Getting Started with Equity

A Discipline Brief for Equity in Chemistry: Jeffrey Paz Buenaflor, Ph.D.

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Contents

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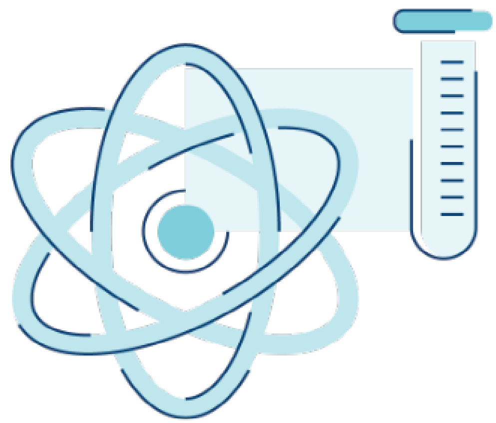
Discipline Brief: Equity in Chemistry

Jeffrey Paz Buenaflor, Ph.D., a Postdoctoral Associate Wissinger Lab Department of Chemistry at the University of Minnesota, describes how representation and the role and mindset of the instructor matters when trying to improve diversity, equity, and inclusivity in chemistry programs.

Strategies to improve diversity, equity, and inclusivity in chemistry programs



The field of chemistry is overwhelmingly white, and while strides have been made to increase racial diversity, equitable representation remains lacking.[1–3] One major contributor to this problem involves disparities in outcomes for students in undergraduate chemistry courses, especially organic chemistry and general chemistry, which serve as gatekeepers, particularly for minoritized students.[4–6] Common methods of addressing these gaps primarily rely on supplemental instruction and bridge programs that are separate from the courses themselves. The use of supplemental instruction programs for STEM courses with high failure rates provides disproportionate benefits to minoritized students.[7] Summer bridge programs that help students transition from either high school or community college to four-year universities have proven largely beneficial. However, they are unsustainable on a grander scale, due to the constant need of external funding to cover large expenses and limited spaces for participants.[8]

The development and implementation of equitable and inclusive teaching practices in general and organic chemistry are crucial in attaining racial equity in STEM disciplines and developing a diverse STEM workforce. The research-informed strategies in this brief are centered around fostering a culture of inclusive teaching, adapting the role and mindset of programs to recognize the disparity in equitable teaching practices in chemistry, and elevating the need to increase and retain minoritized students.to study the progression of syphilis, including the withholding of proven effective medical treatment.

Building an inclusive community: Representation matters

It is the responsibility of the chemistry discipline to develop a community that cultivates relationships and a sense of belonging that allows all members to thrive. One step in that direction involves acknowledging that representation matters. A recent initiative commissioned in the ACS Division of Analytical Chemistry aims to utilize artwork to highlight the visibility of female-identifying chemists and Black, Indigenous, and Latinx chemists.[9–11] Seeing examples of successful chemists from diverse backgrounds can be validating and inspiring for minoritized students.

Chemistry departments can increase the representation of minoritized chemists in several ways. Some ideas and examples include:

Establish an annual distinguished lecture series that celebrate the achievements of diverse scientists.

Incorporate "Chemist of the Week" into their classrooms by presenting examples at the beginning of the lecture or through the course website.[12]

Present a documented history of a department's effort to partake in diversity. Purdue University contributed a chapter to an ACS Symposium Series compiled by Nelson and Cheng that discussed its foundations and efforts in diversity and inclusion.[13-14] While focused on its graduate student and faculty cohort, the chapter acknowledges the need to be inclusive regarding staff and undergraduate students, as well.

There are also national organizations and programs that promote representation of Black, Indigenous, and Peoples of Color (BIPOC), gender identity, and intersectionality in STEM **(Table 1)**. Partnerships with these organizations can be utilized for outreach to promote STEM careers in the communities that neighbor the university. Departments that have established DEI committees should actively participate and network in the annual conferences held by SACNAS, NOBCChe, and ABRCMS.

