

INTEGRATION OF GREEN CHEMISTRY PRINCIPLES INTO EDUCATIONAL ENTREPRENEURSHIP AND INSTRUCTIONAL PRACTICES

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Abstract

Green chemistry has been considered to be a viable approach for addressing environmental issues and advancing sustainable development. An understanding of green chemistry principles is crucial for training future scientists, by emphasizing sustainability from early education stages through advanced courses. The necessity of including green chemistry principles in educational entrepreneurship is becoming increasingly important as the education sector evolves in order to generate creative and sustainable solutions. This research thus, explores opportunities for incorporating green chemistry concepts into instructional practices to promote sustainable education by edupreneurs. It also, emphasizes the potential for green chemistry education to contribute to the United Nations Sustainable Development Goals. The research suggests strategies for creating environmental awareness and promoting sustainable practices through the integration of green chemistry principles into edupreneurship. The study provided valuable insights on the role of educational entrepreneurs in promoting green chemistry practices and highlighted the challenges associated with implementing green chemistry principles in educational entrepreneurship.

Keywords: Sustainability; green chemistry; education and entrepreneurship.

Introduction

As societies are changing rapidly across the globe due to accelerating globalisation and technological developments, the world has been plunged into several challenges over the decades. Such challenges can be broadly categorized into three: environmental challenge, economic challenge and social challenge. Among these challenges, the leading and the prominent is the environmental challenges as posited by Little and Torney (2015). Environmental challenges for instance can be viewed from the lens of climate change and depletion of natural resources as a result of human activities. This challenge requires urgent action and adaptation as it worsen as the year passes by. For example, the effects

of climate change can be observed in increased in temperature, rise in water levels, flooding, water borne diseases, etc as a result of depletion of the ozone layer. These challenges can be overcome through quality education which focus on fostering the spirit of responsibility towards sustainable environment in learners.

Education generally has capability to equip learners with a sense of purpose, and the competencies they need, to shape their own lives and contribute to the lives of others. Education therefore is vital to the global integrated framework of the sustainable development goals (SDGs). It serves as an important means of implementation for sustainable human development due to the number of positive benefits it brings across the development goals (Didham & Ofei-Manu, 2015). The authors noted that education provides important construct where the perceived tensions between economic, social and environmental development can be harmonised and integrated into a single concept and pursuit of sustainable well-being for all. It is based on this premise that the SDGs call on governments to take a fresh look at the content of education. Education will be the lynchpin of a sustainable development agenda whose success relies on individuals, throughout their lifetime, acquiring relevant knowledge and developing positive attitudes to address global challenges (EFA Global Monitoring Report 2015: 294). Hence, the role of education in addressing this challenge cannot be overemphasized, especially science education.

Science education as a field of education that focus on teaching and learning of science contents plays a leading role in finding solution to the environmental challenges. It is regarded as the bedrock for technological advancement with focus on understanding of the natural phenomenon. A qualitative science education is capable of equipping learners with adequate knowledge for critical thinking and problem solving. Chemistry education as domain in science education focus on the teaching and learning of chemistry which is a branch of physical science that deals with the study of the nature, composition and reactions that matter undergoes (Imam et al, 2019). A qualitative chemistry education cannot be achieved without the availability of a functional chemistry laboratory. The activities engaged in the chemistry laboratory in most cases involve the formation of new compounds or transformation of existing compounds. These new compounds are formed along with non-useful chemicals or waste products and gases that are either emitted to the atmosphere or absorbed by the earth surface. These activities have been considered to have negative impact on the health of human and the environment. Hence, the call for sustainability in chemistry education and the advocacy for chemists to go green.

