Journal of Turkish Chemical Society Section C: Chemistry Education (JOTCSC)
Vol. 11, Issue 2, September 2026, pp. 141-166. ISSN: 2459-1734
Türkiye Kimya Derneği Dergisi Kısım C: Kimya Eğitimi
Cilt 11, Sayı 2, Eylül 2026, sayfa 141-166. ISSN: 2459-1734

Research Article/ Araştırma Makalesi

Chemistry for Sustainable Development: Assessing the Perception of the Green Chemistry Concept by Some Chemistry Teachers in Lesotho

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Received: 15.12.2025 Accepted: 20.05.2026

Doi: https://doi.org/10.37995/jotcsc.1842998

In the context of global sustainability challenges, green chemistry offers a critical framework for promoting environmentally responsible science education. This study investigates the perceptions of high school chemistry teachers in Lesotho regarding green chemistry and its integration into the Lesotho General Certificate of Secondary Education (LGCSE) curriculum, as well as their readiness to teach it. Using a semi qualitative questionnaire distributed through the association of mathematics and science teachers, responses from 35 teachers revealed that most teachers (78%) encountered green chemistry informally and demonstrated basic understanding – primarily associated with less hazardous chemical use (57%) and pollution-related ideas (20%). However, many were unable to explicitly identify green chemistry principles within the existing curriculum, despite claiming familiarity with it. Teachers majority strongly supported explicit inclusion of green chemistry (77%), recognizing its relevance to sustainability issues. However, though 86% expressed confidence in teaching it, an equally high proportion expressed the need for further training. These findings suggest that teachers' understanding of green chemistry is implicit rather than formally structured. The study highlights the need for explicit curriculum integration and targeted professional teacher development and stakeholder collaboration to support effective curriculum implementation, aligning Lesotho's education with global sustainability goals that the country has ratified.

Key words: Chemistry teachers, curriculum integration, green chemistry, Lesotho, perception, sustainable development.

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INTRODUCTION

The concept of sustainable development adopted by the United Nations has evolved significantly from the Millennium Development Goals to the Sustainable Development Goals (SDGs), reflecting global recognition of sustainability as essential for long-term human and environmental well-being. However, there can never be any development without education as education provides a basis for human development. Mathematics and Science continue to provide the necessary base for different careers as these subjects are considered enabling disciplines supporting many fields such as engineering, medicine, environmental sciences, finance and technology. But what is sustainable development? Sustainability seems to be receiving more attention in social science than in natural sciences, possibly because scientists often engage less with public discourse beyond classroom and laboratory settings.

The concept of sustainability seems to be a much broader approach that makes science more applicable to development not only in terms of material production and engineering but rather responsible production and consumption that considers existence of future generations. Among the sciences, chemistry is considered the most 'dirty', and consequently, green chemistry has emerged as a key pathway for aligning chemistry with sustainable development discourse through the sustainable implementation of science and technology (Chanshetti, 2014). Green chemistry spans the entire life cycle of a chemical product from design, manufacture, use to ultimate disposal ensuring that less hazardous chemicals are used, generated, or released during the life cycle (United States Environmental Protection Agency, 2024).

The era of sustainable development requires of all stakeholders to reflect on how their practices interact with the environment. Researchers are beginning to consider concepts that ensure sustainability through appreciating that 'everything is connected to everything else' (Rebs et al., 2019), such as systems thinking – defined as the ability to see the world as a complex system of different components whose actions influence the state and the behaviour of another (Mahaffy, et al., 2021), as well as identifying all of the factors and their relationships (Mammino, 2019). Advances in computation have also enabled modelling of chemical reactions before delving into the experimental work (Ramli et al., 2018) leading to development of artificial intelligence driven 'intelligent organic synthesis' concepts (De Almeida et al., 2019).

But what about teachers? Teachers, as the custodians of human development should be conversant with this public discourses in order to introduce the emerging scientific concepts to students from a very young age. After Independence, educational policies in most African countries were refocused on the national development that included Africanisation, national unity and economic growth (Woolman, 2001). In some countries,

the curricula also shifted from pure intellectual exploration to job preparation achieved through combining work related skills with academic content within the schools to equip students with practical skills relevant to the job market as opposed to the examination-oriented curriculum (Seotsanyana, 2018). South Africa adopted a multi-stakeholder model that includes professional bodies, communities, schools, and learners in the development of the curriculum as 'stakeholders' and 'role-players' in implementing meaningful educational change (RSA, 1994). Despite all these strides, curriculum implementation still faces challenges that include resource constraints, lack of teacher training/qualified teachers and poor staffing, equity and access to schools by the citizens due to economic conditions (Maruatona, 1994).

Moreover, integration of contemporary scientific themes -such as green chemistry- has been slow, not only at basic secondary level but also at tertiary level with tertiary institutions reportedly trailing the industries in embracing issues of green chemistry (Etzkorn & Ferguson, 2023). These delays in curriculum innovation are attributed to numerous 'barriers to implementation' associated with the complexity of the curriculum development processes in the academic institutions (Hutchison, 2019). These barriers can be either material/resources, processes and/or attitudes and could include economic & financial barriers, motivational & human barriers, and professional & career barriers (Fathi et al., 2012). It is thus important to ensure that teachers understand and support the emerging approaches and that adequate time and training are provided to engage with the process and the necessity to implement the new curriculum. This is extremely important since most teachers from and currently in universities have not formally studied education thus it is important to navigate the tension between explicit curriculum philosophies that inform alternative curriculum designs and tacit curriculum philosophies embedded in university systems (Cooper, 2017).

Green chemistry provides a basis for students to appreciate environmentally responsible practices and fosters problem-solving skills relevant to real world challenges such as climate change, pollution, waste generation and resource depletion. Its teaching takes a more holistic approach that makes 'space for discussions in the context of social and ecological systems' (Hutchison, 2019); consequently, students are equipped with analytical and problem-solving skills applicable to critical real-life challenges (Bodner, 2016). This allows students to experience the complexity, interconnectedness and relationship of real-life processes and the finite nature of resources (Wang et al., 2018). It encourages 'system thinking' by ensuring that learners shift from a narrow focus on isolated concepts to a broader, integrated understanding of systems by recognizing connections and predicting outcomes (Hurst, 2020), essential for the complex demanding nature of real-life problems such as "…habitat destruction and biodiversity loss, deforestation, degradation of the oceans, scarcity of fresh water for a growing

population, depletion of resources, toxic synthetic chemicals accumulating in the environment, anthropogenic climate change" (Murphy, 2012), all of which some scholars call "wicked sustainability problems" (Lönngren & Svanström, 2016).

