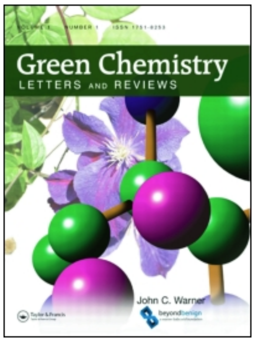


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# Integrating social and environmental justice into the chemistry classroom: a chemist's toolbox

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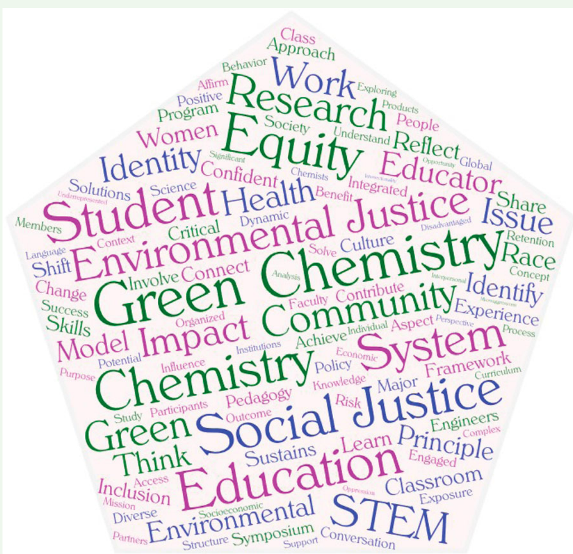
**ABSTRACT**
Although the chemical enterprise has provided numerous contributions to humanity, unintended consequences contribute to a disproportionate exposure of hazardous chemicals to certain populations based on race and socioeconomic status. Integrating concepts of social and environmental justice within chemistry curriculum provides an educational framework to help mitigate these impacts by training the next generation of chemists with justice-centered and green chemistry principles to guide their future work. Green and sustainable chemistry technologies can contribute to social equity and environmental justice. However, equity and social justice have only recently become a significant part of the green chemistry conversation. This article summarizes how the authors have explored issues of equity and environmental justice with the green and sustainable chemistry community. It offers a toolbox for college and university instructors containing foundational language, research, and idea-generation that can be used to strengthen the transition of a traditional chemistry curriculum toward a justice-centered one.

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## Introduction

The American Chemical Society's (ACS) vision (*1*) focuses on '[i]mproving people's lives through the transforming power of chemistry.' Chemistry has inarguably provided numerous contributions to humanity; however, it has come with a history of unintended consequences of chemical impacts on human health and the environment (*2–4*) including planetary-level impacts on atmospheric processes and climate (*5*). In some cases, these have contributed to a disproportionate exposure to hazardous chemicals in vulnerable populations (children, women, communities of color, and low socioeconomic communities) (*6–11*) and warrants discussion around ethics and responsibility of the chemical enterprise to reduce

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these burdens. For example, in low- and middle-income countries, environmental pollution is a leading cause of mortality and morbidity (*12*) and is associated with illnesses such as diabetes (*13–15*), metabolic syndrome (*16*), cardiovascular disease (*17–19*), and hypertension (*20*) among many others. In other cases, naturally-occurring and human-made chemicals have impacted access to clean air, food, and water globally such as Flint, MI lead water poisonings (*21*, *22*), lead exposure in inner city housing (*23*); higher BPA levels in the blood of individuals using emergency food assistance due to higher BPA in donated food bank items (*9*); jet fuel exposure in the air surrounding air force bases (*24*); and other impacts. Attending to principles of social and environmental justice within chemistry curriculum provides a framework to reduce these impacts and ensures that the next generation of chemists hold justice-centered principles and actions as a steadfast aspect of their future work. Green chemistry principles can also guide scientists and policy-makers in making evidenced-based decisions in how we design, make, use, and dispose of chemicals and chemical products.

## Exploring issues of equity and environmental justice with the green and sustainable chemistry community

Only recently has equity and social justice become a significant part of the green chemistry conversation. While the 12 Principles of Green Chemistry do shift accountability toward environmental impact consideration, only one of them, 'Principle #4: Designing safer chemicals. Chemical products should be designed to achieve their desired function while being as non-toxic as possible,' (*25*) is specific to human health. While great strides have been made to design safer chemicals within the chemical enterprise, there is more work to be done around recognizing the existence within and impact of chemicals on disadvantaged communities, particularly those of lower socioeconomic status and communities of color. It is implicit that green and sustainable chemistry contributes to social equity and environmental justice because these innovative technologies have excellent potential to offer solutions to achieve equity. As well, this fully complements the dynamic ACS Mission Statement, which is 'to advance the broader chemistry enterprise and its practitioners for the benefit of Earth and its people' (*1*).