Name	Acronym
Organizations[a]	
American Association for the Advancement of Science's Entry Point!	-
American Chemical Society's Women Chemists Committee	WCC
American Indian Science and Engineering Society	AISES
Association for Women in Science	AWIS
Canadians Working for Inclusivity in Chemical Sciences, Engineering, and Technology	CWIC
Empowering Women in Organic Chemistry	EWOC
Great Minds in STEM	GMiS

Name	Acronym
Latinas in STEM	
National Organization for the Professional Advancement of Black Chemists and Chemical Engineers	NOBCChE
National Organization of Gay and Lesbian Scientists and Technical Professionals	NOGLSTP
Out in Science, Technology, Engineering, and Mathematics	oSTEM
Scientista	-
Society for Advancement of Chicanos/Hispanics and Native Americans in Science	SACNAS
The Society of Asian Scientists and Engineers	SASE
Women of Color Research Network	WoCRN
Programs[b]	
Annual Biomedical Research Conference for Minority Students	ABRCMS
Louis Stokes Alliances for Minority Participation Programb	LSAMP
Maximizing Access to Research Careers	MARC
American Chemical Society Project Summer Experiences for the Economically Disadvantaged	ACS Project SEED
Research Initiative for Scientific Enhancement Program	RISE

[a] Other diversity STEM organizations not on the list can be found here.
[b] Refer to universities that have LSAMP Programs for more information

Role and mindset of the instructor

As facilitators of the course content, instructors oversee the learning outcomes that will build interest, relevance, and self-efficacy in undergraduate students. To aid in this endeavor, the perception and mindset of chemistry programs must be adapted to acknowledge disparities in equity with students from disadvantaged socioeconomic backgrounds who face challenges with increasing costs of education, and the barriers that come with chemistry acting as a gatekeeper instead of a gateway.[15] An example of faculty mindsets that recognizes the need to reshape the toxic culture and teaching practices prevalent in chemistry is addressed by a group of junior faculty who published an editorial detailing their approach to improving DEI in the field.[16] They identify six essential starting materials that can improve DEI in chemistry:

- Increasing awareness
- Improved approachability
- Mentorship
- Sponsorship
- Inclusive teaching practices
- Building communities.

While originally envisioned for organic chemistry, these six components are applicable for all chemistry programs. Additionally, the present attitude showcased by these junior faculty is an example that should be exhibited at all levels within the hierarchical structure of chemistry departments.

White et al. describe proactive methods where instructors should allow their students to make mistakes and ‘be intrusive’, a term coined by Center for Organizational Responsibility and Advancement (CORA) Learning’s J. Luke Wood. The term is a call to action for instructors to conduct an informal assessment of students’ experiences, provide onboarding resources for digital learning technologies, check in on students’ progress, and be proactive about student engagement. This idea is built on enhancing student-instructor relationships to create trust and motivate students.[17] Knezz has shown how instructors can improve this relationship further, and also addresses the overall lack of diversity in chemistry courses through personal identity.[18] Instructors can share personal information unveiling the humanity behind the scientist. This affirmation of one’s own identity can foster a sense of belonging that can empower students.

Teaching inclusively

Graduate students and faculty who primarily conduct research are usually required to teach in undergraduate chemistry courses. Quite often, these instructors are not formally trained in teaching pedagogy and consequently default to traditional teaching methods. Typically, graduate students are incentivized to focus on their research over their teaching responsibilities. This cultural attitude exemplified in chemistry programs can have negative impacts on undergraduate student learning, as the teaching competency of instructors may vary. In this portion of the brief, several strategies will be discussed in hopes of better serving chemistry instructors.

While traditional lecture-based approaches remain prevalent in chemistry courses,[18] instructors must be aware that this teaching method has proven to not benefit every student. Active learning, group work exercises, integrating social and environmental justice, bringing research-guided studies into chemistry classrooms, and using games are strategies that can supplement the traditional learning methods. These practices can be potentially more inclusive and account for the different learning strengths of each student. It is common for gateway chemistry courses to be taught in lecture halls to hundreds of students. When this is the case, the use of recitation, discussion, or quiz sections led by teaching assistants can resolve the implementation of active learning strategies.