Chemical industries have been at the fore front of production of basic amenities for improvement in quality of living. These products range from medicine, food, clothing, shelter, household materials, among others. Hence, functional chemical industries plays a significant role in the global economy. These

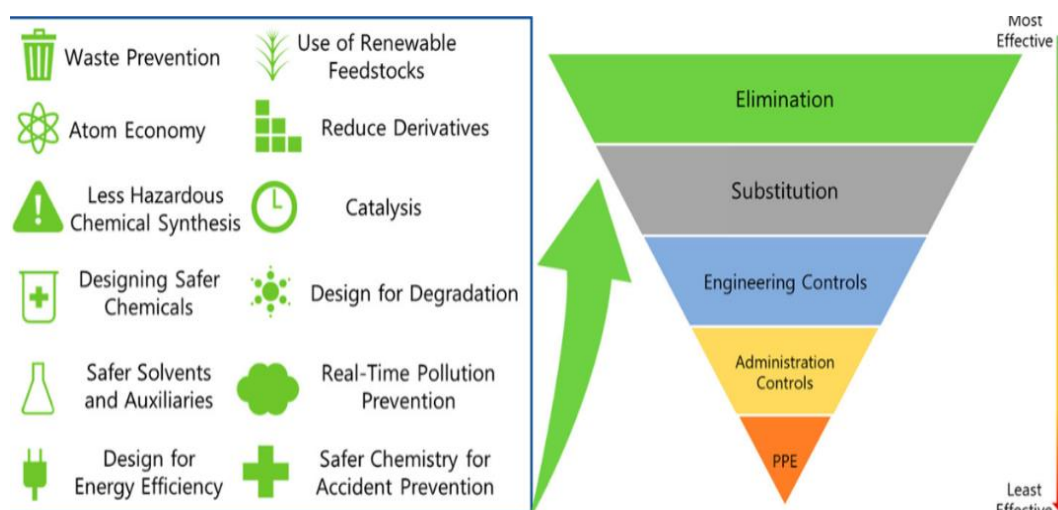
industries have also created problems that are considered increasingly recognized as a must solve to ensure environmental, economic and social stability. Therefore, the intrinsic safety of chemicals available in the market and in addition to the hazardous materials emitted into the environment during manufacture, use and disposal becomes an issue of concern. These challenges are daunting but not insurmountable, especially as there is no shortage of technical innovations and advances in sustainable chemistry from around the world (Clark & Pasternak, 2021).

Hence, entrepreneurs are becoming empowered to harness such innovations and market them. It is only through the development, scale-up and commercialization of sustainable chemical technologies that these challenges can be overcome. It therefore becomes imperative that chemists are aware and scale-up to the emerging technologies to ensure sustainable practices. Education therefore is a vital tool for equipping individuals with required knowledge and skills to meet up with such demand.

Incorporating Green Chemistry Principles into Instructional Practices

An environmentally and sustainable approach to attain eco-friendly practices in the field of chemical sciences is the green chemistry. Green chemistry refers to the sustainable practice of chemical science and technology within the framework of industrial ecology best practices. This specifically involves creation of chemical products and processes that reduces or eliminates the use and production of harmful substances (Inankovic et al., 2017). The aim of green chemistry is to reduce chemical-related impact on human health and virtually eliminate contamination of the environment through dedicated, sustainable prevention programs. Green chemistry in its focus, searches for alternative, environmentally friendly reaction media and at the same time strives to increase reaction rates and lower reaction temperatures. The green chemistry concept applies innovative scientific solutions to solve environmental issues posed in the laboratory. Abdussalam- Mohammed (2020) highlighted 12 principles of green chemistry which are as follows: waste prevention; atom economy; less hazardous chemical syntheses; designing safer chemicals; using safer solvents and auxiliaries; design for energy efficiency; use of renewable feedstocks; reduce derivatives; catalysis; design for degradation; real time analysis for pollution prevention; inherently safer chemistry for accident prevention.

Figure 1: Green Chemistry Principles and Hierarchy of control pyramid



Source: O'Neil et al. (2021).

