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Integrating Green Chemistry Approach in Teaching and Learning Esterification Among Senior Secondary Students in Uyo, Nigeria

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ABSTRACT

Traditional chemistry teaching methods often emphasize conventional techniques, which can overlook sustainability. Integrating Green Chemistry into the curriculum addresses this gap by promoting eco-friendly practices and enhancing students' critical thinking skills. This study aimed to examine the impact of the Green Chemistry (GC) approach on students' academic achievement in teaching esterification. The study was guided by two specific objectives, research questions, and hypotheses. A quasi-experimental control group design was employed, with post-test data. A sample of 120 students were drawn from a population of 3,246 students across 15 public secondary schools in Uyo. The experimental group, consisting of 28 urban and 30 rural students, was taught esterification using ethanol extracted from fermented palm wine and vinegar. The control group, comprising 62 students, was taught using conventional chemicals such as ethanol and ethanoic acid. Data were collected through the Chemistry Achievement Test (CAT) on esterification, with a reliability coefficient of 0.85. Analysis using mean, standard deviation, and independent t-tests revealed a significant difference in the academic achievement of students taught using the Green Chemistry approach compared to those taught using the conventional laboratory approach (CL). Furthermore, urban students outperformed rural students when both were taught using the Green Chemistry approach. Based on these findings, the study recommends that educational institutions adopt the Green Chemistry approach for teaching esterification and that teachers receive training to ensure its effective integration into classrooms.

KEYWORDS: Green chemistry education, esterification, students' academic achievement.

1. INTRODUCTION

The aim of chemistry education goes beyond merely preparing students for careers in the chemical sciences; it also seeks to help them understand the relevance of chemical applications and use of chemistry responsibly and sustainably. Unfortunately, the traditional way of teaching chemistry does not prioritize this aspect.Omoniyi[1] noted that, to meet the challenges of the 21st century, there is a need for an effectively implemented chemistry curriculum that inculcates in students the nature and benefits of chemistry to life and society. The current curriculum is designed to align with the objectives of science education as stated in the National Policy on Education[2], one of which is to foster critical thinking, problem-solving skills, and scientific attitudes in students. Achimugu[3] emphasized that, to achieve these objectives, chemistry teachers must effectively bridge curriculum and the students. Not only that they must also provide a grassroots approach to education -equipping young learners with advocacy skills, exposing them early to sustainable practices, and preparing them to contribute towards the achievement of the UN SDGs and to tackle environmental challenges in the future. This underscores the importance of Green Chemistry Education.

According to Achu[4], Green Chemistry in education is a novel approach to teaching chemistry that emphasizes risk mitigation and keeping hazardous substances out of the environment. Incorporating Green Chemistry into the chemistry curriculum at every level—beginning with secondary schoolis a strategic way to equip students with the knowledge and skills necessary to ensure environmental sustainability for both present and future generations. Similarly, Chen, Jeronen, and Wang [5] observed that demonstrating chemistry experiments using the principles of green chemistry fosters collaborative and problem-based learning. This approach engages students in real-world scenarios requiring critical thinking and teamwork, making chemistry more accessible, practical, and relevant to contemporary environmental issues.

Chemistry as a subject involves both theoretical content and practical skills learned through scientific methods such as experimentation. However, in Nigeria, many students perceive chemistry as abstract because they rarely have the opportunity to carry out experiments that make concepts tangible. The

lack or insufficiency of chemicals and equipment for experiments has long hindered effective teaching and learning of chemistry [6] and is a contributing factor to the low academic achievement of secondary

school students in the subject. By applying the principles of Green Chemistry, both teachers and students can think critically about using readily available chemicals, improvised apparatus, natural catalysts, green solvents, renewable feedstocks, reused materials, cost-effective synthesis methods, microscale demonstrations, and energy-efficient workflows—all of which make learning more relevant and resourceful.

Furthermore, Green Chemistry demonstrations place a strong emphasis on safety, ensuring that experiments are conducted in ways that are environmentally friendly and non-hazardous to both students and teachers[7]. This intervention is particularly important in addressing the common situation where students shy away from practical work due to fear of accidents or exposure to toxic substances. Such fears have long hampered student-centered learning, as advocated in this contemporary era of education.

Researches have shown that green chemistry activities improve students' understanding of chemical principles and spark their interest in learning the subject, both of which are critical to their academic success [8,9]Ma and Shengli[10]investigated students' comprehension of green chemistry concepts. Grades 9–12 students were interviewed, and a semi-structured two-tier diagnostic instrument was developed. After revisions through pilot surveys, the final instrument was administered to examine students' understanding. Findings revealed that secondary school students have limited knowledge of green chemistry. This shows that the integration of green chemistry into the secondary school curriculum is still at its infancy stage in Africa.To facilitate this shift in Africa, there's a need to intergrate simple GC activities into the curriculum. This study explores the green alternative to demonstrating esterification which can be carried independently by students to help them better understand and appreciate this concept. The aim of this study is to determine to impact of this green demonstration on the academic achievement of students from both urban and rural school location.

