Larry Kolopajlo and Mark Benvenuto

Preface: the continuum of green chemical education

Abstract: The theme of this introductory chapter is that green chemistry education is evolving as a continuum with many interconnecting subdisciplines. In this chapter are previewed ten articles of deep scholarly inquiry that should pique one's green interest and imagination.

Keywords: green chemistry, education, diversity, outreach, chemical feedstocks

1 Introduction

Welcome to *Green Chemistry Education*, the fourth volume of Green Chemical Processing. This volume is intended for science professionals, both academic and industrial, who want to keep abreast of how green chemistry is evolving across the educational spectrum. From work done at universities to high schools, readers will be introduced to authoritative narratives that treat specific topics in depth, rather than review recent developments.

In retracing previous published work in this series, Volume 1, titled *Sustainable Green Chemistry*, explored the philosophy of green chemistry, some practical applications in solvent synthesis and disposal, educational pedagogy, and how green chemistry has influenced the teaching of organic chemistry. Last of all, courses for both non-science and science majors were elaborated. In Volume 2, *Green Chemical Processes: Developments in Research and Education*, a notable contribution by George Bodner, set the stage by explaining the value of incorporating green chemistry in the undergraduate major. By recognizing contributions from Middle Eastern academicians, Kolopajlo asserted the importance of a diverse international effort in attaining a green and sustainable environment on a global scale. *Green Chemistry in Industry*, Volume 3, shifted the focus to industrial research and development, the heart and soul of green chemistry.

2 This volume

Volume 4, *Green Chemistry Education: Recent Developments*, promotes an inclusive approach, treating the educational spectrum as a continuum by including papers authored by prestigious scientists, academicians at smaller colleges, and creative scholars who do the invaluable work of secondary science instruction. Volume 4 is divided into four parts.

3 Part I: Pure and applied green chemistry at large institutions

3.1 Green chemistry and the grand challenges of sustainability

We are privileged to have the *Chair of the ACS Committee on Environmental Improvement*, Anthony M. Noce, present an inspiring opening chapter to volume 4. Noce's scientific acumen is apparent throughout this first chapter through which he knowledgeably discusses the foremost challenges to a sustainable future, which succeeding authors in this volume will elaborate on.

3.2 Turning the tables on metal ion pollution by using an invasive species

Jillian Goldfarb, Assistant Professor of Energy Engineering in the John and Willie Leone Family Department of Energy and Mineral Engineering at Penn State University, has graciously put forward a paper with her colleagues Michael Berger, and Madeline Karod of Simmons College. Their paper will merit much attention in the green chemistry community for its ecological significance in using an invasive plant species, phragmites, to filter out harmful manganese (II) ion in the Muddy River of Massachusetts.

3.3 Green biological chemistry for chemical feedstocks

We are indebted to Professor Trant and his colleagues, S. Iraj Sadraei and Brent St Onge, of the University of Windsor for contributing an intriguing paper on how widely available carbohydrates, in the form of chitin, chitosan and cellulose, may be utilized as renewable and sustainable chemical feedstocks that can help replace the production of chemicals from fossil fuels. Work in this field is of the utmost importance in combating climate change.

3.4 Understanding how synthetic organics become ecological problems

It is a distinct pleasure to have three distinguished scientists: Theodore Mill of the Stanford Research Institute and both Jay M. Patel and Caroline Tebes-Stevens of the US EPA write a veritable treatise on the serious problem of environmental toxins produced through the degradation of organic compounds. Their paper reviews the physical and chemical processes through which synthetic substances are transported

and transformed in the environment, thereby illuminating the field and providing a wealth of valuable examples to be used in both teaching and research. As this chapter wraps up contributions made by authors at prestigious institutions, the focus shifts to work done at smaller facilities.

4 Part II: Green chemistry at the undergraduate level

In this section are four papers on green chemistry at non-research I institutions.

4.1 A summer of fun in green chemistry

To a college professor, there is no more important a task than the teaching and training of the next generation of scientists. Mark Benvenuto of the University Detroit Mercy has built a very successful career in transforming the lives of his students, and colleagues, and that is why his chapter has been chosen to open this section. Professor Benvenuto's offering also bridges the gap between research done at large and smaller institutions. In his contribution, Benvenuto details how in a collaborative research program, he led a team of high-school students and a teacher to synthesize multidentate ligands that can be used in the water remediation of eight transition metals, including copper, zinc, and iron. This work is also important because it serves as a way to attract talented high-school students to the field of green chemistry.

4.2 SOTL in green chemistry

Professors Kovacs, Krikke, and Mack of Grand Valley State University have contributed greatly to the scholarship of teaching and learning of green chemistry by writing an authentic metacognitive reflection on the design, implementation, and evaluation of a series of undergraduate green chemistry courses. Their groundbreaking work can be used as a model for others who plan to introduce green chemistry courses for both majors and non-majors into their curriculum.

4.3 Streamlining laboratory work through cheminformatics

Professor Wathen of Sienna Heights University has contributed an impressive account addressing the underappreciated intersection of green chemistry and cheminformatics, a discipline that offers a unique way of understanding and evaluating new and greener chemicals for their toxicity. Cheminformatics also allows scientists to

assess the risk/reward status of proposed green chemicals by evaluating physical properties such as solubility without undertaking expensive laboratory work. With the ever-increasing, ubiquitous, and accessible online databases, one grand challenge is to educate chemical professionals in the efficient use of such resources as part of their research programs.

4.4 Rethinking outreach

Dr Kolopajlo at Eastern Michigan has been using green chemistry to reach out to a diverse and underrepresented audience of students and teachers through a myriad of methods designed to address social, cognitive, and affective modes of thought. This last section on green chemistry at the undergraduate college level uses outreach to make a transition to the next section addressing green chemistry at the high-school level.

5 Part III: Green chemistry in secondary schools

We are thrilled to have two invited contributions from teachers who have distinguished themselves in the science classroom.

5.1 A bioenergy-based green chemistry curriculum for high schools

Craig Kohn has delivered an impressive paper that provides an in-depth view on a revolutionary biotechnology laboratory course on biofuels taught in a Wisconsin high-school agriscience department. Through collaborations with universities, federal research facilities, and the surrounding community, students were able to engage in rigorous learning experiences in a sociocultural setting in a manner that maximized their preparation for college and sustainable careers.

5.2 Green chemistry through the lens of a high-school teacher

Robert Ause of the prestigious Greenhills High School in Ann Arbor, Michigan, has contributed a chapter explaining how green chemistry has been infused into his school's science curriculum with the goal of educating students on how to lead a sustainable lifestyle. It is very obvious that Ause has succeeded in reaching his students by incorporating and applying the 12 green chemistry postulates to many broader and more relevant problems like climate change.

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