

 Research Article

Exploring the Level of Teachers' Knowledge of Green Chemistry in Senior Secondary Schools in North-West Sierra Leone

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Abstract

Green chemistry has emerged as a key approach in promoting sustainable development through environmentally responsible chemical practices. Despite this, the successful inclusion of green chemistry in secondary school education depends largely on teachers' knowledge and preparedness. This study explored the extent of green chemistry knowledge among senior secondary school chemistry teachers in the North-West region of Sierra Leone. Specifically, the study investigated whether teachers' knowledge differed according to academic qualification, teaching experience, and school type. The study adopted a descriptive survey research design. Data were gathered from 187 chemistry teachers selected from 24 public and private senior secondary schools using a multistage sampling procedure between March and April 2025. Data were collected using the Green Chemistry Knowledge Questionnaire (GCKQ), a 30-item multiple-choice instrument with a KR-20 reliability coefficient of 0.84. Descriptive statistics, one-way ANOVA, Tukey post hoc test, and independent t-test were used for data analysis at the 0.05 level of significance after establishing that all assumptions for parametric tests were met. The findings showed that teachers exhibited a moderate level of green chemistry knowledge ($M = 17.71$, $SD = 4.95$). Significant differences were found according to academic qualification, teaching experience, and school type ($p < .001$). Teachers with postgraduate qualifications and highly experienced teachers demonstrated significantly higher knowledge than their counterparts, while public school teachers outperformed private school teachers in green chemistry knowledge. The findings suggest that teacher characteristics substantially influence teachers' knowledge of green chemistry and underscore the need for continuous professional development, curriculum reform, and equitable access to sustainability-focused training. The study contributes empirical evidence to support the implementation of green chemistry education in Sierra Leone and other developing countries seeking to strengthen sustainable science education.

Keywords: Green Chemistry, Teachers' Knowledge, Teaching Experience, Academic Qualification, Sierra Leone

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1. INTRODUCTION

The field of chemistry faces major paradigm shifts towards sustainability in response to emerging environmental challenges such as global warming, depletion of resources, and pollution in the current 21st century. At the heart of this transformation lies sustainable chemistry, or green chemistry, which entails the design of chemical products and processes that limit the utilization and production of dangerous compounds (Auliah et al., 2018). The application of green chemistry principles seeks to transform the perception and execution of the chemical process through its emphasis on energy conservation, chemical

synthesis, and the employment of renewable resources (Auliah et al., 2018; Linkwitz & Eilks, 2020). In the developing world, adherence to these principles has been recognized as an essential element in promoting national development and environmental sustainability (Hurst et al., 2019; Jumbam, 2015).



Figure 1. Open Burning of Waste Remains a Major Environmental Challenge in Sierra Leone (Sierra Leone Telegraph, 2023)

Sierra Leone, a country blessed with abundant natural resources and scenic beauty, is experiencing growing environmental problems that are jeopardizing its ecological and socioeconomic stability. Waste burning is one example of an environmental problem that has been persistently occurring and is causing severe pollution problems (The Sierra Leone Telegraph, 2023). The rising number of climate-induced occurrences like drought, flooding, and hurricanes further complicates the situation, making it increasingly difficult for Sierra Leone to achieve sustainability. It is necessary to immediately address these challenges by investing in green technology and environmental education.

Due to the crucial role that teachers can play in influencing students' perspectives on environmental concerns, there is an urgent need to assess their understanding of green chemistry. This paper endeavors to examine the level of awareness of teachers concerning green chemistry at the senior secondary school level in the North-West region of Sierra Leone.

1.1. Literature Review

1.1.1. Teachers' Content Knowledge in Chemistry

Effective teaching of green chemistry requires the teacher to have good pedagogical content knowledge that helps them simplify concepts of green chemistry and make instructional material out of these ideas (Idul & Walag, 2024). Studies reveal that the likelihood of a teacher incorporating green lessons in their classroom depends greatly on the degree of training; those with professional development tend to adopt green initiatives much more than those without formal training (Idul & Walag, 2024). Unfortunately, inadequate conceptualization limits teachers from utilizing instructional methods that do not promote cognitive skills required for sustainable learning. The incorporation of green chemistry in classrooms demands technical knowledge of transforming classical experiments into micro-scale green chemistry experiments (Taha et al., 2021).