2. RESEARCH HYPOTHESES

The following null hypotheses were generated and tested at 0.05 level of significance.

1. There is no significant difference between the achievement mean scores of students taught esterification using GC approach and those taught using CL approach.
2. There is no difference between the achievement mean scores of urban and rural school students taught esterification using GC approach.

3. RESEARCH METHODOLOGY

This study employed a quasi-experimental, posttest-only design to examine the effect of teaching esterification using the Green Chemistry approach compared to the conventional laboratory method. A total of 120 Senior Secondary School Two (SSS2) science students from two purposively selected public secondary schools formed the sample. One intact class from each school was randomly selected, with one class (58 students: 28 urban, 30 rural) assigned to the experimental group and the other (62 students: 30 urban, 32 rural) to the control group. The researcher-developed Chemistry Achievement Test (CAT) on Esterification, comprising 20 multiple-choice questions with a maximum score of 20 marks, was used for data collection. In the experimental group, the researcher guided the students on the demonstration of esterification using the Green Chemistry approach. In this approach, the mixture of fermented palm wine and yeast was distilled at about 78℃ to obtained ethanol. 10 drops of concentrated tetraoxosulphate (IV) acid was first added to 2ml of vinegar in a dry test tube and mixed followed by the addition of 4ml of the distilled ethanol. The mixture was warmed in a water - bath (hot but not bubbling) for 25 minutes and poured into a beaker partially filled with sodium chloride solution. The reaction yielded a fruity smell vapour tested to be ethyl ethanoate. Students in the control group with guidance, carried out the esterification demonstration using the conventional laboratory approach. Same procedures as in the GC approach was involved here but with the use of conventional chemicals

namely; ethanol and ethanoic acid. The reaction also yield ethyl ethanoate. After the two-weeks treatment period, the CAT was administered to all 120 students. The test scripts were collected and analysed for assessment.

4. RESULTS AND DISCUSSION

4.1 Results

Table 1: Independent t-test analysis of mean achievement scores of students taught esterification using GC approach and those taught using CL approach

Variables	n	X	SD	df	t-cal	t-crit	Decision at p<.05
GC approach	58	14.18	2.52	118	13.19	1.98	Rejected
CL approach	62	7.65	2.91				

The findings in Table 1 above indicated that the calculated t-value of 13.19 is greater than the critical value of 1.98 at 0.05 level of significance. Based on this result, the null hypothesis earlier stated was rejected and the study claimed that there is a significant difference in students' academic achievement taught esterification using GC approach and those taught using CL approach.

Table 2: Independent t-test analysis of mean Achievement scores of urban and ruralstudents taught esterification using GC approach

Variables	n	X	SD	df	t-cal	t-crit	Decision at p<.05
Urban	28	15.46	2.08	56	2.12	2.00	accepted
Rural	30	13.00	2.91				

The findings in Table 2 above indicated that the calculated t-value of 2.12 is less than the critical value of 2.00 at 0.05 level of significance. Based on this result, the null hypothesis earlier stated was accepted. This means that there is no significant difference in academic achievement of urban and rural school students taught esterification using GC approach.

4.2 Discussion

The finding of this study as indicated in Table 1 shows that students taught esterification using GC approach performed significantly better than those taught using CL approach . The finding agrees with Karpudewan[8] who concluded that GC learning approach led to the highest learning outcomes among students than lecture learning approach. The finding also agrees with Umannah and Udo[9] who investigated the impact of GC approach on teaching Le chartler's principle among secondary schools students in Akwa Ibom State and concluded that GC approach does not only improve student engagement but also foster critical thinking skills, making chemistry more relevant and applicable to real-world scenarios.

The findings as shown in tables 2 shows that there is no significant difference in the mean achievement scores between urban and rural school students taught esterification using GC approach. This finding agrees with Karpudewan, Roth and Sinniah[8] who examined students' understanding of acid–base concepts and argumentation skill through GC approach and reported a no significant difference in the students' academic achievement between the two geographical locations of the schools taught using GC approach. The study contradicts the findings of Ovat, Nwogwugwu, and Idika[11], who found that school location has a significant impact on academic performance of upper basic nine students. Both groups performed well, but urban students outperformed rural students by a small margin. This is because the urban students are more frequently exposed to laboratory activities than the rural students.

5. CONCLUSION

The following conclusions were drawn from the findings of the study;

1. There is a significant difference between the mean achievement scores of students taught esterification using GC approach and those taught using CL approach .
2. There is no significant difference in the mean achievement scores of urban and rural school students taught esterification using GC approach

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CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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