The purpose of this study is to explore the understanding of green chemistry concept by the chemistry teachers in Lesotho, their assessment of the extent to which it is incorporated in the LGCSE curriculum and their comfort level in teaching it. Another important aspect is that green chemistry concept is not explicitly taught in pre-service teacher training programmes in Lesotho. Teachers may therefore rely on informal exposure to the green chemistry concepts –such as seminars or personal reading rather than structured instruction. Literature argues that students appreciate concepts better when they encounter them without the pressure of passing or failing which leads to '…deeper processing and better retention of new information about the topic' and that such information should somehow connect with their motivational zones of proximal development as well as mediating in ways that scaffold the learning and the appreciation of what is being learned (Brophy, 1999). This therefore supports that individual learning for teachers might not completely be misinformed but it can possibly be inconsistent of the content delivered to learners.

Lesotho, a small mountainous South African landlocked, is a typical least developed country with minimal chemical-based industry (George, 2015; George, 2016); and it is among the countries that still continue to face significant challenges related to achieving the UNSDGs (United Nations SDG, 2016). The education system has two levels, the basic level, comprising of primary and secondary levels then the tertiary level. The basic curriculum is coordinated by the National Curriculum Development Centre (NCDC) established in 1980 under the Ministry of Education and Training (MoET) which aims to ensure relevance, quality and alignment with broader educational programs and instructional materials with the nation's educational goals (Phakisi, 2008). At this level, Chemistry is merged with Physics into what is called 'Physical Science', the merger that exacerbates the challenge of appreciating chemistry as an independent subject to the extent of appreciating the importance of chemistry in the realization of the SDGs. Chemistry Education in Lesotho is constrained by numerous challenges including lack of functional laboratories limiting the experimental work (George & Kolobe, 2014; George, 2017). The use of alternatives to hands-on experiments to counter this lack of resources is still being explored at research level (Bohloko et al., 2019; Mohafa et al., 2022).

At tertiary level, specifically looking at teachers' development, there are only two institutions, namely, National University of Lesotho (NUL) and Lesotho College of Education (LCE) that offer degree and diploma in chemistry-related teacher qualifications respectively, influencing the composition of teaching staff in schools. NUL offers

chemistry degree in combination with either Biology, Geography, Maths, Physics and Computer Science. On the other hand, the LCE offers diploma in education for primary and secondary school teachers. It would therefore be expected that most of the respondents would have studied from either or both of these two institutions with few having studied outside the country. This context underscores the importance of investigating their perception of green chemistry concept cognizant of the fact that this concept is not implicitly incorporated in the teachers training program as well as to identify opportunities for strengthening curriculum alignment with global sustainability agendas.

METHOD

Research Design

This study aims to respond to the following research question: How do chemistry teachers perceive and engage with the concept of green chemistry in relation to the LGCSE curriculum? This question is subdivided into three sub-questions: (i) What is the current state of teachers' conceptual understanding of green chemistry and its principles? (ii) How do teachers perceive the extent to which green chemistry concepts are currently integrated into the LGCSE Physical Science curriculum and its supporting documents? (iii) How do teachers describe their level of comfort and preparedness to teach green chemistry concepts, considering their pre-service training and any informal learning experiences?

To respond to these questions, the study adopts the Interpretivist/Constructivist paradigm given its focus on understanding the teachers' subjective experiences, knowledge, and perceptions of the subject in question and its aim to understand the meaning that the teachers ascribe to the green chemistry within the context of LGCSE curriculum. This study adopts a descriptive mixed-method survey design**,** combining quantitative summaries of responses with qualitative thematic analysis to explore teachers' perceptions and understanding of green chemistry and interpretation and coding of the responses by the researcher according to the established 12 green chemistry concepts, exploring how much the teachers believe these are incorporated in the LGCSE curriculum as well as their preparedness to teaching these concepts should they be incorporated explicitly in the curriculum.

Data Collection Instrument

To achieve the objectives of this research, a questionnaire was developed to follow descriptive mixed-method survey approach. The questionnaire had four sections: (i) respondents profile (qualification, age, teaching experience), (ii) exploring their

understanding of green chemistry, (iii) their attitudes and/or opinions about its inclusion in the LGCSE curriculum and (iv) their attitude towards teaching the content should it be included explicitly in the curriculum. None of the questions were compulsory so that respondents voluntarily responded to the questions they were comfortable with. One question about the teachers' understanding of green chemistry was open-ended to allow participants to elaborate on their responses to uncover their understanding constructed about their experiences and how much sense they made out of their experience (Merriam, 2002; Bordens & Abbott, 2011).

Sampling Method and Sample Profile

A purposive sampling strategy that targeted chemistry teachers was used. Participants were reached through the voluntary associations - Lesotho Science and Mathematics Teachers Association (LSMTA) and Chemical Society of Lesotho social media platforms including individualised social media networks. Participants were invited to engage in the study voluntarily and their confidentiality was assured. They were requested to respond to the questions without referring to any source that could influence their own perception. The online survey was identified as the most feasible and cost-effective data collection method (Young, 2015), and the forms would reach teachers randomly without the expense of distributing the forms to teachers physically. However, this approach affords respondents freedom to respond to the questionnaires at their own time which could be an advantage as well as a disadvantage (Dykema et al., 2013). Reminders were posted on the same social media platforms every week for four weeks.

The responses were collected instantly after they were submitted via Google forms. Only 35 completed questionnaires were received and used in the data analysis. While this response rate was low, it was significant since the study was preliminary, and it was reported elsewhere that online surveys are usually associated with low response rate challenges (Cohen et al., 2017). To contextualize this, Lesotho has around 350 post-secondary schools, assuming each school has one chemistry teacher translates the response rate to about 10% of total eligible number. It should also be noted that not all the chemistry teachers are members of the LSMTA, as such this number is still considerable.

Analysis of the Data

Data analysis was conducted in two ways, the usual graphical representation of the semi-quantitative data as well as using both deductive and inductive approaches (Creswell, 2014), thus both quantitative and qualitative techniques were used. Qualitatively, the data was analysed to identify any thematic areas and extract them from response narratives iteratively through the six-phase thematic analysis framework that includes familiarising oneself with the data, generating initial codes, searching for themes,

reviewing themes, defining and naming themes (Braun & Clarke, 2006; Maguire & Delahunt, 2017). Some extracts were made from the raw responses, especially relating to the understanding of the concept, to provide further support, clarity and validity of the findings (Merriam, 2002; Creswell, 2014).

