SYSTEMIC APPROACH FOR TEACHING AND LEARNING GREEN CHEMISTRY (SATLGC)

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ABSTRACT

Green chemistry courses have been recently described in the chemistry education curriculum. Its teaching and learning strategy include course content, student assessments, and pedagogical style. Current trends in education research and practice have established the importance of the intended learning outcomes and the effectiveness of high-impact practices, active learning, and inclusive teaching. In this article we designed the pedagogy for teaching and learning green chemistry through the systemic approach (SATLC). *[African Journal of Chemical Education—AJCE 13(4), December 2023]*

INTRODUCTION

Systemic Approach in Teaching and Learning Chemistry (SATLC) **[1- 9]** which. means study of chemistry concepts through interacted systems in which all relationships between concepts are clear. Chemistry is the core of all other science subjects due its special concepts and importance. But many are considered chemistry as a very complicated discipline of science, starting from atomic structure, reaction kinetics, energetics of bond breaking and formation, micro-molecules, to macromolecular compounds. All of chemical processes require deep understanding of the chemical concepts and basics, training on scientific thinking and inquiry and also, problem-solving skills. However, there are some challenges facing chemistry, such as the word "chemicals" which has become linked with environmental pollution, unsustainable growth and unhealthy toxins. meanwhile there is the word green chemistry, which is *the design of chemical products and processes that reduce or eliminate the use or generation of* hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal.

Although there are tremendous developments in science as genera and in chemistry as particular, many students prefer studying other disciplines than chemistry, even if they have interest in science due to its difficulty in understanding. Moreover, many teachers are not up to the job of inspiring and not enthusing to their students, due to their traditional lecturing style as it allowed for maximum content coverage, and it was the mode with which they were most familiar.

Enthusiasm is crucially needed in teaching and learning of chemistry at educational and should be addressed on top priority. In this scenario the role of the instructor is of vital significance. A teacher can minimize the difficulties in concept building by providing better perspective related to the basics of the subject. This can be accomplished through novel efforts involving personal input. The recently emerged concept-based teaching methodology, systemic approach to teaching and learning chemistry (SATLC), is a fascinating route to meet this noble endeavor. This new teaching method has been discovered to play a pivotal role, towards the efforts for promoting better understanding of chemical concepts. In addition to that, the results reported from the evaluation of SATL technique have been very promising as far as the improvements in students' academic achievements are concerned **[1-9]**.

However, to make chemistry easy, funny to learn, important and applicable, we always need to find strategies that make the above parameters are well addressed. Among the mechanisms method of teaching and using appropriate instructional materials are the important strategies used to make chemistry attractive and effective. This is a common concern, though it is our impression that many faculties involved in curriculum reform feel that the benefits provided by alternative instruction. This article will focus on systemic approach for teaching and learning green chemistry (SATLGC).

Differences between Systematic and Systemic Approach

At the beginning we should differentiate between systematic and systemic approach. Systematic, means something is well organized and arranged according to a set of plan or is grouped into systems. Whereas systemic means that something has or can affect the entire system. Systemic approach describes something that belongs to, work together with, or can affect the entire body or system as a whole [10]. We represent Figs. 1 and 2 to simplify the difference between systemic and systematic approach in a system consisted of items A, B, C, and D. In the systemic approach (Fig. 1) the items (A-D) are well arranged in an organized order so that you cannot see A through D, whereas in the systemic approach (Fig. 2), all the items (A-D), are affecting each other and seen synchronously.

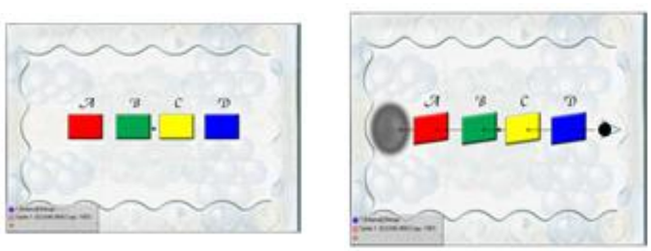

Fig.1 (Systematic Approach)

Fig.2 (Systemic Approach)

Systemic Approach for Teaching and Learning Green Chemistry

What is the Green Chemistry?

Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal.

Impact of Green Chemistry on Societies Sustainability:

- Prevents pollution at the molecular level.
- Is a philosophy that applies to all areas of chemistry, not a single discipline of chemistry.
- Applies innovative scientific solutions to real-world environmental problems.
- Results in source reduction because it prevents the generation of pollution.
- Reduces the negative impacts of chemical products and processes on human health and the environment.
- Lessens and sometimes eliminates hazards from existing products and processes.
- Designs chemical products and processes to reduce their intrinsic hazards.

Differentiation between Green Chemistry and Cleaning up Pollution

Green chemistry reduces pollution at its source by minimizing or eliminating the hazards of chemical feedstock, reagents, solvents, and products.

This is unlike cleaning up pollution (also called remediation), which involves treating waste streams (end-of-the-pipe treatment) or cleanup of environmental spills and other releases. Remediation may include separating hazardous chemicals from other materials, then treating them so they are no longer hazardous or concentrating them for safe disposal. Most remediation activities do not involve green chemistry. Remediation removes hazardous materials from the environment; on the other hand, green chemistry keeps the hazardous materials from being generated in the first place.

If a technology reduces or eliminates the hazardous chemicals used to clean up environmental contaminants, this technology would also qualify as a green chemistry technology. One example is replacing a hazardous sorbent [chemical] used to capture mercury from the air for safe disposal with an effective, but nonhazardous sorbent. Using the nonhazardous sorbent means that the hazardous sorbent is never manufactured and so the remediation technology meets the definition of green chemistry.

Principles of Green Chemistry

1.**Prevention of Waste**

It is better to prevent waste than to treat or clean up waste after it has been created.

2.**Maximize Atom Economy**

Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3.**Design Less Hazardous Chemical Syntheses**

Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4.**Designing Safer Chemicals and Products**

Chemical products should be designed to affect their desired function while minimizing their toxicity.

5.**Use Safer Solvents and Auxiliaries/Reaction Conditions**

The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

6.**Design for Energy Efficiency**

Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.

7.**Use of Renewable Feedstocks**

A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.

8.**Reduce Derivatives**

Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

9.**Use Catalysts, Not Stoichiometric Reagents**

Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. **Design Chemicals and Products that Degrade After Use (for Degradation)**

Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

11. **Real-time Analysis for Pollution Prevention**

Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

12. **Inherently Safer Chemistry for Accident Prevention (Minimize the Potential for Accidents)**

Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

Impact of Green Chemistry on Society

Green chemicals either degrade to innocuous products or are recovered for further use. Through green chemistry, plants and animals suffer less harm from toxic chemicals in the environment, lower potential for global warming, ozone depletion and smog formation, and less chemical disruption of ecosystems take place. Therefore, it is very important to integrate green chemistry in the chemistry curriculum using the most attractive methodology of teaching and learning chemistry such as the systemic approach (SATLC), in addition to the other appropriate interactive attractive educational strategies in teaching and learning chemistry such as systemic approach (SATLC), E-learning, M-learning, and any other tools in which modern technologies are integrated (Fig. 3). **[10]**