1.1.2. Global Studies on Green Chemistry Education

There is an obvious mismatch between environmental awareness and knowledge of green chemistry in international literature (Auliah et al., 2018; Taha et al., 2021). Research in Makassar, Indonesia, concluded that despite the fact that 97.14% of teachers consider themselves familiar with the concept of "green chemistry," only 32.30% have proper knowledge regarding its principles (Auliah et al., 2018). Similarly, an

analysis in the Philippines suggested that senior high school chemistry teachers possess only moderate levels of knowledge, while 94.74% of the sample respondents considered themselves in dire need of further professional development (Carangue et al., 2021; Idul & Walag, 2024). In Malaysia, the main barriers to applying sustainability in classrooms included a heavy workload and a lack of instructional material (Taha et al., 2021).

1.1.3. Green Chemistry in the African Context

Green chemistry practices in Africa have been hindered by infrastructural challenges and a lack of explicit educational policy (Akinsipo & Anselm, 2025; Jumbam, 2015). For example, studies indicate that the absence of sustainable learning themes in the curriculum and inadequate awareness among instructors have posed considerable obstacles to green chemistry practices (Akinsipo & Anselm, 2025; Jovero & Picardal, 2022). The conventional teaching style in the laboratories in many African countries still utilizes dangerous chemicals and lacks appropriate waste disposal techniques (Jumbam, 2015). Nonetheless, there exists a potential to apply the concept of “Small Scale Chemistry” to minimize waste and decrease the expenses associated with the purchase of laboratory materials (Jumbam, 2015). Some researchers propose the use of the Culturo-Techno-Contextual Approach to link traditional African knowledge with green chemistry concepts (Conteh & Camara, 2026; Oladejo et al., 2025; Adam et al., 2025).

1.2. Research Gap

Despite the fact that some research done in the West African sub-region has touched on other topics, such as the role of private versus public schools on students' achievement in sciences in Nigeria (Olasehinde & Olatoye, 2014) and the effect of teaching strategies on difficult concepts (Akintoye et al., 2023; Conteh, 2026; Oladejo et al., 2023), there is limited research concerning Sierra Leone. Most of the available research done in the West African sub-region concentrates on overall achievements and language obstacles in sciences (Conteh, 2026; Olasehinde & Olatoye, 2014). However, there is a gap in research related to teachers' knowledge of sustainable chemistry. There is no empirical evidence regarding the level of teachers' preparedness for sustainable chemistry in Sierra Leone.

1.3. Research Questions

Four research questions and three null hypotheses provided the guiding framework for the study.

1. What is the level of teachers' knowledge of green chemistry in senior secondary schools in the North-West region of Sierra Leone?
2. Does the qualification of teachers have any impact on their knowledge of green chemistry?
3. Does teachers' knowledge of green chemistry differ between very experienced, moderately experienced, and less experienced chemistry teachers?
4. Does teachers' knowledge of green chemistry differ between teachers in private and public senior secondary schools and their counterparts in public senior secondary schools?

Null Hypotheses

- H₀1: There is no significant difference in teachers' knowledge of green chemistry based on their academic qualification.
- H₀2: There is no significant difference in teachers' knowledge of green chemistry among very experienced, moderately experienced, and less experienced chemistry teachers.
- H₀3: There is no significant difference in teachers' knowledge of green chemistry between teachers in public and private senior secondary schools.

2. METHODOLOGY

2.1. Study Design

A descriptive survey research design was employed in this study as it was believed to be the most appropriate method that would enable the research objectives to be achieved in an actual classroom setting. With this design, data were gathered from a large group of chemistry teachers who were randomly selected from the north-western part of Sierra Leone, thus providing useful insights into teachers' knowledge of green chemistry within the North-West region of Sierra Leone. In addition, the design also made it possible to analyze the relationship between the level of teachers' knowledge of green chemistry and some selected variables, including qualification, experience, and school type.

