JOURNAL OF CHEMICAL EDUCATION

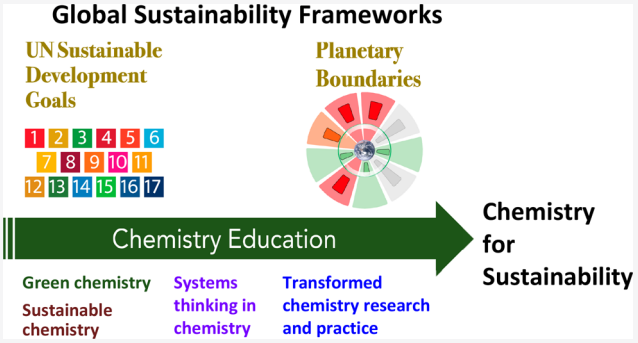
pubs.acs.org/jchemeduc Editorial

Integrating Sustainability into Learning in Chemistry

Cite This: J. Chem. Educ. 2021, 98, 1061−1063 Read Online

ACCESS | Metrics & More | Article Recommendations

ABSTRACT: Earth Day 2021, with the theme of "Restore Our Earth", along with Chemists Celebrate Earth Week 2021 from ACS with the theme "Reducing Our Footprint with Chemistry", provides a rich opportunity to reflect on the extent to which we integrate sustainability into chemistry education. Chemistry plays a central interdisciplinary role among all the sciences. It provides the essential key to understanding chemical processes and products operating within and among physical, biological, ecological, and engineered systems with far-reaching impacts on the health and well-being of people and our planet. Capitalizing on this pivotal role requires interchanges of knowledge among all these disciplines as well as the social sciences, humanities, and the arts, so that we can tease out the specific knowledge relevant to sustainability in the chemistry curriculum. This editorial highlights how the interdisciplinary work of integrating sustainability into chemistry education can be guided by systems thinking, and by the United Nations Sustainable Development Goals and Planetary Boundaries frameworks. Such systematic approaches can energize educators and learners to situate chemistry within a broader landscape of knowledge and thus tap chemistry's potential to enhance sustainability.



KEYWORDS: *General Public, History/Philosophy, Applications of Chemistry, Green Chemistry, Systems Thinking, Sustainability*

Downloaded via 80.136.96.188 on April 13, 2021 at 16:18:49 (UTC).
See https://pubs.acs.org/sharingguidelines for options on how to legitimately share published articles.

"Restore Our Earth." The three words in this year's Earth Day theme[1] convey complementary messages from and for different stakeholders. The message from global change science is that society's environmental footprints are becoming so damaging that it is now essential and urgent to take corrective action.[2,3] The global political message is that this planet is the shared home of humankind and the diverse forms of life we share this planet with, and present and future humans need to live sustainably within the limits of the natural world. There is no "Planet B" if conditions become intolerable here, so the international effort over the coming decade will be vital. The message for educators is that we (everyone in society: citizens, policy-makers, business leaders, scientists) all share responsibility for ensuring that this restoration of our planet happens.

The complementary theme from the ACS Chemists Celebrate Earth Week (CCEW) is "Reducing Our Footprint with Chemistry".[4] The outreach activities of chemists associated with CCEW are important for building awareness of the central role for chemistry in achieving sustainability. As the science that focuses on understanding the structure, properties, behavior, and metamorphoses of matter,[5] chemistry underpins two necessary strands of effort: understanding and addressing the urgent current sustainability challenges and contributing to solutions that will ensure a sustainable future. However, what does this mean for chemistry educators and learners?

As is often true when connecting curricular content and larger societal issues, a chemistry educator must make choices for how to frame an overarching theme of sustainability. Several frameworks might be leveraged for learners, at all stages in the profession. The urgency of the challenge compels educators to take a step back and look at potential options to address the environmental and societal interfaces with chemistry meaningfully, while retaining systematic and deep engagement with core disciplinary ideas, cross-cutting concepts, and the practices of science.[6]

Using the themes of Earth Week and CCEW, chemistry educators can integrate sustainability itself as well as related frameworks into their teaching and learning. The United Nations Sustainable Development Goals (UN SDGs)[7] document offers a sustainability framework with an international reach in which chemistry plays an essential role in achieving steps for action in the coming decade.[8] Chemistry connects to the UN SDGs not just through the environmental goals (SDGs 13, 14, and 15) but also through the societal provision of food, water, and clean energy (SDGs 2, 6, and 7), assuring people's health and well-being (SDG 3). Economic growth is achieved through innovation of sustainable and inclusive work, resilient infrastructure, and responsible production and consumption

Published: April 13, 2021

(SDGs 8, 9, and 12). Quality Education (SDG 4) defines the responsibility of educators in the chemical enterprise to provide sustainable education (target 4.7) to the world's learners with the knowledge and skills needed for a sustainable planet. Adaption and promotion of the UN SDGs by chemical societies, academic institutions, and industries provide a platform for student engagement through a vision of how careers in chemistry will build a better future.