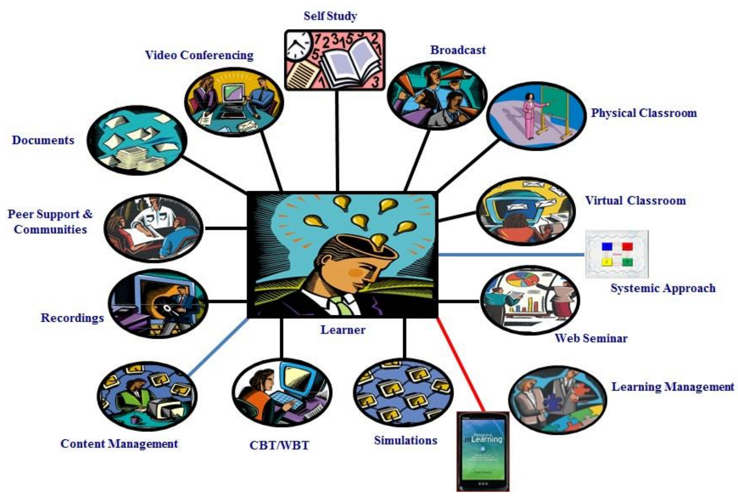

Fig. 3; Different Strategies and Methodologies in Teaching and Learning Green **Chemistry**

The goals of the green chemistry branch is to develop chemical products and processes that are less harmful for the environment and safer for workers. This article highlights some of the many ways green chemistry can be used in the daily life in consumer products, transportation, agriculture and food production, construction and packaging, pharmaceuticals, among other industries. **[12]**

Some Uses of Green Chemistry in the Daily Life (Green Society)

Uses of green chemistry in daily life are numerous, including the use of green transportation. ingredients in the food industry, new materials for construction and packaging, safer use of chemicals in agriculture and pharmaceuticals. Green chemistry is still developing but will play an increasingly important role in ensuring our wellbeing in the future Fig. 4).

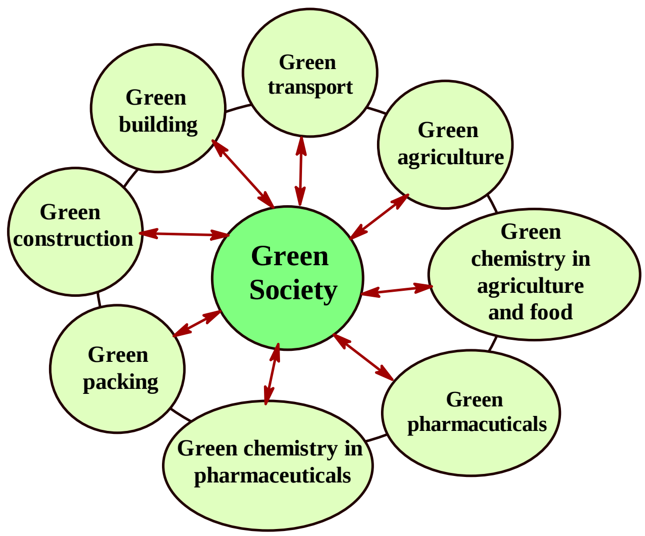

Figure 4

Challenges and Impact OF Green Chemistry Concepts on Sustainable Environmental and Social Development

Green chemistry is a cutting-edge method of creating chemical goods and processes that reduce the usage and production of harmful compounds. Utilizing renewable resources, increasing energy efficiency, and lowering waste are some of its key objectives to avoid pollution at its source and promote sustainability. With environmental issues including climate change, resource depletion, and hazardous pollution, green chemistry concepts are becoming more and more crucial **[13]**. The 12 Principles of green chemistry are becoming understood as crucial for the chemical industry's growth and hence societies sustainability. However, implementing green chemistry is challenging due to several factors, such as lack of knowledge, expense, technical problems, regulatory barriers, and a lack of government backing. To encourage the use of green chemistry concepts in business it should be publicized through the governments, industries community, society and it should be integrated in the academia, i.e., chemistry curriculum at all levels starting from schools (K-12) to higher education.

This article recommends integrating the green chemistry in the curricula of chemistry at all levels due to its important impact on the societies sustainability and improvements, with the concentration on the interrelationships between its principles, using attractive and interactive teaching and learning methodologies such as (SATLGC) to encourage its practice that leading to benefit the environment and the economy.

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