Organized conversations around social and environmental justice as a framework to address the *why* of green chemistry began at the 20th Green Chemistry and Engineering Conference in Portland in June 2016 during a symposium on green chemistry and the social and environmental (in)justice of chemical exposure. The purpose of this unique symposium was to bring together, for the first time, a multidisciplinary group of participants to begin exploring the racial and socioeconomic disparities in how hazardous chemicals impact society. This topic was discussed with over 75 participants who attended the symposium event.

This justice- and equity-centered symposium has now been held at the last 3 GC&E conferences (2016, 2017, 2018 and will be again in 2019), each time building on strong and consistent attendance and sharing knowledge across disciplines and fields to better define, identify, and determine how to mitigate these issues from a chemistry perspective. The growth of this symposium is not surprising. Chemistry professionals connect with green chemistry from science, education, and business perspectives. Others intersect from areas such as public health, toxicology, occupational health, policy, government, engineering, industry, etc. Linking green and sustainable chemistry to equity and environmental justice inspires and resonates with a completely new audience (*26*) and has expanded the reach of green chemistry's influence. A central theme from these symposia has been how these topics connect to green and sustainable chemistry. It is important to note that the narrative of these symposium and subsequent events, workshops, etc, has never been that 'chemicals are bad.' Instead, it has been an exploration of how different sectors of the chemical enterprise interpret the topics of 'social equity' and 'environmental justice' and how there is a specific connection of justice to green and sustainable chemistry.

Teaching students these connections (exposure impacts on health, disease status, and the environment as well inequitable access to clean water, air, and food for communities of color and low socioeconomic status) has emerged as a significant thread in all three symposium and in the subsequent work that participants have done within their own institutions to expand their chemistry curriculum to focus more on justice and equity. Another new and emerging theme is the way in which the ACS and the chemical enterprise can contribute to equity on a global scale by contributing to achieving the United Nations Sustainable Development Goals (SDGs) (*27*). The concept for using the SDGs to drive forward work that supports equity arose indirectly from these justice-focused symposia at GC&E, and participants and workgroups are noting that the keys for the chemical enterprise will be innovative technology, economics, and systems- and life-cycle thinking.

## Integrating justice into the chemistry classroom

Social and environmental justice provides a framework for teaching and investigating chemistry as solutions to inequitable health and environmental impacts due to chemical exposure that can be mitigated through green chemistry principles that influence the design, manufacturing, and use of products with an emphasis in considering human and environmental health (28). Social justice supports the equality of all in economic, political, social, and human rights access and environmental justice assumes the same equal access of rights through regulations and policies of environmental laws and considerations (28). The community as a whole is considered as focal as the individual itself and this community-mindedness advocacy for the health and wellness of place and community are an important part of many student's values and goals. Research shows that programs that incorporate aspects of cross-cultural and social systems are key to student engagement and retention (29–33) especially for students of color and women (34, 35). Leadership skills also develop in students when courses focus on social justice and civic responsibility (36–39), while civic engagement in young adulthood has been shown to have a positive impact on income, education level achieved, and positive mental health and health behaviors (40). When these concepts are integrated into major-level courses, students frame these skills within the context of the subjects studied, further strengthening their experience in the classroom (41).

Integrating social and environmental justice frameworks into chemistry courses and/or programs requires a multi-faceted approach that involves many pieces of a complex puzzle. Recently, a two-year endeavor by Koretsky et al. (42) to shift the School of Chemical, Biological, and Environmental Engineering (CBEE) at Oregon State University (OSU) toward fostering inclusivity, diversity, and meaningful experiences for students was undertaken. Their process included developing and implementing guiding principles that can be used as a model. These guiding principles exemplify the principles of green chemistry by including the student experience as part of the learning process that develops young chemists into justice-focused researchers, developers, and engineers with a systems-level approach to considering impact. Additionally, by prioritizing pedagogy that supports successful retention and completion of students of color and women chemists, (43–45), a more diverse STEM workforce results as well. The guiding principles are as follows:

(1) 'Increasing inclusivity, diversity, and social justice in engineering education requires active cultural changes at organizational/departmental and interpersonal levels that affect the experiences and perceptions of students and faculty to increase the degree to which diverse individuals identify as chemical engineers.
(2) Organized cultural change leads to inclusion when it reflects and affirms the lived experiences of all members of the community (e.g. students, staff, faculty, administrators) as people with complex, multifaceted identities. These changes should align with our community's core shared mission of developing students' chemical engineering knowledge and skills.
(3) Explicit pedagogical and social supports for students and faculty will help to transition their identities, knowledge and skills from engineering school world to engineering practice world' (42).