In addition to thematic analysis, responses describing green chemistry concepts were interpreted and mapped to the twelve principles of green chemistry. It is important to note that respondents did not explicitly identify specific principles; rather, they provided general examples or topics (e.g., pollution, salt preparation), which were subsequently interpreted and categorized by the researcher. A coding framework was developed in which key ideas expressed in the responses were matched to relevant principles based on conceptual alignment. For example, references to reducing harmful substances were mapped to less hazardous chemical syntheses, while mentions of pollution control were aligned with waste prevention or real-time analysis for pollution prevention.

In some cases, a single response reflected multiple principles. For instance, topics such as **salt preparation** were interpreted as encompassing several principles depending on context. Coding was conducted by a single researcher using consistent criteria. While this ensured internal consistency, the absence of multiple coders is acknowledged as a limitation.

FINDINGS

The findings of the study are presented in this section as well as their interpretation to derive appreciation of the concept by the respondents. Just like in the questionnaire, the findings are divided into three main categories: respondent qualification, teaching experience and subject majors, and the appreciation of green chemistry concepts coupled to their inclusion in the LGCSE curriculum as well as their comfort towards teaching it.

Characterisation of the respondents by qualification, age, teaching subjects and teaching experience

This section presents the profile of the respondents as their responses were received. Table 1 profiles the respondents by their highest qualification among the qualifications recognised by the Ministry of Education and Training.

Table 1

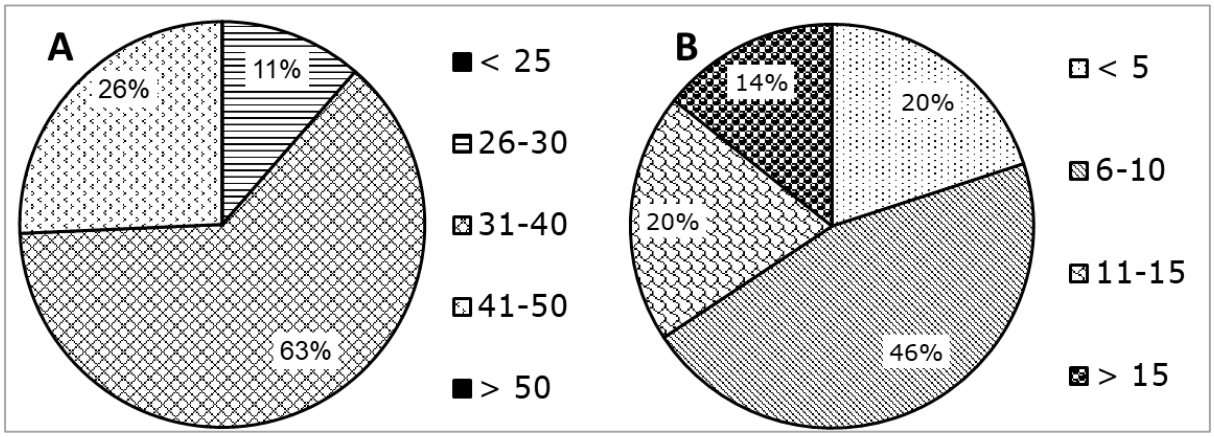
A Summary of Respondent's Highest Qualification

Highest Qualification in Chemistry	Number of Respondents	
	Count	Percentage (%)
Diploma in Science Education	12	34
Bachelors' Degree	17	47
Postgraduate Certificate	1	3
Master's Degree	5	14

As it can be seen, profile of the highest qualifications for the respondents indicate that most teachers (47%) hold a bachelor's degree, followed by those with diploma (34%), then Masters' degrees (14%) and lastly Honours/Post Graduate Certificate (3%). Figure 1 presents the respondents by age and year of teaching experience.

Figure 1

A Profile of Teachers by Age (A) and a Number of Teaching Years (B)



Age distribution shows that most respondents were between 31 to 40 years, with teaching experience ranging from 6 – 10 years. Except for three teachers who were above 31 years but had a less than 5 years of service (teaching experience), there is a good correlation between the years of service and the age of the teachers.

Profiling the same respondents by subject majors (See Fig 2) demonstrates that majority of the teachers majored in Biology and Chemistry, rather than Physical Science, despite the LGCSE curriculum merging Chemistry and Physics. The numbers are followed by those of teachers who majored in Chemistry and Mathematics.