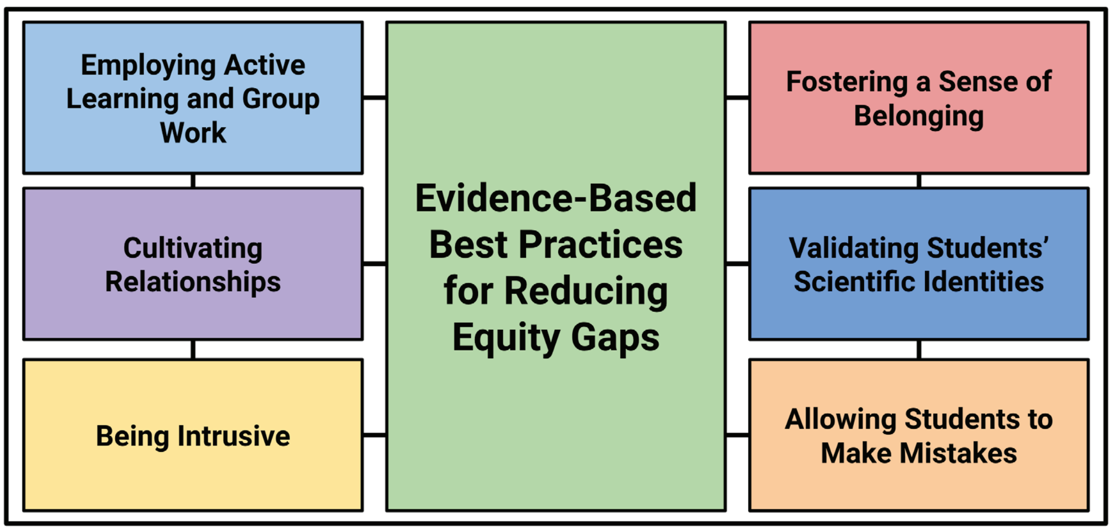


Figure 1. Practices that chemistry can use to improve learning for racially minoritized, first-generation, and poverty-affected students. [see reference 16]

Active learning

White et al. describe six practices **(Figure 1)** that can provide immediate feedback and address gaps in knowledge while also building an inclusive community.[19] These opportunities can increase self-efficacy and improve problem-solving skills of students struggling in general and organic chemistry courses. Examples of activities that employ these strategies are available in the Supporting Information from White et al. Activities 2 ("Teach Your Peers" Group Quiz) and 7 (Exam Wrapper Intervention) take the primary forms of assessment in general and organic chemistry and turn them into active learning exercises. Activity 2 is divided into two components: Students first individually complete a timed quiz, and afterwards walk around to discuss the answers with classmates. If a student discovers an incorrect response from a classmate, they are required to explain the concept to teach their peer how to reach the correct response. This Peer-Led Team Learning (PLTL) exercise provides many benefits to students in the form of stronger communication skills, improved understanding of the course material, and classroom camaraderie through networking. PLTL is effective in reducing gaps in course outcomes and the model has been incorporated across several STEM disciplines.[20] Activity 7 focuses on a low-stakes assignment where students assess their exam results. Students are required to evaluate their preparation, review their errors, and develop strategies to avoid repeating mistakes. This approach to active learning motivates students to improve and overcome obstacles.

Integrating social and environmental justice

Integrating social and environmental justice into chemistry courses helps to provide a framework that connects the relevance of the field to real-world problems.[21] This has the potential to inspire a new generation of scientists with a focus on finding solutions that can contribute to the United Nations Sustainable Development Goals (UN SDGs)[22] **(Figure 2)**. Today, social justice in chemistry curriculums is rare and few examples exist in the literature.[23] This is an area that has a tremendous amount of room for development and presents a way of highlighting the inequities experienced by students from poverty-impacted and racially minoritized communities, who are disproportionately impacted by harmful exposure to hazardous chemicals.

Figure 2. The seventeen UN SDGs [see reference 22]

Environmental justice is commonly presented through the efforts of green chemistry education. In this discipline, the benefits and hazards of chemical processes are highlighted through the 12 Principles of Green Chemistry[24] **(Figure 3)**. These principles are mainly specific to environmental impact, while the UN SDGs also incorporate equity and social justice.