In addition, the Planetary Boundaries framework[3] identifies nine interconnected Earth system processes that regulate Earth's stability and resilience, but that are currently under pressure because of human activities. The framework suggests measurable parameters for these processes and identifies quantitative planetary boundaries for seven of them, demarcating the need to restore Earth systems from regions of high risk to the long-term "safe operating space" for humanity. Many of these Earth system processes have control variables that are based on chemical parameters. Even where processes are defined in terms of physical or ecological parameters (as for climate change and biodiversity loss), they are fundamentally linked to the chemistry of life itself through the cycles of carbon, nutrient elements, and water, as well as climate change.

However, formidable barriers hinder integration of sustainability frameworks into chemistry education. These include the sense of inertia that must be overcome to transform long-standing practices and a body of curriculum that has been quite static, particularly in foundational courses at the secondary and postsecondary levels. Chemists live at the nexus of the sciences and have the inherent professional training to equip them to introduce students to the cross-disciplinary and societal interfaces with chemistry. Nevertheless, they need the confidence, support, and resources to do so.

Systems thinking is one approach that shows promise in advancing chemistry education from presenting fragmented knowledge to understanding more holistically how chemical reactions and processes are part of larger Earth and societal systems.[9−12] Beyond Earth Day and CCEW in 2021, the upcoming UNESCO International Year of Basic Sciences for Sustainable Development (IYBSSD-2022)[13] offers a timely longer-term opportunity for chemistry educators to integrate sustainability considerations into teaching and learning chemistry. The international year can help to amplify and strengthen existing sustainability initiatives, including integrating green and sustainable chemistry practices and approaches into courses and programs. The overarching goal for IYSSD-2022 is to develop and strengthen links between the basic sciences and sustainable development goals. A systems thinking approach to developing those links can bring chemistry educators into meaningful sustainability conversations with other STEM educators, along with educators in the social sciences and humanities.

An International Union of Pure and Applied Chemistry (IUPAC) task group is working on a project: "Systems Thinking in Chemistry for Sustainability: Towards 2030 and Beyond (STCS 2030+)".[14] It begins with the rationale that systems thinking is one of five key competencies identified as essential for a sustainable future.[15] By applying systems thinking, one of the three IUPAC STCS 2030+ project working groups is highlighting the centrality of chemistry as a sustainability science and developing systems-thinking-oriented activities and approaches that integrate sustainability frameworks into chemistry education with the aim of contributing to the goals of the International Year, IYBSSD-2022. In this effort, this working group is developing approaches and examples that illustrate how the UN Sustainable Development Goals and planetary boundaries frameworks, which can facilitate systems thinking, can contribute to integrating sustainability considerations into teaching and learning of chemistry.

The authors encourage readers to become involved, as the stewards of matter and energy that we are, in Earth Day and CCEW activities in 2021. It is equally important to build on that momentum to implement longer-term, sustainable initiatives to transform chemistry education so that it can play a meaningful role in achieving a sustainable future for our planet and its people. Stay tuned for invitations by the IUPAC STCS 2030+ task group to contribute to developing activities and sharing of effective practices leading up to next year's International Year of Basic Sciences for Sustainable Development.[13]

Jane E. Wissinger orcid.org/0000-0002-9240-3629
Aurelia Visa orcid.org/0000-0003-4968-4709
Bipul B. Saha
Stephen A. Matlin orcid.org/0000-0002-8001-1425
Peter G. Mahaffy orcid.org/0000-0002-0650-7414
Klaus Kümmerer
Sarah Cornell orcid.org/0000-0003-4367-1296

AUTHOR INFORMATION

Complete contact information is available at:
https://pubs.acs.org/10.1021/acs.jchemed.1c00284

Notes

Views expressed in this editorial are those of the authors and not necessarily the views of the ACS.
The authors are members of the IUPAC Working Group on "Connecting Understanding in Chemistry to Sustainability" of the IUPAC Project (2020-014-3-050), Systems Thinking in Chemistry for Sustainability: Toward 2030 and Beyond.