Figure 2

A Profile of Respondents by Subject Majors Taught

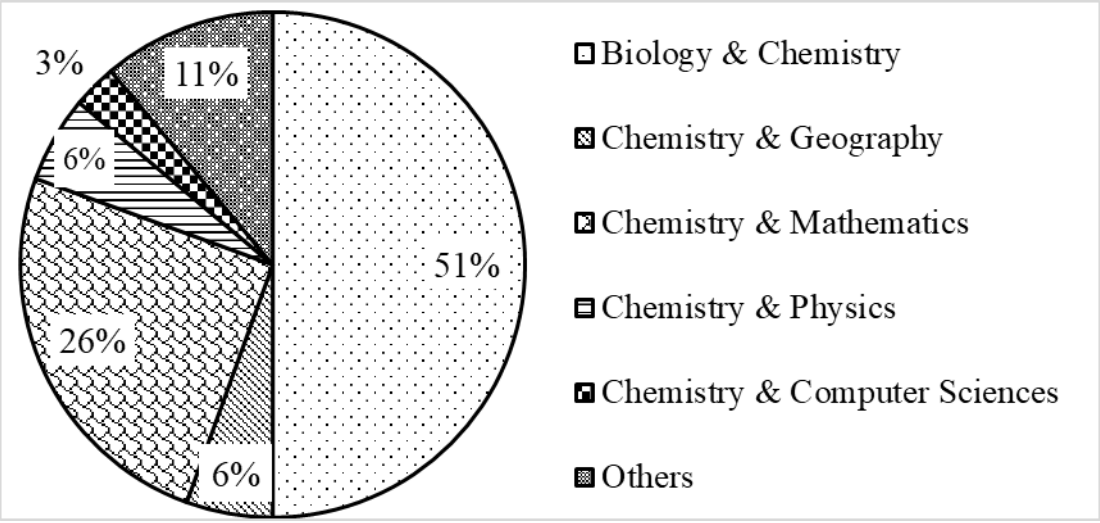


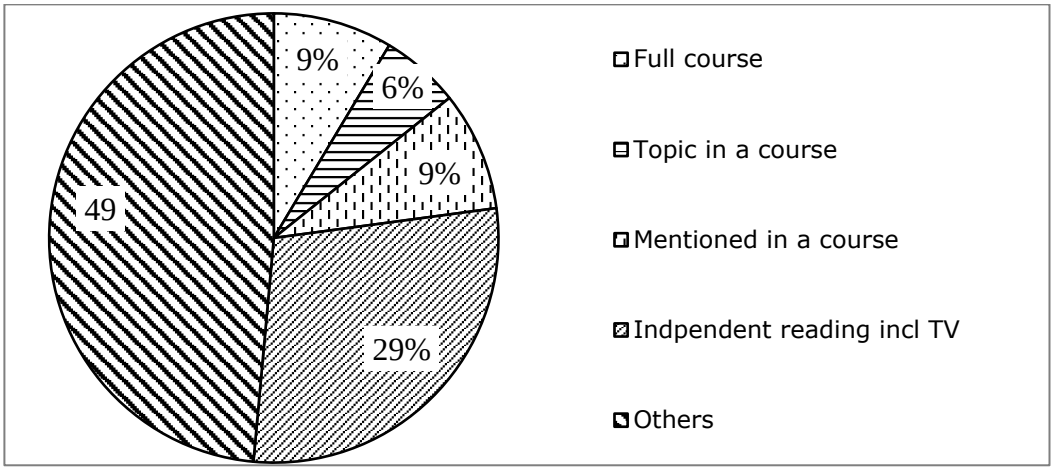
Figure 2 is interesting since it demonstrates that only a few teachers majored in Chemistry and Physics that create the Physical Science in the LGCSE curriculum. This raises important concerns about teaching efficiency and subject content matter depth in the merged curriculum. The category of others includes those teachers with the diploma qualification which is still not classified as the respective sciences are not separated as well as those with degrees from outside Lesotho where the teaching curriculum includes physical sciences.

Assessment of the respondents' first encounter with green chemistry

This question was important to establish if the respondents have had some formal introduction to the concept in class or anywhere else. Figure 3 shows that nearly half of the teachers first encountered green chemistry informally through independent reading, seminars, or social media, rather than through formal instruction. Only one respondent had completely completed a full course in which green chemistry was included. Two respondents indicated that the questionnaire itself introduced them to the concept, highlighting gaps in formal exposure.

Figure 3

The Respondents categorized by their First Encounter with the Green Chemistry Concept



Clearly the concept of green chemistry is not introduced explicitly to the teachers as a significant fraction, almost 80%, heard about it from other sources including those that encountered it for the first time responding to this questionnaire (2 respondents). Very few (9%) encountered the concept in a full course. It is suspected that most of the respondents that responded 'full course' are likely those that have taken the industrial or environmental courses that respondents in a different study looking at the perception of the same by the senior university students revealed that students enrolled in these courses appreciated green chemistry better than those that were not.

Assessment of the appreciation of green chemistry and its incorporation into LGCSE curriculum

When asked what they understood by green chemistry, i.e. the question seeking to establish their understanding of the principles of green chemistry, the respondents gave varying responses (See Table 2) which were subsequently interpreted and coded by the researcher according to the twelve principles of green chemistry as adopted from Anastas and Warner (Anastas & Warner, 1998), namely: P1 - Waste prevention, P2 - Atom economy, P3 - Less hazardous chemical syntheses, P4 - Designing safer chemicals, P5 - Safer solvents and auxiliaries, P6 - Design for energy efficiency, P7 - Renewable feed-stocks, P8 - Reduce derivatives, P9 - Smart catalysis, P10 - Degradable design, P11 - Real-time analysis for Pollution Prevention and P12 - Hazard and accident prevention. To achieve the coding, several key words and concepts relating to the state principles were identified and used in the coding.

Table 2.

The teachers' responses about their understanding of green chemistry concept

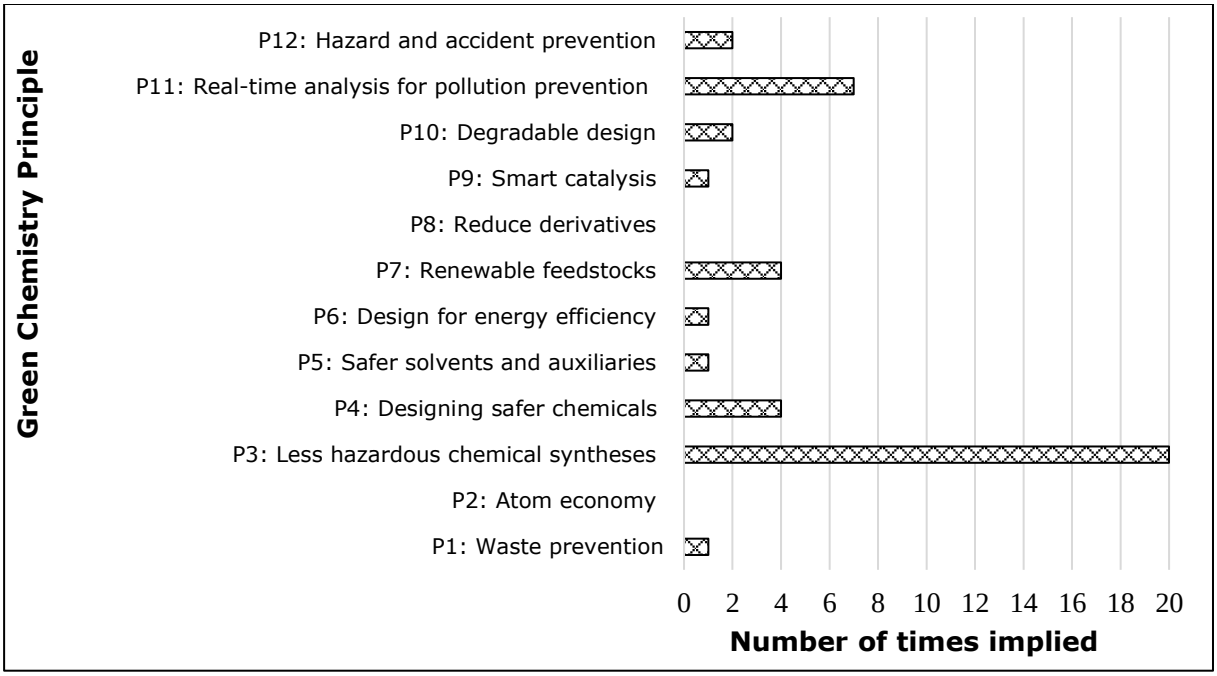
Listed concepts as stated by the teachers	Category of the principle
Learners are expected to be able to list air and water pollutants, describe how they are formed, describe their effects and measures that can be made to reduce it.	P3, P11
1. Environmental awareness 2. Safer solvents and chemicals	P3, P5
Prevention of pollution, less hazardous chemical synthesis, designing safer chemicals	P3, P4, P11
AIR, WATER AND ENVIRONMENT: This is the topic entails; Chemistry of Air; Air composition, nitrogen cycle, carbon cycle and harber process; Chemistry of water (brief important details though, about water as a substance); Fossil Fuels; fractional distillation of crude oil, Uses of fractions, Impact to the environment of burning fossil fuels without advantages and disadvantages of organic fertilizers and inorganic fertilizers. Macromolecules; polymers (very brief)	P1, P2, P3, P4, P5, P6, P7, P10, P11, P12
Courses and effects of air pollution	P11
Renewable sources; Water treatment; Neutralization; Air pollution	P1, P2, P3, P4, P7, P11
Atoms pollution, alloys, organic chemistry	P3, P4, P11
*Vehicles with catalytic converters; *Iron extraction; *Recycling *Solar energy, hydropower, wind energy	P1, P3, P7, P9, P11
A little bit on the environmental Chemistry part, metals and non-metals, and other	P3
Use of catalytic converters in car exhausts, flue gas desulphurization. Sewage collection and treatment	P3, P9, P11
1.Use of catalytic converters and environmental impacts of emitted gases into the atmosphere. 2.Advantages and disadvantages of synthetic polymers.	P2, P3, P9, P11
Air....Catalytic converter	P9, P11
Analysis of pollution and prevention	P11
Prevention of pollution	P1
Learning outcome of chemistry of Air	P3, P7, P10
Preparation of salts	P1, P3, P5, P6, P7, P8, P9, P10, P11, P12
Pollution, important fuels such as ethanol and hydrogen. Use of catalytic converters in cars.	P3, P11
Use of renewable food stork; Use of catalyst no stoichiometric reagents; Prevent wastes; Analyze in real time to prevent pollution	P1, P7, P10, P11
Air and environmental chemistry	P1, P2, P3, P4
Chemistry of water and organic chemistry	P1, P2, P3, P5, P6, P8
Most of them	Not sure
It comes as a small content in one topic	Not sure
As mentioned I'm not really working in that space	Not sure
I am not sure maybe experimental techniques	Not sure
Feels like somewhat none of them are incorporated in chemistry syllabus.	None