The following discussion is offered as a toolbox of foundational language, exploratory research, and idea-generation that can be used to strengthen the transition of a traditional chemistry curriculum toward a justice-centered one.

## STEM identity and its impact on student success

Confidence and science self-efficacy have long been recognized as an important indicator of student success and retention in STEM majors, and women historically have less confidence in STEM abilities or perceived success (34, 46–49). In one study researching the role of identity development and values in STEM retention, researchers found that confidence in a Chemistry II class was directly related to course grade and overall retention in STEM majors. Students who started their Chemistry II class with more confidence earned a higher grade than those who did not; students who earned higher grades in the beginning of the term gained confidence over the semester and were less likely to leave their STEM major; and those students who were confident in their place within a STEM major earned higher Chemistry II grades than those who were not (50). This is good news for those students who feel like they 'belong' in the chemistry major, but what about those who do not?

Women of color, among other underrepresented groups, do not persist in STEM at the same rates as their White male counterparts due to social or interpersonal factors, contributing to a lack of a sense of social belonging in STEM spaces (35, 51, 52). Likewise, women of color experience microaggressions disproportionality in STEM spaces, including being questioned about their 'presence' in STEM as well as experiencing racial harassment (35, 53, 54). STEM identity is traditionally described as competitive, individualistic, and solitary (think 'lone genius') (*34*, *55*), which disadvantages women and students of color who are engaged and retained when they have access to and belonging within cross-cultural social systems (*29–32*). This is of critical importance when of the 21,821 degrees awarded in chemistry in 2016, only 1,978 were awarded to Hispanic students and only 1,168 were awarded to African-American students (*56*).

It is important that the space that chemistry exists within (be that the classroom, laboratory, office, program, community, etc.) be inclusive, diverse, and welcoming to *all* students but particularly mindful toward the additional work required to support underrepresented minority students. One approach is applying critical race pedagogy in the classroom. Critical race pedagogy 'is an instructional approach designed to challenge and transform the prevailing Eurocentric power structure that organizes higher education curricula in order to cultivate spaces that validate the experiences of Students of Color' (*57*). This framework helps minimize microaggressions in spaces where students are growing their confidence and self-efficacy around chemistry success. It also has been shown to empower students of color when conversations and acknowledgements are made in regard to system-level biases and discriminations (*57*), especially as they exist as barriers for students.

Acknowledging the role of intersectionality in STEM identity is also critical. Intersectionality is defined as 'the social, economic and political ways in which identity-based systems of oppression and privilege connect, overlap and influence one another' (*58*). It recognizes that there are biases occurring at multiple levels when considering intersectional identity such as gender, ethnicity, disability, age, veteran status, etc. and prevents individuals from feeling included. For example, 76.9% of African-American women in one survey around gender bias for women of color stated that they were more likely than other women to have to prove their expertise and competence (*59*). Likewise, 'Latinas who behaved assertively risked criticism for being angry or 'too emotional,' even when the women themselves reported that they weren't angry – they just weren't deferential. Nearly 60% of Latinas surveyed noted backlash for expressing anger, as compared with 54.4% of Asian-Americans, 49.7% of Whites, and 47.8% of Blacks' (*59*). When learning and research spaces are compromised, no one benefits.

## Social justice education pedagogy

Social justice education as a pedagogy is one that 'explicitly recognizes the disparities in societal opportunities, resources, and long-term outcomes among marginalized groups' (*60*). A social justice educator is one that models, affirms, and sustains socially-just learning spaces so that the student may recognize equitable social relations and structures in the greater context of work and life. It's not just *what* they are learning but *how* and *why* they are learning it. It explains how a classroom that models social justice equity influences the development of social and equitable decision-making by the student after the class is over (*61*, *62*), and that 'using a social justice lens to actively engage learners in STEM content provides motivation and engagement not found in decontextualized academic knowledge.' It allows students to build critical consciousness around the social function of their chemistry knowledge (*63*). Since chemicals know no borders, it is important that students recognize the global impact of the work they will be doing and that they grow a social consciousness that allows for green chemistry and justice principles to guide pre-production design decisions. In the classroom, faculty could facilitate having weekly discussions around case studies that highlight regrettable substitutions, environmental, or human health impacts of chemicals such as DDT, lead, asbestos, chemicals in cigarettes, eWaste, noeniciti-noid and chlorinated pesticides, etc. Depending on the curriculum that week, examples can be brought in that mirror the content and can complement the required learning for that unit. Students learn to associate chemical classes, reactions, and processes with outcomes beyond the 'final product' and recognize their role in supporting outcomes that will not negatively impact communities and ecosystems.