2.2. Sample and Sampling Technique

All senior secondary chemistry teachers within the North-West region of Sierra Leone formed the sampling frame for the study. There were 24 schools selected for the study, which were made up of public and private institutions. Teachers formed part of the study population if they were teaching chemistry at the senior secondary school level and agreed to participate in the study. 200 questionnaires were sent to chemistry teachers in the study, and a total of 187 questionnaires were successfully completed and returned, making the response rate to be 93.5%. There were 108 chemistry teachers in the public schools and 79 chemistry teachers in the private schools.

In collecting data, multistage sampling was used to ensure validity and unbiased sampling. The first step was the classification of the schools into two categories based on their category as public or private schools. The second step was the random selection of the schools through simple random sampling, whereby all the schools had an equal chance of being selected. The third step was the purposive selection of the chemistry teachers from the selected schools based on specialization and availability.

2.3. Instrumentation

The data required for this study were obtained via the use of an instrument known as the green chemistry Knowledge Questionnaire (GCKQ). This particular instrument was very well-designed in order to obtain as much information as possible regarding teachers' knowledge concerning green chemistry as related to chemistry teaching in secondary schools. It had two main parts. Part A focused on obtaining demographic data from teachers regarding their gender, educational qualifications, years of teaching experience, category of the schools they taught at, and previous training in green chemistry. Part B contained 30 multiple-choice questions testing teachers' knowledge of green chemistry. Each question carries one mark for a correct response and zero marks for an incorrect response. The minimum obtainable score was 5, whereas the maximum obtainable score was 30. Participants required approximately 40 minutes to complete the questionnaire under supervised conditions in the presence of the researchers. The GCKQ measured teachers' understanding of major green chemistry concepts, including waste prevention, atom economy, safer chemical synthesis, energy efficiency, renewable resources, reduction of hazardous substances, and environmentally sustainable laboratory practices.

To guarantee the validity of the instrument, it underwent content and face validation from four experts in chemistry education at Ernest Bai Koroma University and Njala University. These experts critically analyzed the clarity, relevance, and completeness of the items in light of the research questions. According to their recommendations, appropriate amendments were made to increase the accuracy and breadth of the instrument. The reliability of the instrument was assessed using a pilot study comprising 202 chemistry teachers who were not part of the sample used in the main study. Reliability of Section B (Knowledge Test) was assessed using the Kuder-Richardson Formula 20 (KR-20), which yielded a reliability value of 0.84.

2.4. Methods of Data Analysis and Testing of Assumptions

Descriptive and inferential analysis of the collected data was carried out using the Statistical Package for the Social Sciences (SPSS). All inferential tests were conducted at a 0.05 level of significance. The assumptions about parametric test statistics were carefully evaluated before carrying out hypothesis testing in order to ensure reliable results of analysis.

In terms of the normality assumption, the Shapiro-Wilk test, along with visual examination of the histogram and normal Q-Q plot, was used. The analysis revealed that the obtained results could be considered approximately normally distributed since the p-value of all the Shapiro-Wilk tests was above 0.05 (for example, the overall knowledge score had $p=0.087$), and there were no evident deviations from normal distribution in the distribution curves.

The test for Homogeneity of Variance was conducted through the use of Levene's Test of Equality of Error Variances. The results showed non-significant findings among all relevant comparisons ($p > 0.05$) and demonstrated equivalence of variances between the groups under study. For example, the Levene test conducted on the level of qualifications showed $p = 0.214$, which demonstrates compliance with the assumption of equality of variances. Standard procedures of ANOVA and t-tests could be considered, and where needed, robustness could be enhanced with the inclusion of such considerations as the use of Welch's ANOVA and "equal variances not assumed" options.