NB: The responses in this table were copied as received no editing was done. The mapping reflects the researcher's interpretation of the concepts mentioned and not explicit identification by the respondents.

Figure 4 illustrates the frequency of each of the 12 green chemistry principles that were implied by the teachers' responses when asked to mention what they understand by the concept of green chemistry. It should be noted that the respondents were not asked to mention one aspect, but rather to mention any of the principles they are aware of.

Figure 4

The Frequency of the Green Chemistry Principles Implied in the Responses about what the Teachers Understood by Green Chemistry



From Figure 4, it is interesting to note that less hazardous chemical synthesis appeared with the highest frequency (mentioned 20 times) followed by real time analysis for prevention of pollution although the respondents mentioned pollution prevention without the prefix real time analysis. Another interesting aspect was a lowly frequency (1) for the waste prevention principle while it could have been expected that this would be one of the most obvious concepts owing to the fact that there are a lot of public initiatives regarding waste, especially solid waste, country-wide where teachers are expected to play a leading role in conscientising the students even outside the curriculum prescripts. There were also 2 principles which were not mentioned all together, namely, atom economy (P2) and derivative reduction (P8).

There were few respondents that showed some level of uncertainty with their responses ranging from *'Most of them', 'It comes as a small content in one topic', 'I am not sure maybe experimental techniques'* and *'Feels like somewhat none of them are incorporated in chemistry syllubus'*. Of the 10 that did not state any content that could be related to any of the principles, two stated that they were not sure, one (1) flatly stated 'I really don't know', while the other one stated 'Clueless'. The remaining six stated 'None'.

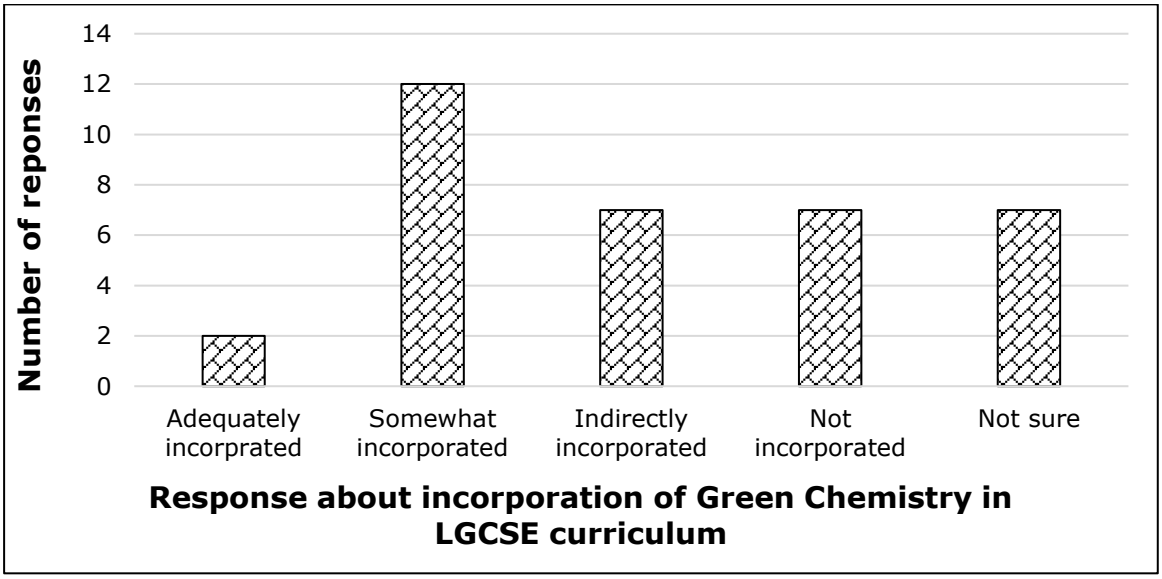
Following on the understanding of the teachers regarding the principles of green chemistry, and given that all the teachers claimed familiarity (83% stated being very

familiar while 17% stating being somewhat familiar) with the LGCSE curriculum, a question about the teachers' familiarity with sustainable development would therefore be justified considering the close relationship between the green chemistry and sustainable development. The assessment of the data indicated that the majority of the respondents (63%) had some familiarity with the SDGs with the remaining 37% claiming no familiarity at all with the SDGs. This is quite surprising, and worrying for chemistry teachers to claim no familiarity given how much SDGs are being spoken about even at the grassroots level in rural villages. Even more interesting is the fact that these teachers could not identify the role chemistry, a subject they teach to the future generation, can play in pursuit of the SDGs.