Hahn Tapper (*60*) suggests a model of social justice pedagogy that involves five pillars: A: Freirean notions of social justice; B: An examination of individual and group identities (social identity theory); C: Intersectionality; D: Experiential education (text study, guest speakers, field trips, interactive activities); and E: Responsibility and empowerment. This model was developed after analysis of an educational organization founded in 2003 that offers intergroup programs that deeply integrates social justice (*60*). This is just one of many models developed and employed across organizations, agencies, and educational programs.

It is important to note that while there is no 'unified approach' to social justice education, there are some shared principles: '[1] There are very real differentials in access to social and institutional power between relationally positioned group members. [2] While all people have socialized prejudices and can discriminate, only the dominant group is backed by social and institutional power, which is multidimensional and constantly operating, being contested, and renegotiated. [3] Those who claim to be for social justice must also be engaged in self-reflection on their own socialization into patterns of oppression and continually seek to counter those patterns. This is a lifelong project and is not achieved at the completion of an article or workshop' (*64*). Reflection on these shared principles can be a starting point for the multi-layered work required for integrating social justice into the chemistry classroom: (1) reflecting around your identity and role in the dynamics of oppression, privilege, identity, and -isms, (2) understanding that students come with their own needs to reflect and learn more about these systems and their own place within them, and (3) and framing curricular learning around justice-related content.

Some of this work should be done *before* shifting curriculum toward a justice-centered approach (self-reflection and research and training in cultural-competency, identity, bias, threats, etc) while other aspects of this work will happen in the classroom, in real time. Creating inclusive classroom spaces is also imperative for student success. Inclusive classrooms require that content be created that accounts for multiple perspectives and varied lived experiences from all students. It embraces how an individual's values and perspectives are valuable in how they construct, retain, and apply knowledge (*65*). It is also imperative that faculty address their own potential assumptions around student identity and learning capabilities. This may be difficult or uncomfortable passage for faculty who have not yet done this reflective work. One tool to help begin the process of self-reflection is the Implicit Bias test. This test was designed to help individuals identify internal biases by measuring 'the strength of associations between concepts (e.g. black people, gay people) and evaluations (e.g. good, bad) or stereotypes (e.g. athletic, clumsy)' (*66*). It is a frequent starting place for individuals engaging in social justice pedagogy and advocacy. It is also a great tool to use with students as their own implicit biases can shape the classroom community and impact others.

In some instances, inclusivity in the classroom can be challenged by a very important need to discuss and investigate the role of racism, bias, etc within lived experiences of students collectively. Although these conversations may result in unintended consequences ('altercations between individual students or groups of students; silence from students who feel intimidated or fear conflict; the assertion and perpetuation of false stereotypes or problematic assumptions; the expression of offensive speech') (*65*) making sure the conversation is planned and responses to these issues have been well-considered will mitigate potential negative outcomes. A guideline for handling these potentially difficult moments in the classroom is outlined by Sensoy and Diangelo (*64*) as follows: [1] 'Recognize and affirm the importance of the conversation, [2] Be honest about your lack of experience but your willingness to try, [3] Change your pedagogy, e.g. move to small groups for some discussions, [4] Facilitate by inviting other voices in – e.g. 'Does anyone have a similar or different perspective?' 'Who hasn't spoken yet?', [5] Facilitate dialogue rather than debate, e.g. 'both/and' rather than 'either/or' frameworks.' Despite the potential for difficult dialogue, having the conversations and doing reflective work within self and with students creates an inclusive and safe learning environment for all students.

## Community-engaged participatory research

The history of product development globally has rarely prioritized consideration for ecological and human health impacts of the chemicals or products developed. As a result of this omission, more of these impacts are being recognized and reported through clinical research and epidemiological studies, especially within disadvantaged communities and populations. Some researchers are attempting to quantify and qualify those impacts through work with communities to determine the best ways to mitigate them. One way in which this occurs is through Community-Based Participatory Research (CBPR). CBPR ensures that community members are partners in this research and work, not subjects. It uses knowledge within the community to design research or interventions best-suited for the nuances of the systems within that community and helps connect the community with the researchers and policy makers to build relationships. When these parameters are met, it allows the community to realize the benefits immediately and directly (*67*). This model of research diverges from more traditional research found within STEM programs, particularly in chemistry where the work happens in laboratories, not in communities.