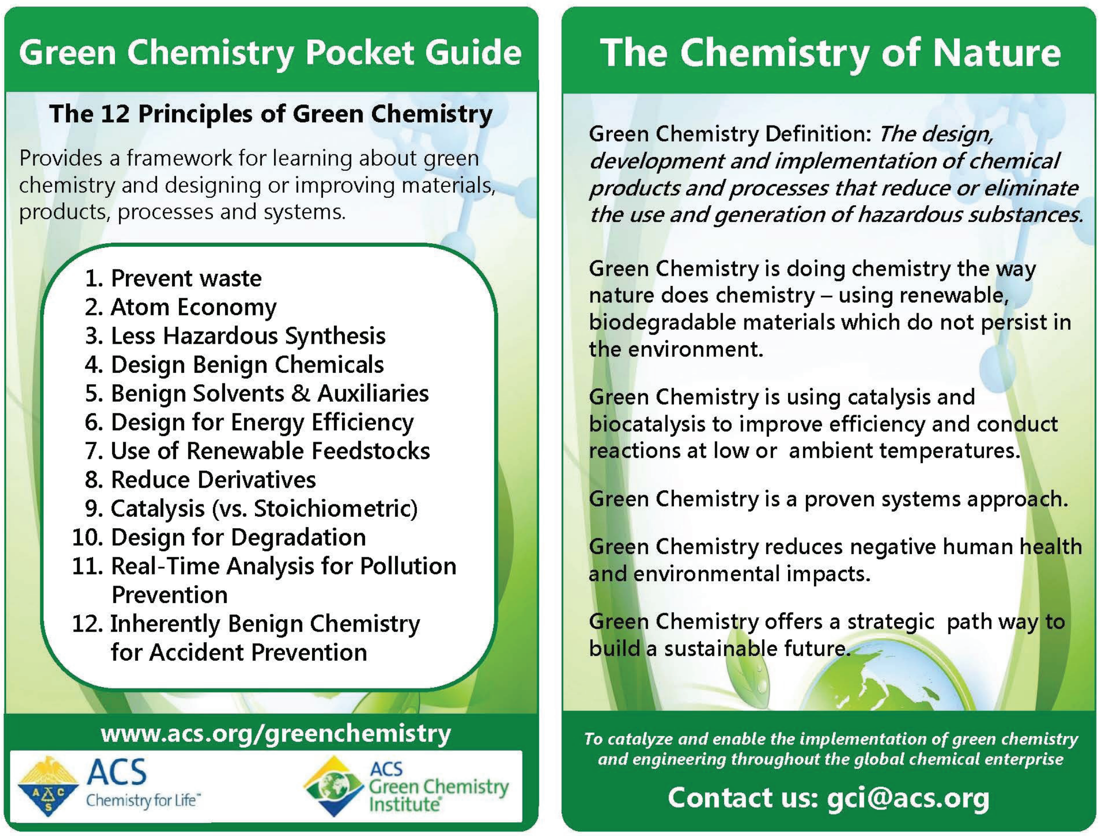


Figure 3. The pocket guide to the 12 Principles of Green Chemistry [see reference 24]

In the past 20 years, green chemistry education has seen a dramatic increase in publications **(Figure 4)**, resulting in numerous resources available for chemistry programs to adapt into their curriculum. Several publications employ the systems thinking approach to interconnect green chemistry with the curriculum, in both lecture and laboratory courses for general and organic chemistry.[25-26] Students are introduced to the UN SDGs and the 12 Principles of Green Chemistry, which are linked to the fundamental topics in class. As of 2019, there is a group of seventy signatories of the Green Chemistry Commitment, comprised of R1, R2, R3, primarily undergraduate institutions, and community colleges.[27] In collaboration with Beyond Benign, chemistry programs are creating a community that is centered around sustainability by changing how chemistry is taught, with an emphasis on the interconnections of chemistry with human health and the environment.[28] A positive effect of incorporating green chemistry content is that it improves safety as benign materials are used, and generation of hazardous waste is minimized.

