Restructuring Chemical Education to Align with Materials Science for Addressing Climate Change and Achieving Environmental Sustainability

David Kumar*, John Hill#

**STEM Education Laboratory, Florida Atlantic University, Davie, Florida 33314, USA*

#La Trobe Institute of Molecular Sciences (LIMS), Bundoora, Victoria 3086, Australia

Abstract

'Chemistry' has a long and distinguished history as a 'core science' in secondary and tertiary science education, and materials science is rapidly emerging as a major discipline in the tertiary sector. Hence, a strong case can be made to align traditional chemistry with materials science at all levels of science education to address climate change and global warming and thereby identify and address the key components of attaining environmental sustainability.

Keywords: *Materials science, chemical education, clean energy, carbon neutral, climate change, environmental sustainability*

*Corresponding author: Email: david@fau.edu

1. Introduction

There is increasing awareness that global warming is directly threatening the sustainability of vital natural resources such as clean air, fresh water supplies, and soil quality, thereby impacting food production. Concurrently, the cost of energy production is rapidly increasing, and hence the demand for alternative affordable, clean, renewable energy resources is paramount. In this context, new paradigms are emerging at political levels, such as 'carbon tax,' 'carbon economy,' 'ecological footprint,' and 'sustainable lifestyles,' among others. The intricacies and implications of these terms are perplexing to most individuals, and their emergence in common parlance suggests that widespread education is an essential prerequisite. The general public will develop an informed understanding of the global warming phenomenon in conjunction with existing and proposed strategies implemented to address it. In this context, materials science, being a conglomeration of several scientific and engineering fields, has the capacity to provide a broad platform for research and development, providing innovative solutions and widespread education for addressing public concerns about global warming. Similarly, traditional chemistry has the capacity for addressing climate change via the ongoing development of green chemistry and industrial chemistry and hence can constructively align with materials science education. Such an alignment would have an 'environmental sustainability' aim and focus. The chemistry components which align with materials science include polymers, smart chemicals, supramolecular chemistry, green chemistry, solid state chemistry, surface chemistry, nano-chemistry, and environmental chemistry [1]. In this context, in addressing topics such as 'clean energy' and 'climate change,' the importance of the connection between core chemistry knowledge, chemical reactivity, human activity, and environmental sustainability should be emphasized and identified as the primary focus of the alignment.

2. Discussion

As Hill et al. [1] proposed, while the fundamental concepts of chemistry pertinent to materials science are addressed in tertiary chemical education, the frontier concepts of computational chemistry, supra-molecular chemistry, and process chemistry need to be included at an introductory level for chemical education to successfully straddle the chemical sciences/materials science interface. Basic chemistry alone is insufficient to address the connectivity between entities such as carbon neutral fuels, global warming, and environmental sustainability [1]. Instead, in generic tertiary chemistry courses, it is necessary to remove the conceptual barrier between fundamental chemistry and emerging nanotechnology in order to establish a crucial learning environment for 'new chemistry' that incorporates many of the key tenets of materials science.

It is generally believed that global warming is primarily due to the excess emissions of greenhouse gases into the atmosphere as a direct consequence of the exponential demand for energy derived from the combustion of fossil fuels (notably coal). This reasoning has been the catalyst in the development of ‘clean,’ ‘green,’ renewable energy resources such as ‘solar’ and ‘wind.’ Concurrently, renewable energy resources such as ‘hydro’ and ‘nuclear’ already exist and are implemented in many countries as primary energy resources. However, it is widely recognized that these alternative energy sources negatively impact the environment since dams displace people from their homes and disturb freshwater ecological systems, and nuclear energy has serious waste disposal issues. An over-arching paradox in this debate is that the predicted global energy demand for the next three decades is of such magnitude that it cannot be met exclusively by renewable energy resources and that fossil fuel combustion, albeit with the co-development of clean coal technology, will inevitably remain a significant component of the global energy resource for the foreseeable future.

Thus, the broader context which incorporates the correlation of coal combustion with green energy supplies must be addressed with recognition of existing widespread coal combustion for power generation, the wide range of chemicals and materials derived from coal, and the well-established petrochemical industry in conjunction with the limited development of clean coal technology and green energy science. As a result, teaching strategies of basic chemistry concepts with a materials science focus becomes a challenge, since a broader vision of chemical education is required.

Often, superficial treatment of environmental topics is found common among school teachers in the United States, minimizing the importance of science content due to inadequate science background. As Kumar and Hansen [2] have identified, teachers who lack the necessary knowledge and educational strategies to address crucial scientific issues such as climate change may tackle these issues superficially, which can have detrimental effects on students. Hence, in secondary science education, teachers should ideally receive training to address environmental issues such as climate change without compromising the scientific basis of these concepts because ‘content knowledge’ is crucial for student understanding.

Sustaining the natural environment involves not only enacting technological initiatives but also empowering responsible stewardship by individuals to reduce their ‘environmental footprint’ by ‘consuming less’ and ‘wasting less.’

Thus, over the last decade, there have been increasing efforts to introduce sustainability themes into education at all levels. For example, "The Development, Implementation and Quality Assurance of a Tertiary Course on Carbon-Neutral Fuels, Energy and Environmental Sustainability" [3] is a practical endorsement of this trend and has been adopted as an optional component of a college science program in an Australian university and a companion 'on-line' version is under development in a university in the United States. Fundamentally, the course recognizes that chemistry education has an over-arching role to play in contributing to public awareness of sustainable clean energy production and in moving towards environmental stewardship. Although this is a college course, it can be adapted for K-12 schools since only elementary knowledge of science, technology, social science, and economics is required. The overall aim of the course is to combine scientific and technological principles related to energy production with contemporary data on global warming and, most significantly, to emphasize sustainable natural resource management through carbon neutral fuels, clean energy, and environmental stewardship.

3. End Note

It is critical to restructure chemical education to align with materials science to define and enact strategies necessary for addressing climate change and achieving environmental sustainability. Efforts to achieve this alignment, in order to address climate change and global warming, should be a priority at all levels of science education. Once the alignment is in place, then identifying and addressing the key components of attaining environmental sustainability becomes an attainable goal.

References

[1] Hill, J., Verma, R. K., Kumar, D. D. Challenges for chemical education: Traversing the chemical sciences/materials science interface.*Journal of Materials Education, 35*(1-2), 1-16 (2013).

[2] Kumar, D. D., Hansen, M.*Climate confusion: Content and strategies, not controversy, are the biggest challenges for science teachers.Brookings Brown Center Chalk Board (October 30)* (2018). Retrieved July, 7, 2023 from https://www.brookings.edu/articles/climate-confusion-

content-and-strategies-not-controversy-are-the-biggest-challenges-for-science-teachers/

[3] Hill, J., Kumar, D. D.The development, implementation and quality assurance of a tertiary course on carbon neutral fuels, energy and environmental sustainability.*The Chemical Educator*, *20*, 157-166 (2015).