Figure 5 shows the responses to the question of whether the curriculum adequately addresses the issues of green chemistry. A high level assessment of the curriculum shows that certain aspects of the green chemistry, such as pollution, are covered in the syllabus albeit indirectly.

Figure 5

The Perception of Incorporation of Green Chemistry Principles in the LGCSE Curriculum by the Teachers



It is interesting that the majority of the teachers, in excess of those that were familiar with the green chemistry indicated that some principles are incorporated in the curriculum. This interesting because ten (10) respondents said they did not know much about the concept, but they stated that it is 'somewhat' incorporated meaning they had a sense of what it could be. This may suggest that respondents attempted to make sense

of the concept during the questionnaire, as it was stated by other respondents that the questionnaire had actually introduced them to the green chemistry concept while the same respondents stated that the questionnaire made them think critically about chemistry and sustainable development. This indicates that the respondents did not just answer the questions absentmindedly, but they did apply their minds to the questions. However, this interpretation remains tentative as it is not directly supported by independent evidence.

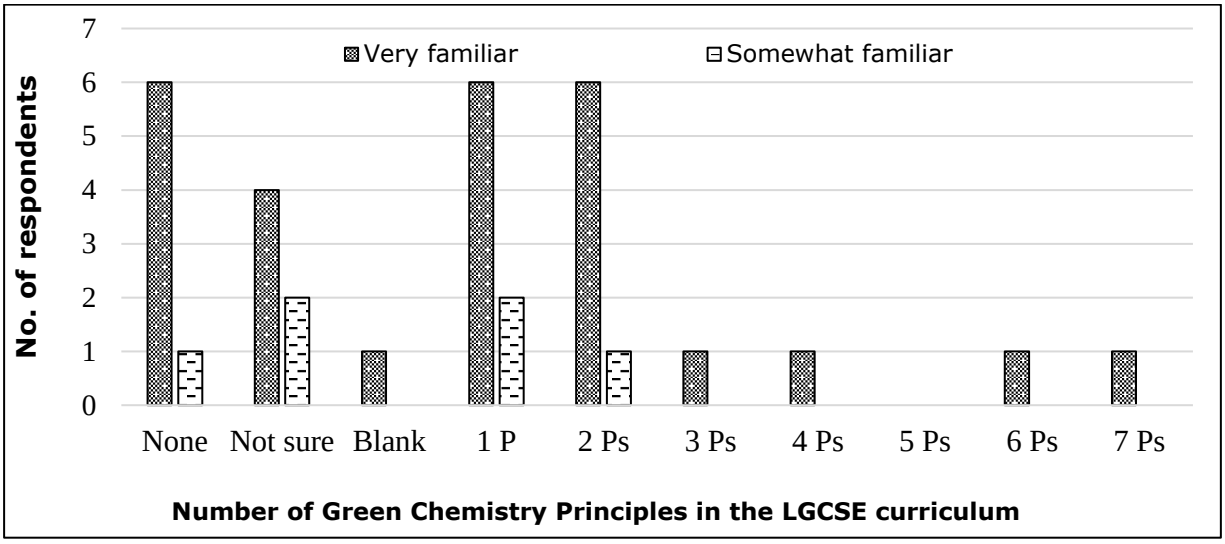
Interestingly one of the respondents who claimed neutrality about the effect of the questionnaire claims to have worked in a research institute but only stated green chemistry is involved with 'eliminating the use of hazardous substances across the life cycle of a product, including the impact on all forms of life' and s/he picked 'analysis of pollution materials' as the concept somewhat incorporated in the LGCSE curriculum. The other respondents who claimed not to be impacted are those who stated they did not appreciate green chemistry at all.

Given that some teachers indicated that there is somewhat incorporation of some green chemistry concepts in the LGCSE curriculum, the next task was to assess which principles these teachers believe they are incorporated into the curriculum. Figure 6 present the principles that teachers stated they are incorporated into the LGCSE curriculum disaggregated by the stated familiarity of the teachers with the LGCSE curriculum.

While it is interesting to note that all the teachers are familiar with the LGCSE curriculum, there still seems a challenge of deducing the principles of green chemistry from the curriculum despite the 'priming effect' alluded to earlier. Furthermore, it is possible that some teachers may not have consulted the curriculum in detail when responding. One such a suspect is one teacher who claimed to be very familiar with the green chemistry concept but left the question unanswered. Only two teachers were able to identify two broad topics that contain a number of green chemistry principles, e.g. formation of salts that covers P1, P3, P5, P6, P7, P8, P9, P10, P11 and P12; the other teacher mentioned the chemistry of water and organic chemistry that covers P1, P2, P3, P5, P6 and P8. What is interesting about these teachers is that none of them had a formal acquaintance with the green chemistry, they both heard about it from informal settings and independent reading. The number of the topics decreased from seven Ps, 5, 4 and 3 respectively with six (6) teachers identifying one and two principles respectively and another six worryingly stated that no green chemistry principle was incorporated into the curriculum. It must be noted though, that the teachers did not state the principles, they only stated the concepts as they appear in the curriculum, but the researchers categorised those according to the 12 green chemistry principles.

Figure 6

The Number of Green Chemistry Principles (Ps) Incorporated into the LGCSE Curriculum as Perceived by the Teachers mapped against the teachers' familiarity with the curriculum.



