analytical concept that describes the sociological roles, cultural responsibilities and expectations of men and women in a given society or cultural setting (Eya and Ezeh, 2020). Studies on gender as it affects the integration of Green Chemistry into science education curriculum are inconclusive. Sameena and Gowda (2015) reported a significant difference in the perception and attitude towards Green Chemistry between undergraduate male and female students, while Owoyemi and Moju (2020) observed that gender has no significant influence on science teachers' perception and attitude towards the integration of Green Chemistry principles. Since the reports from various studies on gender are inconsistent, gender as a variable attracts further investigation in this study.

Statement of Problem

Nigeria as a nation, is not exempted from the various environmental problems such as climate change, air pollution and water pollution among others that are ravaging the world today. One of the ways of addressing these global issues is the integration of Green Chemistry principles through Education for Sustainable Development (ESD) into the educational system to empower the students with adequate knowledge on how to make the environment sustainable for this generation and future generations. In the Nigerian education system, the concept of Green Chemistry is relatively new and Nigerian science teachers are grappling with the challenges arising from the scientific and technological demands of the modern society. Some of these challenges are overwhelming to our science teachers because they do not receive training on them while in the teacher training institutions. To forestall this ugly situation, there is a need to

educate prospective science teachers in Green Chemistry Innovations for sustainable development. This will make the pre-service teachers conversant with the principles of Green Chemistry before they become full-time classroom teachers. This study investigates science teacherseducators' perception and attitude towards educating prospective science teachers in Green Chemistry Innovation for Sustainable Development.

Research Questions

The following research questions guided the study:

- (i) What is the perception of science teacher educators (male and female) towards educating prospective science teachers in Green Chemistry Innovations for sustainable development in Colleges of Education?
- (ii) What is the attitude of science teacher educators (male and female) towards educating prospective science teachers in Green Chemistry Innovations for sustainable development in Colleges of Education?

Research Hypotheses:

- (i) There is no significant influence of gender on science teachers educators' perception towards educating prospective science teachers in Green Chemistry Innovations for sustainable development in Colleges of Education.
- (ii) There is no significant influence of gender on science teachers educators' attitude towards educating prospective science teachers in Green chemistry innovations for sustainable development in Colleges of Education.

RESEARCH METHODOLOGY

The study adopted the descriptive survey research design. The population of the study consisted of all the 882 lecturers in Schools of sciences in the 10 Colleges of Education in South-South Nigeria. Simple random sampling technique was used to select 20 lecturers from Schools of Sciences in each of the 10 Colleges of Education. This constituted a sample size of 200 (108 male and 92 female) lecturers. A researcher developed instrument titled "Perception and Attitude of Science Teacher Educators' towards integrating Green Chemistry Questionnaire (PASTEIGCQ)" was used for data collection. The instrument was made up of three sections (A, B and C). Section A contained demographic information such as name of institution and gender of the participants. Section B was made up of 10 items on participant's perception on educating prospective science teachers on Green Chemistry Innovations for sustainable development and section C was made up of 10 items on participants' attitude towards educating prospective science teachers on Green Chemistry Innovations for sustainable development. Section B and C

were designed on a four-point rating scale of Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD). The questionnaire was subjected to face and content validation by three independent assessors; two content experts in chemistry education and one measurement and evaluation expert. The reliability of the instruments with determined by the statistical analysis of data generated from a pilot today. Cronbach alpha reliability formula was used to obtain a reliability coefficient of 0.84 for the instrument. Out of 200 copies of the questionnaires that were administered, 198 copies were returned representing 99% return rate. The decision rule adopted for the research questions was made using real number as follows: mean scores between 3.50 - 4.00 (Strongly Agree), 2.50- 3.49 (Agree), 1.50-2.49 (Disagree) and 0.50-1.49 (Strongly Disagree). Also, for research question 2, whenever the average means score was less than 2.50, it was taken to indicate negative attitude while 2.50 and above, was taken to indicate positive attitude. Data collected were analyzed using mean and standard deviation to answer the research questions while t-test was used to test null hypotheses formulated at 0.05 alpha level.

RESULTS

Research Question One: What is the perception of science teachers educators (male and female) towards educating prospective science teachers in Green Chemistry Innovations for sustainable development in Colleges of Education?

Table 1: Science Teachers Educators' Perception towards Educating Prospective Science Teachers in Green Chemistry Innovations for Sustainable Development.