REFERENCES

(1) EarthDay.org. Earth Day 2021. https://www.earthday.org/earth-day-2021/ (accessed 2021-03-23).
(2) Rockström, J.; Steffen, W.; Noone, K.; Persson, Å.; Chapin, F. S., III; Lambin, E. F.; Lenton, T. M.; Scheffer, M.; Folke, C.; Schellnhuber, H. J.; Nykvist, B.; de Wit, C. A.; Hughes, T.; van der Leeuw, S.; Rodhe, H.; Sörlin, S.; Snyder, P. K.; Costanza, R.; Svedin, U.; Falkenmark, M.; Karlberg, L.; Corell, R. W.; Fabry, V. J.; Hansen, J.; Walker, B.; Liverman, D.; Richardson, K.; Crutzen, P.; Foley, J. A. A Safe Operating Space for Humanity. *Nature* **2009**, *461*, 472−475.
(3) Steffen, W.; Richardson, K.; Rockström, J.; Cornell, S. E.; Fetzer, I.; Bennett, E. M.; Biggs, R.; Carpenter, S. R.; de Vries, W.; de Wit, C. A.; Folke, C.; Gerten, D.; Heinke, J.; Mace, G. M.; Persson, L. M.; Ramanathan, V.; Reyers, B.; Sörlin, S. Planetary Boundaries: Guiding Human Development on a Changing Planet. *Science* **2015**, *347* (6223), 1259855.
(4) American Chemical Society. Chemists Celebrate Earth Week, April 18−24, 2021, with the theme, "Reducing Our Footprint with Chemistry". https://www.acs.org/content/acs/en/education/outreach/ccew.html (accessed 2021-03-23).
(5) Mahaffy, P. G.; Matlin, S. A.; Holme, T. A.; MacKellar, J. Systems thinking for education about the molecular basis of sustainability. *Nat. Sustain.* **2019**, *2*, 362−370.
(6) Mahaffy, P. G.; Krief, A.; Hopf, H.; Mehta, G.; Matlin, S. A. Reorienting Chemistry Education through Systems Thinking. *Nat. Rev. Chem.* **2018**, *2*, 1−3.

(7) United Nations. Sustainable Development Goals. https://sdgs.un.org/goals (accessed 2021-03-23).
(8) Matlin, S. A.; Mehta, G.; Hopf, H.; Krief, A. The role of chemistry in inventing a sustainable future. *Nat. Chem.* **2015**, *7*, 941−943.
(9) Journal of Chemical Education Special Issue—Reimagining Chemistry Education: Systems Thinking, and Green and Sustainable Chemistry. https://pubs.acs.org/toc/jceda8/96/12 (accessed 2021-03-23).
(10) Mahaffy, P.; Matlin, S. Next Hundred Years: Systems Thinking to Educate about the Molecular Basis of Sustainability. *L'actualité Chimique* **2019**, *446*, 47−49.
(11) IUPAC Committee on Chemistry Education. *Learning Objectives and Strategies for Infusing Systems Thinking into (Post)-Secondary General Chemistry Education. IUPAC Project No. 2017-010-1-050*; International Union of Pure and Applied Chemistry: Research Triangle Park, NC, 2017. https://iupac.org/project/2017-010-1-050 (accessed 2021-03-23).
(12) Aubrecht, K. B.; Bourgeois, M.; Brush, E. J.; MacKellar, J.; Wissinger, J. E. Integrating Green Chemistry in the Curriculum: Building Student Skills in Systems Thinking, Safety, and Sustainability. *J. Chem. Educ.* **2019**, *96* (12), 2872−2880.
(13) UNESCO. International Year of Basic Sciences for Sustainable Development—2022. https://www.iybssd2022.org/en/home/ (accessed 2021-03-23).
(14) IUPAC Committee on Chemistry Education. *Systems Thinking in Chemistry for Sustainability: Toward 2030 and Beyond (STCS 2030+). IUPAC Project No. 2020-014-3-050*; International Union of Pure and Applied Chemistry: Research Triangle Park, NC, 2020. https://iupac.org/project/2020-014-3-050 (accessed 2021-03-23).
(15) Wiek, A.; Withycombe, L.; Redman, C. L. Key Competencies in Sustainability: A Reference Framework for Academic Program Development. *Sustain. Sci.* **2011**, *6*, 203−218.

https://doi.org/10.1021/acs.jchemed.1c00284
J. Chem. Educ. 2021, 98, 1061−1063