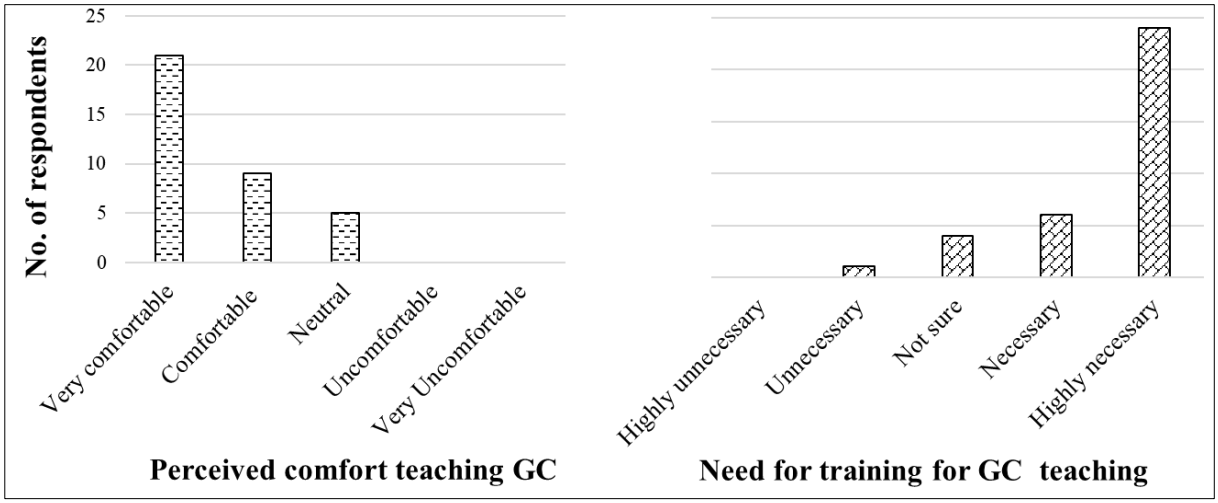
Assessing the perceived importance of green chemistry and its incorporation into the LGCSE curriculum

To understand the perceived importance of green chemistry by the respondents, a question was posed to whether the respondents felt green chemistry was important (see Figure 4) and further asked whether they agree with the proposal of incorporating green chemistry into the chemistry curriculum. More than 75% stated that green chemistry is important (57% - very important and 20% - important) while 23% stated they are not sure of its importance. A similar trend was observed with question of supporting the incorporation of Green Chemistry in the curriculum; 69% strongly supported its explicit inclusion within the curriculum while 17% did not support and the remainder (14%) remained neutral about the recommendation.

Following on the incorporation and the somewhat doubtful understanding of the green chemistry principles, the next question was to identify the training needs for the teachers should the principle be incorporated into the curriculum (See Figure 7).

Figure 7

The Correlation of the Teachers' Comfort versus Perceived Training Needs for Teaching Green Chemistry Concepts



The findings are quite interesting and contradicting – the teachers stated that they would be very comfortable teaching the green chemistry concepts while at the same time they stated the need for training for them to be able to teach the concepts. This contradiction suggests that respondents may overestimate their readiness or interpret 'comfort' differently and can also only be explained if the respondents were referring to the incorporation of the green chemistry in the training of new pre-service teachers. The perceived comfort about the teaching is also interesting given that the majority of the teachers stated that they were not familiar with green chemistry, they even failed to identify topics in the current LGCSE curriculum that deal with green chemistry. It therefore leaves a question whether this question was answered in earnest or the teachers did not want to appear as though they were not adequately trained. This somewhat contradictory or unclear findings validate the importance of conducting some follow up interviews to validate and derive full meaning from the respondents. Nonetheless, the findings still paint a good enough picture on the understanding of green chemistry and the attitude towards its inclusion into the mainstream chemistry curriculum.

DISCUSSIONS AND CONCLUSION

This study provides important insights into Lesotho high school chemistry teachers' perceptions of green chemistry and its potential integration into the Lesotho General Certificate of Secondary Education (LGCSE) curriculum. Most respondents demonstrated

a foundational understanding of green chemistry, but this was acquired largely through informal channels such as individual reading, seminars, or incidental exposure during their studies. Only a small fraction had encountered green chemistry in a formal course, with one respondent citing a full course in a BSc Chemical Technology program. This highlights a significant gap in the formal education and training of chemistry teachers in Lesotho, as green chemistry is not explicitly integrated into the pre-service teacher training curriculum.

Teachers' understanding of green chemistry principles varied, with less hazardous chemical synthesis and pollution prevention mentioned most frequently. Importantly, teachers did not explicitly identify or classify their responses according to the twelve principles of green chemistry. Instead, they provided general examples (e.g., salt preparation, pollution reduction), which the researcher subsequently interpreted and mapped to relevant principles. This distinction is critical, as it suggests that teachers' familiarity with green chemistry is conceptual and intuitive rather than formally structured. The ability to map general classroom topics such as salt preparation to multiple green chemistry principles highlights the inherent alignment between existing chemistry content and sustainability-oriented practices. However, teachers' difficulty in explicitly identifying these connections indicates that such integration remains implicit rather than deliberate within the LGCSE curriculum. This supports the argument that curriculum content alone is insufficient without explicit framing and pedagogical guidance.

Consequently, many teachers struggled to map green chemistry principles onto the current LGCSE curriculum, despite claiming familiarity with it. This suggests that while some aspects of GC are implicitly covered, they are not explicitly framed within the context of sustainability or green chemistry. This aligns with other studies noting that green chemistry concepts are often embedded in broader chemistry topics without explicit labeling, making them less accessible to teachers (Armstrong et al., 2019; Chen et al., 2020).

The findings also reveal an interesting contradiction: while a high proportion of teachers reported confidence in teaching green chemistry concepts, an equally high proportion indicated the need for further training. This may suggest that teachers interpret "confidence" as general teaching ability rather than content-specific pedagogical readiness. Alternatively, it may reflect an overestimation of their familiarity with emerging scientific concepts, or a desire to appear competent without fully appreciating the complexities of teaching green chemistry effectively. Despite this contradiction, teachers overwhelmingly supported the inclusion of green chemistry in the LGCSE curriculum, recognising its potential to address pressing sustainability challenges such as

pollution, climate change, and resource depletion. This aligns with global trends positioning green chemistry as a critical component of sustainable development education (Murphy, 2012; Zuin et al., 2021). However, without structured training and explicit curriculum integration, this support may not translate into effective classroom practice.

The study also highlights challenges of integrating green chemistry into resource-constrained settings like Lesotho. Limited laboratory access, inadequate teacher training, and a lack of explicit focus on green chemistry in pre-service education are significant barriers. These findings are consistent with previous research on curriculum implementation in developing countries, where resource constraints and institutional barriers often hinder the adoption of new educational approaches (Bodner, 2016; Cooper, 2017).