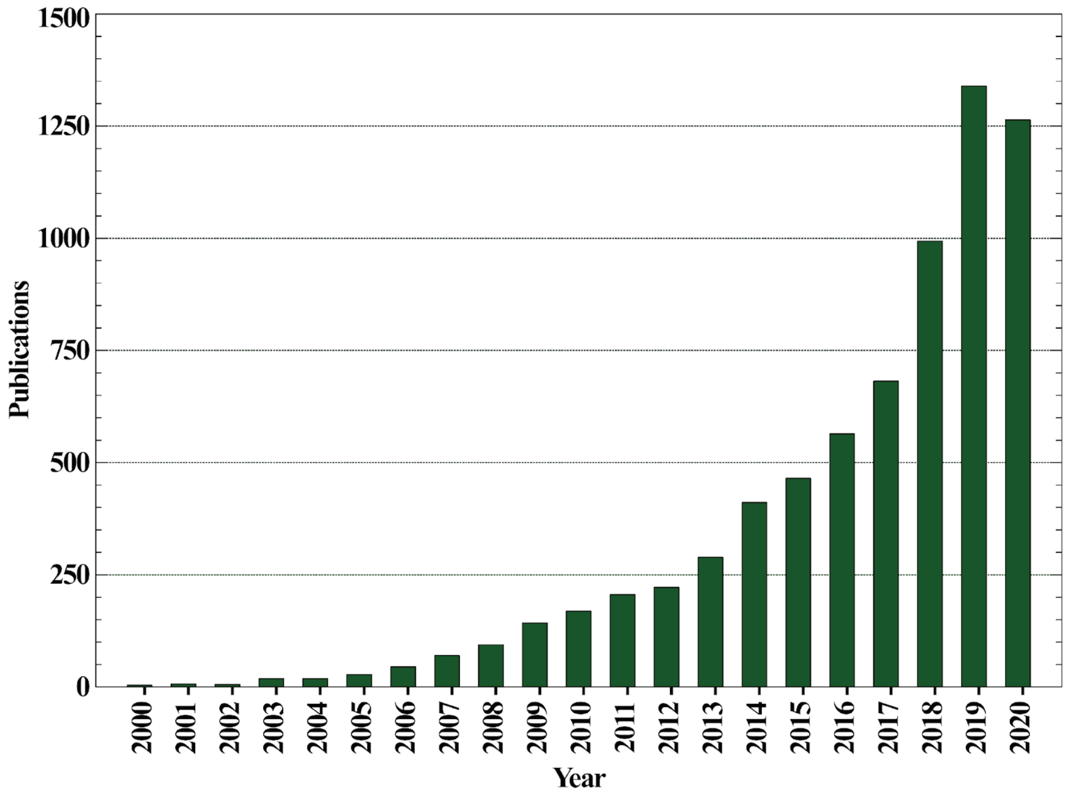


Figure 4. An updated graphical display on annual publications calculated using "green chemistry education" in the PubMed search engine. [see reference 25]

Bringing research into the classroom via sustainability and green chemistry

Engaging and exposing students to current synthetic methodology and characterization techniques in chemistry is highly beneficial to their skill development. Principle investigators in chemistry programs should think about their own research and whether any of their projects can be converted into a teaching lab. A review of the literature lists several green chemistry experiments that have been installed in organic[29-37] and introductory[38–44] laboratory courses. The comprehensive development of green chemistry curricula is predominantly found in organic instructional courses, compared to the few examples observed in general chemistry.[45-47] Reducing this gap is necessary, as general chemistry is a gateway for enrolling in organic chemistry.

Replacing long-overused traditional experiments with current state-of-the-art innovations can help update laboratory curricula to increase their relevance. However, implementation of new teaching experiments can be challenging, as it requires the removal of established content. Here are some examples of how it can be done:

- Palesch, Gilles, and Wissinger implemented a green two-step synthesis where vanillin was iodinated and then subjugated to a Suzuki-Miyaura coupling reaction.[48] This teaching lab replaced two old experiments that taught electrophilic aromatic substitution and C-C bond formation through Grignard reagents.
- Armstrong and colleagues from UC Berkeley were able to adapt green chemistry as an additional learning outcome, while retaining most of the traditional content in general chemistry.[49]
- The National Science Foundation Center for Sustainable Polymers has translated its research into high school and undergraduate chemistry curriculums through guided-inquiry experiments.[50]

Gamification of chemistry

The utilization of games in chemistry can be a fun and engaging way to fulfill learning objectives. These activities can be employed both in and out of the classroom, depending on the format and required materials. Different formats that exist in the literature cover board games, cards, and digital platforms via mobile apps:

- Card games have been utilized for understanding organic functional groups [51-52] and intermolecular forces.[53] Board game formats include 1H-NMR spectroscopy [54] and reaction mechanisms.[55]
- Green Tycoon is a mobile application game that introduces students to green chemistry principles linked to biorefining processes.[56]
- Common games such as Taboo, Battleships, and Charades have been adapted in a learning format themed on introductory and general chemistry topics.[57–59]

The literature listed here demonstrates a high pedigree of creativity that transcends traditional teaching methods. The range of accessibility and approachability of these educational games creates a collaborative and inclusive environment for students, leading to increased positive learning outcomes.

Outlook

Reducing racial and socioeconomic disparities in course outcomes remains a difficult challenge in chemistry. Changing the gatekeeper culture in chemistry requires elevating the importance of diversity, equity, and inclusion to match that of research breakthroughs. There is an abundant number of strategies that can be adopted into chemistry curriculums to supplant or replace traditional methods. The selected strategies in this brief are examples that have demonstrated positive results in their implementations. They serve as examples of how to foster an environment of scholarly learning that reduces inequities experienced by racially minoritized and poverty-affected students. The implementation of these strategies can potentially have a positive impact on increasing interest and improving the retention of undergraduate students in chemistry.

Helpful Links

A Discipline Brief for Equity in Chemistry: Kimberly N. White, Ph.D.

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