S/N	ITEMS	MEAN	STANDARD DEVIATION	REMARKS
1	Green chemistry principles should be practiced in the laboratories	3.58	0.81	SA
2	Science teachers educators are in the right position to promote green chemistry activities in the teaching and learning processes	2.88	0.72	A
3	Science teachers educators remain at the center of any innovation in the science education curriculum.	3.60	0.88	SA
4	As a science teacher educator, I have a pivotal role of integrating green chemistry principles in my teaching.	3.50	0.78	SA
5	It is better to prevent waste generation than to eliminate it after generation.	3.80	0.64	SA
6	The knowledge of green chemistry is necessary for science teachers and students	3.50	0.91	SA
7	Integrating Green Chemistry principles into the science teacher education curriculum can be a solution to environmental issues.	2.58	0.79	A
8	Science teachers are the major stakeholders in the implementation of green chemistry.	2.84	0.67	A
9	Green chemistry has a potential of reducing the negative impact of the chemical products on humans and environment.	3.20	0.91	A
10.	Green chemistry ensures environmental sustainability	3.48	0.80	A
	Average Mean	3.27	0.79	A

N = 198 (106 male and 92 female)

The result in Table 1 showed the perception of science teacher educators towards educating prospective science teachers in green chemistry innovation for sustainable

development in Colleges of Education. The results showed that the mean value of 6 out of 10 items in the table ranged from 2.58 to 3.48 which were between the boundary limit of 2.50 to 3.49 on a 4-points rating scale. This mean that the items were rated “Agreed” by respondent. The remaining 4 items had mean values ranging from 3.50 to 3.80 which is between the boundary limits of 3.50 to 4.00 on 4-point rating scale. This is an indication that the items were rated by the respondents as “Strongly Agreed”. The table also show that the average standard deviations score of 0.79 indicating that the spread of the scores from the mean was not wide apart. However, since the average mean score fell between 2.50 to 3.49 it implies that science teachers educators (male and female) agreed that prospective science teachers should be educated in Green Chemistry Innovations for sustainable development. This implies that the lecturers perceived that educating prospective science teachers in Green Chemistry Innovations can help to tackle the environmental issues.

Research Question Two: What is the attitude of science teachers educators (male and female) towards educating prospective science teachers in green chemistry innovations for sustainable development in Colleges of Education?

Table 2: Science Teachers Educators' Attitude towards Educating Prospective Science Teachers in Green Chemistry Innovations for Sustainable Development

S/N	ITEMS	MEAN	STANDARD DEVIATION	REMARKS
1	I would like to know more about Green Chemistry.	3.20	0.58	A
2	I am ready to incorporate Green Chemistry principles into my science classes.	2.96	0.91	A
3	I am ready to change my current laboratory practices in order to incorporate Green Chemistry principles.	3.20	0.84	A
4	Curriculum planners should integrate Green Chemistry principles into the science curriculum.	2.94	0.62	A
5	As a teacher, I believe that the knowledge of Green Chemistry is necessary for science students.	3.08	0.81	A
6	Green Chemistry should be made compulsory in science teacher education	2.70	0.78	A
7	I have a responsibility to engage in Green Chemistry practices.	3.20	0.88	A
8	Green Chemistry concept in the science teacher education curriculum can help to solve our current environmental challenges.	2.72	0.71	A
9	As a teacher, I can play an important role in solving environmental problems through Green Chemistry.	2.84	0.82	A
10	I am of the opinion that Green Chemistry can improve teacher's and student's interest in science.	3.21	0.79	A
	Average Mean	3.01	0.72	A

N = 198 (106 male and 92 female)

The data presented in Table 2 revealed the attitude of science teachers educators' towards educating prospective science teachers in Green Chemistry Innovation for sustainable development in Colleges of Education. The result showed that the mean value of all the thing items in the table ranged from 2.70 to 3.20 which were between the boundary limit of 2.50 to 3.49 on a 4-points ratings scale. This means that the items were rated "Agreed" by the respondents. The table also showed the average standard deviations score of 0.72 indicating that the spread of the scores from the mean was wide apart. However, since the average mean score is

greater than 2.50, it implies that the science teacher educators (male and female) have a positive attitude towards educating prospective science teachers in Green Chemistry Innovations for sustainable development.

Hypotheses Testing

HO₁: There is no significant influence of gender on science teachers educators' perception towards educating prospective science teachers in green chemistry innovations for sustainable development in Colleges of Education.

Table 3: T-test Analysis of Science Teachers Educators' Perception towards Educating Prospective Science Teachers in Green Chemistry Innovations for Sustainable Development in Colleges of Education

Gender	N	Mean	SD	Df	T-cal	T-crit	Decision at $p \leq 0.05$
Male	106	3.11	0.78				
Female	92	2.98	0.62	196	1.30	1.97	NS

Data in Table 3 above shows the mean and standard deviation of science teachers educators' perception towards educating prospective science teachers in Green Chemistry Innovations for sustainable development classified by gender. The calculated t-value 1.30 is less than the critical t-value 1.97 at degree of freedom, Df 196. This implies that there is no significant difference between male and female science teachers educators' perception towards educating prospective science teachers in Green Chemistry Innovations for sustainable development in Colleges of Education. Therefore, the null hypothesis, HO₁, is accepted.