In conclusion, despite these challenges, this study underscores green chemistry's potential to foster deeper student understanding of sustainability and equip them with skills to address real-world environmental problems. Integrating green chemistry into the curriculum, Lesotho can align its educational goals with global sustainability agendas such as the United Nations Sustainable Development Goals (SDGs). This is particularly important for least developed countries, where science and technology play a critical role in addressing socio-economic challenges (Phakisi, 2008; United Nations SDG, 2016). However, this requires concerted efforts to address existing barriers and ensure adequate support for teachers' professional development. This study therefore calls for moving from implicit exposure toward deliberate, structured integration of green chemistry into both teacher training and curriculum design.

LIMITATIONS AND FUTURE RESEARCH

While this study provided valuable insights into the perceptions and attitudes of high school chemistry teachers in Lesotho regarding green chemistry, several notable limitations must be acknowledged. Foremost among these is the low response rate: only 35 teachers responded, despite the wide distribution of the survey through social media and professional networks. This low response rate limits the generalizability of the findings and may not fully capture the perspectives of all chemistry teachers in the country. Additionally, the online nature of the survey allowed respondents to consult external resources, potentially influencing their answers. This introduces the possibility of biased responses that do not accurately reflect their true understanding of green chemistry; for instance, respondents may have overstated their familiarity or comfort with the concept. Another limitation is the lack of pilot testing for the questionnaire, which could have helped identify unclear or ambiguous questions and allowed for timely

improvements. This oversight may have contributed to certain contradictions in the responses, such as teachers expressing confidence in teaching green chemistry while simultaneously indicating a need for further training.

From a methodological perspective, the qualitative coding and mapping of responses to the twelve principles of green chemistry were conducted by only two researchers. Although consistent criteria were applied throughout the analysis, the absence of multiple coders or inter-coder verification may introduce subjectivity and limits the reproducibility of the findings.

To address these limitations and build on the study's findings, several recommendations are proposed. First, green chemistry principles should be explicitly integrated into the LGCSE curriculum, ensuring that sustainability and environmental considerations are clearly highlighted. This will help students understand the relevance of chemistry to real-world challenges and foster a culture of sustainability. Second, targeted professional development programs should be established to enhance teachers' understanding of green chemistry and equip them with the skills needed to teach it effectively. Such programs could include workshops, online courses, and access to teaching resources.

Third, follow-up studies should be conducted with larger and more diverse samples of teachers, accessed through the Ministry of Education and Training, using both qualitative and quantitative methods to validate these findings. These studies could include interviews or focus groups to gain deeper insights into teachers' understanding, attitudes, and challenges. Fourth, future studies should incorporate multiple coders or inter-coder agreement measures to enhance the reliability and transparency of the analysis. Finally, awareness campaigns should be carried out to highlight the importance of green chemistry among students, teachers, and the broader community. These campaigns could involve public lectures, science fairs, and media initiatives to emphasize the role of chemistry in addressing environmental challenges.

By addressing these limitations and implementing the recommendations, Lesotho can take significant steps toward integrating green chemistry into its education system. This will not only foster a culture of sustainability but also equip students with the skills needed to tackle pressing environmental issues, thereby aligning national educational goals with global sustainability agendas, particularly the Sustainable Development Goals (SDGs). Consequently, this will align the national curriculum with the broader development agenda. Despite the small sample size, the findings provide valuable baseline insights into chemistry teachers' perceptions in Lesotho. Future studies should employ larger, mixed-methods designs, including interviews with teachers, policymakers, and curriculum developers, to build a more comprehensive understanding.

Conflict of Interest Declaration

The authors declare no potential conflict of interest during the research, authorship, and publishing of this article.

Acknowledgements

The authors thank the LSMTA for distributing the questionnaire to their member teachers. Commonwealth Chemistry and Chemical Society of Lesotho are also acknowledged for inspiring and sponsoring the presentation of this work at the Commonwealth Chemistry Congress 2025 held in May in Stellenbosch South Africa.

Sürdürülebilir Kalkınma için Kimya: Lesotho'daki Bazı Kimya Öğretmenlerinin Yeşil Kimya Kavramına İlişkin Algılarının Değerlendirilmesi

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Gönderme Tarihi: 15.12.2025 Kabul Tarihi: 20.05.2026

Doi: https://doi.org/10.37995/jotcsc.1842998

Özet: Küresel sürdürülebilirlik sorunları bağlamında, yeşil kimya, çevreye duyarlı bilim eğitimini teşvik etmek için kritik bir çerçeve sunmaktadır. Bu çalışma, Lesotho'daki lise kimya öğretmenlerinin yeşil kimya ve bunun Lesotho Genel Ortaöğretim Sertifikası (LGCSE) müfredatına entegrasyonu hakkındaki algılarını ve bunu öğretmeye hazır olma durumlarını araştırmaktadır. Matematik ve fen bilimleri öğretmenleri derneği aracılığıyla dağıtılan yarı nitel bir anket kullanılarak, 35 öğretmenden alınan yanıtlar, öğretmenlerin çoğunun (%78) yeşil kimyayla gayri resmi olarak karşılaştığını ve temel bir anlayış sergilediğini ortaya koymuştur – bu anlayış öncelikle daha az tehlikeli kimyasal kullanımı (%57) ve kirlilikle ilgili fikirlerle (%20) ilişkilidir. Bununla birlikte, birçoğu aşina olduklarını iddia etmelerine rağmen, mevcut müfredat içinde yeşil kimya ilkelerini açıkça tanımlayamamıştır. Öğretmenlerin çoğunluğu (%77), sürdürülebilirlik sorunlarıyla ilgili olduğunu kabul ederek, yeşil kimyanın açıkça dahil edilmesini güçlü bir şekilde desteklemiştir. Ancak, %86'sı bunu öğretme konusunda kendine güven duyduğunu ifade ederken, aynı oranda yüksek bir oran da daha fazla eğitime ihtiyaç duyduğunu belirtmiştir. Bu bulgular, öğretmenlerin yeşil kimya anlayışının resmi olarak yapılandırılmış olmaktan

ziyade örtük olduğunu göstermektedir. Çalışma, Lesotho'nun eğitim sistemini ülkenin onayladığı küresel sürdürülebilirlik hedefleriyle uyumlu hale getirmek için, etkili müfredat uygulamasını desteklemek amacıyla açık müfredat entegrasyonuna, hedefli öğretmen mesleki gelişimine ve paydaş işbirliğine duyulan ihtiyacı vurgulamaktadır.

Anahtar kelimeler: Kimya öğretmenleri, program entegrasyonu, yeşil kimya, Lesotho, algı, sürdürülebilir kalkınma.

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