



# Worldwide Trends in Green Chemistry Education

Edited by Vânia Gomes Zuin and  
Liliana Mammino



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**Vânia Gomes Zuin**

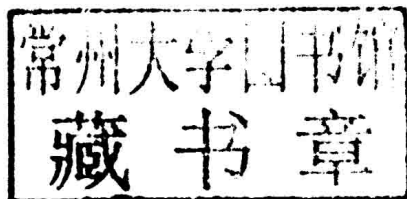
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# Worldwide Trends in Green Chemistry Education

# *Foreword*

## **Green Chemistry Education: Worldwide Trends Amidst Changing Times**

The time is right to draw the attention of chemists, educators, and others to the global status of green chemistry education. Timely, because of the mismatch between the everyday practice of chemistry teachers at the secondary and post-secondary level and high profile interrelated global initiatives that are guiding scientific and public sustainability discourse. Timely also, because of the opportunity presented to transform that educational practice, to take green and sustainable chemistry out of the aside boxes in textbooks and the margins of curriculum, and infuse it through the body of knowledge included in student learning outcomes and assessments.

While relatively little change is evident over the past several decades in curricular emphases in chemistry, interdisciplinary science is pressing forward with two important initiatives that should push scientific understandings of sustainability onto the agenda of formal and informal science educators. The first initiative rewrites our understanding of the times we live in on our planet, by moving the clock ahead on the geological time scale. An International Union of Geological Sciences blue-ribbon working group of the Sub-commission on Quaternary Stratigraphy is expected to report by 2016 on whether sufficient scientific evidence is present to formally determine that we have moved from the relatively stable interglacial Holocene Epoch to the Anthropocene Epoch [Greek 'anthropo-' (human), and '-cene' (new)], on the geological time scale. Many expect the determination to be that we are in the Anthropocene already, an epoch on the geological time scale that is defined by the human imprint. A leading candidate for the beginning of this epoch is the industrial revolution, when we observe the beginning of steep and steady rises in numerous chemical parameters related to our planetary life support

systems. A second, interconnected initiative is the systematic attempt to define and quantify 'planetary boundaries', the state of earth system parameters that define a safe operating space for humanity.

Is there a community of research and practice that is better equipped to give leadership in connecting these two global interdisciplinary scientific initiatives to chemistry educational practice than the green chemistry community? Green chemistry philosophy and principles, formally articulated two decades ago, have been put forward out of concern that the everyday practice of chemistry be fundamentally transformed so as to start with sustainability and safety considerations. For green chemistry to take firmer hold, the next generation of educators, scientists, and citizens needs to own the philosophy and embed it into practice. To move ahead we need to understand where we are, and this volume presents an important snapshot of trends in world-wide green chemistry education.

Contributions to this title cover a wide range of green chemistry education initiatives on different continents, and include descriptions of formal and informal learning environments at secondary, post-secondary, and tertiary levels. Green chemistry education is appropriately situated relative to global sustainability education initiatives such as the Decade of Education for Sustainable Development, which ends the year this title is published. Connections are made to disciplines such as toxicology, and the crucial and often neglected area of assessment receives attention, with presentation of metrics for the 'greenness' of chemistry teaching.

The contributions in this book provide an important global snapshot of the progress being made in greening chemistry education practice, and point the way toward the important steps that are still needed to make mainstream chemistry education more relevant to the future of our planet.

Peter Mahaffy  
*The King's University, Alberta, Canada*

# Preface

Green chemistry education can be considered one of the hottest themes in our time. As is well known, green chemistry aims at the design, production and use of substances that are non-hazardous and at the design and use of environmentally benign production processes, in the perspective of sustainable development. This constitutes one of the most innovative and challenging tasks worldwide. Green chemistry education aims at incorporating information about green chemistry into chemical education, thus being called to design suitable options for all the broad educational areas—curriculum development, teaching, learning and outreach—and their specific components, from in-class activities to laboratory experiments to the dissemination of information to the public. A major objective of green chemistry education is to foster sustainable scientific literacy and to develop the corresponding skills among the present and future generations.

With this book, we aim at considering key issues of green chemistry education through the presentation of research, practices and theoretical reflections in different contexts, by educators from different countries and continents, *i.e.*, Austria, Brazil, Canada, England, Germany, Israel, Malaysia, Portugal, Russia, South Africa, Spain, Thailand and the USA. Our intention is that of offering a panorama of approaches and highlighting the connections between the general objectives of green chemistry education and the design of pedagogical options at different academic and school levels, apt for the characteristics of each individual experience and simultaneously interesting for other contexts. Presenting concrete didactic activities from different realities gives the opportunity to consider a variety of diverse possibilities for the incorporation of green chemistry education into chemical education. The book includes analyses of concrete experiences from the educational point of view, as well as general theoretical reflections on the approaches and on their suitability to promote the desired types of awareness in the young

generations, keeping in mind the importance of social and environmental sustainability (nowadays and in the future) and the role that Chemistry can play to promote sustainable development.

The first part of the book considers the significance of green chemistry, green chemistry education, sustainable development, education for sustainable development, and other crucial issues, and a variety of corresponding approaches. This is followed by the presentation of a number of current initiatives in, or designed for, secondary school level. The attention given to the teaching of the green chemistry and sustainability concepts at basic education level is presently inadequate, and this needs to change. Teacher training courses and other training initiatives constitute an excellent opportunity to raise the profile of secondary school green chemistry education, and can conveniently incorporate experiences from the undergraduate and postgraduate university levels, with suitable adaptations. We believe that, by presenting a panoramic of challenges and possible responses and offering an updated insight into the most recent trends in green chemistry education worldwide, this book may constitute a valuable resource not only for chemical educators specifically interested in green chemistry education, but also for scientists, students, professionals, industrialists and policy-makers. We really hope that the readers will enjoy the direct contact with the experiences presented.

We wish to express our sincere gratitude to Merlin Fox, Alice Toby-Brant, Rowan Frame and Marisa Sartori for their fruitful cooperation and dedicated efforts in supporting the preparation of this book.

Vânia Zuin and Líliliana Mammino



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## CHAPTER 1

# *A Great Challenge of Green Chemistry Education: The Interface between Provision of Information and Behaviour Patterns*

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## 1.1 Introduction

Green chemistry<sup>1-3</sup> aims at promoting environmentally benign patterns, a change that is essential for development to be sustainable. In line with the nature of chemistry as the science of substances, green chemistry is concerned with all the stages of the 'life' of a substance or a material: production, utilization and final disposal. For the production stage, green chemistry aims at designing inherently safer substances and less-polluting manufacturing processes. Pursuing these objectives falls within the technical domain of the design of substances and processes and, therefore, it concerns chemistry research and the chemical industry. After the production stages, the rest