The Independence of Observations was ensured through proper planning of the experiment, as every teacher was surveyed independently and belonged to only one category among the variables of interest (qualification, experience, and school type). Data were collected between March and April 2025.

The approach used in answering research question one involved the use of descriptive statistics, where the means, standard deviations, minimum scores, and maximum scores for green chemistry knowledge among teachers were determined. Since the knowledge test had 30 multiple-choice questions, the classification bands of 0–10 (low knowledge), 11–20 (moderate knowledge), and 21–30 (high knowledge) were adopted to provide a simple interpretive framework for evaluating teachers' overall knowledge levels based on one-third divisions of the total obtainable score.

On the other hand, to answer research question two, one-way analysis of variance (ANOVA) was used due to the fact that the independent variable (qualifications) was classified into three different classes: undergraduate (Bachelor's degree holders), graduate (teachers with professional graduate teaching qualifications such as PGDE or Higher Teachers Certificate), and postgraduate (Master's degree or higher holders), whereas the dependent variable (knowledge score) was quantitative in nature. Since there were significant differences among the groups ($p < 0.05$), Tukey post-hoc analysis was done.

Additionally, for the third research question, one-way ANOVA was used because the independent variable (experience) was classified into three groups: less experienced (1-5 years), moderately experienced (6-10 years), and highly experienced teachers (11 years and above). One-way ANOVA examined the differences in the scores of knowledge at different levels of the independent variable, and significant differences were further investigated using Tukey post-hoc tests.

For the fourth research question, an independent samples t-test was used because the independent variable (school type) was classified into two categories: public schools and private schools. The test checked whether there was a statistically significant difference between teachers' knowledge of green chemistry based on the school type.

Overall, assumption diagnostics indicated that the data set met all criteria needed for parametric testing. Statistical and graphical analyses showed that the data set met all criteria for ANOVA and t-tests.

3. FINDINGS

3.1. Research Question 1: Level of Teachers' Knowledge of Green Chemistry

Descriptive statistics were used to determine the level of teachers' knowledge of green chemistry.

Table 1. Descriptive Statistics of Teachers' Green Chemistry Knowledge

	N	Minimum	Maximum	Mean	Std. Deviation
Green Chemistry Knowledge	187	9.0	28.0	17.706	4.9540
Valid N (listwise)	187				

Based on the provided classification criteria, the findings suggest that the teachers' knowledge of green chemistry is at a moderate level ($M = 17.71$; $SD = 4.95$). Although the mean in Table 1 falls within the moderate level, there is a high degree of variability in the distribution of scores obtained, ranging from 9 to 28. It could imply that while many of the teachers understand the fundamentals of green chemistry, some of them lack a good grasp of the concepts taught. Therefore, a disparity exists in the competency levels of green chemistry teachers, necessitating intervention to enhance their baseline knowledge.

3.2. Research Question 2: Influence of Qualification on Knowledge

A one-way ANOVA was conducted to examine whether teachers' qualifications significantly influenced their knowledge of green chemistry.

Table 2. One-Way ANOVA for Qualification and Knowledge

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1991.307	2	995.654	71.187	.000
Within Groups	2573.516	184	13.987		
Total	4564.824	186			

The results presented in Table 2 show that teachers' qualifications significantly influenced their knowledge of green chemistry, $F(2, 184) = 71.19$, $p < .001$. Therefore, the null hypothesis (H_{01}) was rejected. Descriptive statistics revealed that teachers with undergraduate qualifications recorded a mean score of 15.39 ($SD = 1.86$, $n = 56$), teachers with graduate qualifications obtained a mean score of 14.70 ($SD = 5.38$, $n = 56$), while teachers with postgraduate qualifications recorded the highest mean score of 21.68 ($SD = 3.28$, $n = 75$).