A closer look at these principles suggests that it emphasizes safety precaution. Thus, there seems to be some kind of overlap between green chemistry and safety practices. Due to the overlap between green chemistry and safety, Ivankovic et al., (2017) emphasized that green chemistry is an interdisciplinary approach to science due to its capacity to ensure chemical, social and ecological responsibility which provides opportunity for creativity and advancement of innovative research.

Hence, Hurst (2020), advocated that sustainable chemistry education should be incorporated into university curriculum and training courses. This is to enable chemistry educators to develop learners in interdisciplinary research, systems thinking, safety and sustainability practices as they progress in their career. The design of safer technologies is enabled by a system thinking approach, which analyses the life cycle of every component of a chemical process (Aubrecht, et.al, 2019). Adopting the systems thinking approach, epitomized by green chemistry, educators considers the unintended consequences of chemicals on human and environmental health. It therefore becomes imperative that educators key into strategies and opportunities for incorporating green chemistry principles into their instructional practices.

Considering the need to for educators to incorporate green chemistry principles into their instructional practices, there abound several opportunities that can be harnessed by educational entrepreneurs whose focus is on providing innovative solutions to improve education. Edupreneuers can harness several opportunities to key into green chemistry principles to ensure sustainable chemistry education. Such opportunities include engaging in development of green chemistry curriculum for different levels of education for implementation in schools and creating learning resources for teachers and students on green chemistry. Especially, development of systems thinking models for classrooms

and laboratory. Furthermore, writing, designing and creating contents for green chemistry in educational blog or YouTube channels as well as designing virtual or hands-on laboratory experiments that demonstrate green chemistry principles. In a similar vein, more opportunities include developing interesting and engaging on-line courses on green chemistry; crafting innovative teaching methods that can be utilized by teachers to engage students in green practices and serving as consultants to schools in revamping their laboratories to be eco-friendlier. Other opportunities include: promoting green chemistry entrepreneurship among students by serving as mentors and providing support in terms of consulting services to interested learners; advocating for green chemistry policies by partnering with government and non-profit organizations to ensure sustainable chemistry education and organizing workshops for teachers and students on green chemistry using platforms like Udemy, Coursera and Teachable to reach a larger audience. Harnessing these opportunities would create more opportunities for wealth creation through service delivery and qualitative education by educational entrepreneurs.

Nexus between Green Chemistry Education and UN's Sustainable Development Goals

Sustainable development refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development addresses use the existing resources to accomplish the needs of the present generation by saving for future generations (Abeyrathna, 2021). In addressing this issue, the UN formulated the 2030 agenda for sustainable development by highlighting 17 Sustainable Development Goals (SDGs). In a bid to achieve the SDGs, efforts are put into place by embedding the values of Education for Sustainable Development and SDGs in the curriculum (Zguir et al., 2021). The July, 2024 report on the attainment of SDG goals revealed that only seventeen per cent of SDGs targets are on track to be achieved, nearly half are showing minimal or moderate progress, and progress on over a third has stalled or even regressed as spelt out in SG- SDG Progress Report, 2024 (Assembly, 2024). Green chemistry education is one way of ensuring sustainable chemistry practices and by implication, attaining UN's sustainable development goals. It revolves around equipping learners with knowledge and skills required to engage in sustainable practices in chemistry. Eilks and Rauch (2012) posited that the goal of green chemistry is at making chemistry more energy efficient, reducing waste disposal, and/or producing innovative products with less consumption of natural resources to ensure safer environment. It therefore can be inferred that green chemistry has a major role to play in attaining SDG goals. The underlisted are areas in which green chemistry can contribute to SDG goals:

1. Through design of more efficient, safer and less hazardous chemicals materials, green chemistry can minimize waste, emissions, and the use of toxic substances, aligning with SDG 12 targeted at responsible

consumption and production. This by extension make impacts on SDG 13 which focus on taking urgent action to combat climate change and its impact.