HO₂: There is no significant influence of gender on science teachers educators' attitude towards educating prospective science teachers in Green Chemistry Innovations for sustainable development in Colleges of Education.

Table 4: T-test Analysis of Science Teachers Educators' Attitude towards Educating Prospective Science Teachers in Green Chemistry Innovations for Sustainable Development in Colleges of Education

Gender	N	Mean	SD	Df	T-cal	T-crit	Decision at $p \leq 0.05$
Male	106	2.98	0.69				
Female	92	3.03	0.74	196	0.50	1.97	NS

Data in Table 4 above shows the mean and standard deviation of science teachers educators' attitude towards educating prospective science teachers in green chemistry innovations for sustainable development classified by gender. The calculated t-value 0.50 is less than the critical t-value 1.97 at degree of freedom, Df 196. This implies that there is no significant difference between male and female science teachers educators' attitude towards educating prospective science teachers in Green Chemistry Innovations for sustainable development in Colleges of Education. Therefore, the null hypothesis, H_0 , is accepted.

DISCUSSION

The result in Table 1 showed that science teachers educators are of the view that prospective science teachers should be educated in Green Chemistry Innovations for sustainable development, this is evidenced in their high level of agreement displayed in their perception towards educating prospective science teachers in Green Chemistry Innovations for sustainable development. This is impressive as science teachers educators in Nigeria are willing to integrate the concepts of Green Chemistry in educating prospective science teachers. This finding is in agreement with Owoyemi and Moju (2020) who observed that science teachers in Nigeria are of the view that Green Chemistry concepts should be integrated into science teachings. This finding is also consistent with Chhangani (2023) who observed that Green Chemistry concept when properly harnessed has the potential of shaping future sustainability and development. However, findings negate that of Auliah Muharram and Mulyadi (2018) who observed in their study that only 31.88% of science teachers believed that the principles of Green Chemistry should be integrated into science teaching and learning.

The result in Table 2 showed that science teachers educators possess positive attitude towards educating prospective science teachers in Green Chemistry for sustainable development in Colleges of Education. This is a sort of relief as it is a known fact that teachers' attitude is key in any effort to incorporate any emerging issue into the curriculum. This finding is in line with the findings of Owoyemi and Moju (2015) and Owoyemi and Moju (2020) who observed that Nigerian teachers possess high positive attitude towards the incorporation of green chemistry principles into the curriculum in Nigerian learning institutions. This finding corroborates the findings of Caruana (2015) who opined that positive attitude to the practice of Green Chemistry in schools is a good sign for sustainable development. This finding contradicts that of Umanah and Udo (2021) who observed that teachers in Nigerian schools are negatively disposed towards the integration of Green Chemistry principles into the curriculum of Nigerian schools.

The results in Table 3 and 4 reveal that gender does not have any significant influence on the perception and attitude of science teacher educators towards educating prospective science teachers in Green Chemistry innovations for sustainable development. This implies that both male and female lecturers hold the same view and possess the same attitude towards the

integration of Green Chemistry principles in science teacher education programme. This finding is in agreement with Owoyemi and Moju (2020) who observed that gender has no significant influence on science teachers' perception and attitude towards the integration of Green Chemistry principles. However, the finding contradicts that of Sameena and Gowda (2015) who reported a significant difference in the perception and attitude towards Green Chemistry between undergraduate male and female students.

Recommendations

The following recommendations were made based on the findings of the study:

- (i) Green Chemistry principles should be integrated into science teachers' education program for sustainable development in Nigeria.
- (ii) The government should support and prioritize industries that adhere to Green Chemistry principles in their operations.
- (iii) Stakeholders in education, industries and environmental protection agencies should promote and raise the awareness on Green Chemistry principles.
- (iv) In-service training, seminars, workshops and conferences should be organized for science teachers for capacity building on Green Chemistry education.

Conclusion

Educating prospective science teachers in Green Chemistry Innovations is a significant step towards ensuring environmental sustainability. Consequent upon the findings of this study, it is concluded that prospective science teachers should be educated on Green Chemistry Innovations for sustainable development in Colleges of Education. This is evident in their high level of agreement displayed in their perception and positive attitude towards incorporating Green Chemistry into the science teacher education curriculum.

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