Additional analysis employing the Tukey HSD post hoc test further showed statistically significant differences in the performance of teachers with postgraduate qualifications and those with undergraduate and graduate qualifications ($p < .05$). However, there were no statistically significant differences in the performance of teachers with undergraduate and graduate qualifications. From the effect size analysis using eta squared, there was a large effect size ($\eta^2 = .44$). Therefore, qualification explains a large percentage of the variance in the knowledge score of green chemistry for teachers.

3.3. Research Question 3: Influence of Teaching Experience on Knowledge

A one-way ANOVA was conducted to assess differences in knowledge across levels of teaching experience.

Table 3. One-Way ANOVA for Experience and Knowledge

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3183.370	2	1591.685	212.001	.000
Within Groups	1381.454	184	7.508		
Total	4564.824	186			

The results presented in Table 3 show that teaching experience had a statistically significant influence on teachers' knowledge of green chemistry, $F(2, 184) = 212.00$, $p < .001$. Therefore, the null hypothesis (H_{02}) was rejected. Descriptive statistics revealed that less experienced teachers (1–5 years) recorded a mean

score of 12.09 (SD = 1.83, $n = 56$), moderately experienced teachers (6–10 years) obtained a mean score of 17.91 (SD = 2.36, $n = 67$), while highly experienced teachers (11 years and above) recorded the highest mean score of 22.41 (SD = 3.63, $n = 64$).

Further analysis using Tukey's HSD post hoc test revealed statistically significant differences among all three experience categories ($p < .05$). Specifically, highly experienced teachers scored significantly higher than moderately experienced and less experienced teachers, while moderately experienced teachers also performed significantly better than less experienced teachers. The eta squared effect size indicated a large practical effect ($\eta^2 = .63$), suggesting that teaching experience accounted for a substantial proportion of the variance in teachers' green chemistry knowledge scores. The findings therefore indicate a strong positive association between teaching experience and teachers' knowledge of green chemistry.

3.4. Research Question 4: Difference Between Public and Private School Teachers

An independent samples t -test was conducted to compare knowledge scores between public and private school teachers.

Table 4. Independent Samples t -Test for School Type

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig. (2- tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Green Chemistry Knowledge	Equal variances assumes	6.113	.014	4.022	185	.000	2.8275	.7030	1.4406	4.2144
	Equal variances not assumed			4.118	183.420	.000	2.8275	.6866	1.4729	4.1821

The results reported in Table 4 reveal a statistically significant difference in green chemistry knowledge between public and private senior secondary school teachers, $t(183.42) = 4.12$, $p < .001$. Thus, H_{03} was rejected. Descriptive statistics revealed that teachers from public schools had a higher mean score ($M = 19.31$, $SD = 4.27$, $n = 108$) compared to those from private schools ($M = 16.48$, $SD = 5.11$, $n = 79$). The difference between the means of these groups was 2.83.

According to Cohen's d effect size calculation, the practical effect between these two groups was considered moderate ($d = 0.60$). Thus, the results indicate that school type affects the level of teachers' knowledge of green chemistry. Nevertheless, the reasons behind this phenomenon cannot be determined based on this research and should be taken into account when interpreting the results.

Overall, the findings of the study indicate that teachers' knowledge of green chemistry varies according to qualification, teaching experience, and school type. Among these variables, teaching experience demonstrated the largest practical effect. The results therefore highlight the importance of continued professional development, curriculum integration, and equitable access to instructional resources and training opportunities aimed at improving teachers' competency in green chemistry within the North-West Region of Sierra Leone.

4. DISCUSSION

The results suggest that chemistry teachers within the North-West zone of Sierra Leone have a moderately good understanding of sustainable chemistry, which can be considered one of the important

pillars of their students' academic success. One of the important findings includes the notable gap in chemistry understanding between public and private schools. Teachers from public schools showed significantly better understanding of specialized knowledge when compared to teachers working in private institutions, with an average difference of 2.83 (Std. Error Difference of .70). One possible explanation for these findings may be differences in access to institutional support systems and professional development opportunities within the public education sector. Public school teachers may have greater exposure to government-supported seminars and workshops, although this variable was not directly examined in the present study.