2. Most chemical industries involve in productions that generates wastes which are emitted either to the air, land or water bodies. Hence, the advocacy for real-time analysis for pollution prevention in the green chemistry principles. This is in accordance with the first principle of green chemistry that emphasizes prevention of waste rather than cleaning up waste when generated. Therefore, adhering to these principles is essential to address this challenge and consequently attaining the SDG 13 (climate action) and SDG 8 (availability and sustainable water and sanitation for all).
3. The principles of green chemistry, such as atom economy and the use of renewable feedstocks, can make a major contribution to SDG 7 (affordable and clean Energy) by enabling the development of more sustainable energy sources and fuel.
4. Innovations in green chemistry can lead to development of safer and more sustainable products from chemical industries as well as cost reduction. This specifically is in line with SDG 9 goals targeted at building resilient infrastructure, promote inclusive and sustainable industrialization and fostering innovation. This at the long run ensures healthy lives and promotes well-being at all ages which is the focus of SDG 3.
5. The interdisciplinary nature of the principles of green chemistry allows it to contribute majorly to safety issues and climate action by reducing environmental impacts and processes. Consequently, this allowed it to contribute to several SDGs such as SDG 13 (climate action); SDG 14 (life below water); and SDG 15 (life on land).

Therefore, it can be inferred that incorporation of green chemistry principles in science classrooms is crucial to attaining the SDGs. Educational entrepreneurs can harness opportunities from green chemistry to create environmental awareness in service delivery. Such services could be delivered by using strategies like case studies and citing real life examples of green chemistry innovations and its impact. Similarly, education entrepreneurs should use the opportunity to introduce green chemistry principles beyond chemistry education to enable then inform a larger populace. Hence, a call for reviewing the general school curriculum to address sustainability issues in all subject areas. Furthermore, edupreneurs can adopt teaching resources such green chemistry kit for teaching, while engaging students in project-based learning to find solutions to environmental challenges in their environment using green chemistry principles. Educational entrepreneurs should engage with industries to ensure synergy among instructional content and real-world

applicability. Hence, they should harness the power of planned field trips and excursion for instructional purposes.

Challenges of Implementing Green Chemistry for Sustainable Education

In spite the need to incorporate green chemistry principles for sustainable education, several challenges have been highlighted in previous studies to hinder its successful integration into the school curriculum. As opined by Hill et al., (2013) such challenges include the following:

1. Overcoming resistance to modifying established curriculum and teaching methods.
2. Ensuring green chemistry is fully integrated throughout the curriculum programme without just adding it as a separate topic.
3. Non-availability of necessary training and resources to effectively teach green chemistry.
4. Non availability of specialized equipment and materials needed for green chemistry laboratory.
5. Securing funding and resources to fund students' green chemistry projects.
6. Integrating green chemistry labs within existing curriculum and time constraints.
7. Building and maintaining meaningful partnerships with external stakeholders.

Overcoming these challenges by concerned stakeholders would provide opportunity for successful integration of green chemistry principles into teaching and learning for sustainable education.

Conclusion

This research concludes that green chemistry education is an essential component of chemical education that is targeted towards sustainable practices. It revolves around equipping learners with knowledge and skills required to engage in sustainable practices and by implication, attaining United Nations sustainable development goals. It is targeted at making more energy efficient materials, reduction of waste, pollution prevention, and production of innovative products with less consumption of natural resources to ensure safer environment. Through systems thinking approach, educators can equip students with required knowledge and skills for sustainable practices by considering the unintended consequences of chemical products on human and environmental health.

Suggestions

Based on conclusion from this study, the following suggestions were made:

1. Chemistry educators should be engaged in professional development programmes that will provide avenue for learning about innovative

strategies that can be used for successful incorporation of green chemistry principles into their instructional practices.

2. Seminars and symposiums should be organized for chemistry teachers on using online learning platforms to teach green chemistry principles to students beyond classroom instruction.
3. Teachers encouraged to attend conferences that will provide them with knowledge of opportunities, challenges of incorporating green chemistry principles in their classroom instruction and ways to overcome such challenges.

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