The results obtained from the current study, when placed in the context of the West African educational system, reveal a number of similarities and contradictions with the previous research on such variables as school ownership, resources available, and teachers. In many parts of Nigeria, private schools are usually considered to perform better compared to public schools due to better laboratory equipment and small classes (Oladejo et al., 2023). At the same time, the results from Sierra Leone reveal a different pattern in the sense that teacher competence and quality are higher in public schools, which may indicate the role of human resources in education. Such results can also be explained by the fact that the perception of the science inquiry process skills of learners is better in government schools compared to private schools in Liberia (Nicol et al., 2022), meaning that human resources may contribute to effective science learning as much as the quality of laboratory equipment. However, at the same time, one needs to be careful with the interpretation of the results, as the evidence from Katsina State, Nigeria shows that there was no difference in the chemistry achievement of students in public and private schools, although in some sciences like physics the differences were observed (Olasehinde & Olatoye, 2014).

In addition to the aforementioned distinction between the two types of schools, the current investigation has found that teaching experience is the most influential factor determining teacher effectiveness, which means that practical experience accumulated through on-the-job training may be especially vital in acquiring pedagogical expertise. The above-mentioned findings can be interpreted to mean that even though education is essential for becoming a good teacher, years of experience working in the classroom might provide more professional advantages. This conclusion corresponds to existing research according to which teaching experience is one of the key elements that contributes to students' achievements in secondary-school chemistry classes (Ibe et al., 2021). Thus, it appears that teacher competence, professional experience, and school resources are interrelated aspects that affect the educational process differently.

5. CONCLUSION

This study found significant differences in green chemistry knowledge between teachers in public and private schools in the North-West Region of Sierra Leone. However, the factors responsible for these differences were not directly examined and therefore should be interpreted cautiously. Although the level of general knowledge is satisfactory, the greater level of specialized knowledge among the teachers from public schools shows that the government has been able to implement an effective policy concerning human capital investment. Nevertheless, it should be noted that the "educational landscape" is currently fragmented, and unless this gap is filled, the overall quality of green chemistry education within the region may remain limited (Ibe et al., 2021).

5.1. Limitations and Future Research

There are certain limitations to the current study that need to be considered in light of the results of the study. Firstly, the fact that the design of the study is that of a descriptive survey means that causality cannot be established on the basis of the findings of this study. Secondly, the fact that the sample population used in the study consisted of only chemistry teachers of the North-West Region of Sierra Leone reduces the generalizability of the results of the study.

These limitations can be overcome by conducting future research that would involve both quantitative and qualitative methods to investigate the issue under consideration. In addition, future research can adopt an experimental design to conduct this research. In addition, a nationwide study

involving teachers from all regions of Sierra Leone is recommended to improve the generalizability of the findings.

5.2. Recommendations

From the study's results, the following suggestions are offered:

1. Integration into the Curriculum: The chemistry curriculum in Sierra Leone needs updating to incorporate green chemistry among its key elements, just like nuclear chemistry and other topics already incorporated into the syllabus.
2. Direct Knowledge Transfer: Chemistry teachers need to work hard at transmitting concepts of green chemistry to their students, especially considering the moderate to advanced knowledge level of teachers in Sierra Leone. They are poised to equip students with knowledge of a sustainable world.
3. Professional Development Program Consistency: The Ministry of Basic and Senior Secondary Education should require that chemistry workshops organized by the ministry include teachers from the private sector.
4. Incentivizing Experience: There is a need to develop "Master Teacher" programs in schools, whereby senior teachers (the best predictors of knowledge) impart their juniors with knowledge of pedagogy.

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Research Ethics. Ethical clearance to carry out the study was sought and secured from the Ministry of Basic and Secondary Education, Sierra Leone, via the Kambia District Education Office and the principals of the schools used for the study. The research was carried out in compliance with the British Educational Research Association (BERA) Ethical Guidelines for Educational Research (2018).

Data Availability Statement. All data can be obtained from the corresponding author.

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