Recognizing the role of communities as an integrated aspect of research requires interpersonal reflection on the equality of communities (especially communities of color and disadvantaged communities). One must dismantle hierarchies of systems and judgement around educational, income, class, and race/ethnicity status to allow community members to be equal partners in finding solutions for their issues. Faculty who shift toward CBPR demonstrate this commitment to diversity and inclusion by modeling research as a partnership that benefits all involved, not just the institutions already advantaged. It is important that there is a direct role that the community has in the design and conduction of research and the development of policy around the issues that directly impact them. This can be difficult for a number of reasons, some of which are related to scientific and health literacy levels, where 36% of adults have at or below basic levels in health literacy skills (*68*) and the use of complicated language, contradictory health information, and quantity of information that makes understanding science and health concepts difficult for individuals, especially those who are of a low socioeconomic status (*69*). Likewise, communicating environmental exposure risks to communities may have ethical concerns when research hasn't yet finalized real risk outcomes associated with exposures in many instances (*70*). Still though. there is still a significant benefit to involving students and communities together in finding solutions to issues around chemical exposures such as helping students develop concepts around culturally-tailored interventions (*71*), building leadership skills (*72*) and civic responsibility (*73*), helping to dismantle hierarchy of academic systems in research (*74*), increasing critical thinking skills among students (*75*), and linking knowledge to action (*76*). Some barriers for faculty may include lack of departmental or institutional support for this type of work, funding issues, and lack of time to properly build relationships with communities and to implement CBPR research that meets the criteria of ethically-responsible engagement.

## Systems thinking in chemistry

Systems thinking was conceptualized in 1987 by Barry Richmond, a pioneer in systems thinking and the dynamics of systems (*77*). Later, Arnold and Wade pointed to a need for a 'common language and framework' that allows interdisciplinary teams to share knowledge and solve global issues in part due to the commonality of this language and framework. The complexity of systems prompted Arnold and Wade (*77*) to redefine systems thinking as a 'system of thinking about systems,' and they analyzed eight well-regarded systems thinking definitions. They found among them that 'common elements tend to include interconnections, the understanding of dynamic behavior, systems structure as a cause of that behavior, and the idea of seeing systems as wholes rather than parts' (*77*). Investigating and visualizing this interconnected web of topics, disciplines, partners, etc., is particularly helpful for chemistry students who wish to connect justice to their work as chemists and designers to directly or indirectly resolves potential justice-related health and environmental issues. Systems thinking demonstrates chemistry's 'place' in the larger context of the world (*78*) by challenging student to 'think about how chemistry may be used to provide services and functions to other sciences and end-uses as opposed to being an end all to itself to advance the science of chemistry' (*79*). This serves justice-oriented outcomes by challenging ideas of hierarchy and helping students recognize post-production impacts in the context of lifecycle inventory and assessment in product development (*79, 80*).

Matlin et al. (*81*) calls for systems thinking in the development of a 'one world chemistry.' They cite chlorofluorocarbons, antibiotics, and plastic waste in the sea as three examples where the chemical enterprise has applied principles of systems thinking toward recognizing impacts and devising solutions to concerns. Systems thinking is inherently interdisciplinary, yet Reeve (*82*) suggested that the *educational* approach may be better framed as 'STEM Thinking,' which is 'purposely thinking about how STEM concepts, principles, and practices are connected to most of the products and systems we use in our daily lives.' As students apply what they have learned within their chemistry courses or programs to solving problems within the context of systems thinking assignments or case studies (or on projects across different schools and disciplines of study), they recognize their impact within these greater systems. Expanding their question *'Why am I studying chemistry?'* beyond STEM-based learning outcomes into social and behavioral, artistic and creative, health and medicine, and systems of race, culture, and identity, challenges them to work interdisciplinarily to solve complex issues and provides relevance to the real-world systems beyond the classroom and laboratory (*28*).

Systems thinking analysis is generalized by six steps: [1] Identify influences on a desired outcome or process. [2] Indicate the relative strength of impact of the identified influences. [3] Determine how the influences all interact. [4] Identify feedback loops that indicate potential dynamic changes that may occur in a system that changes. [5] Identify bottlenecks and limitations of the system. [6] Identify leverage points that can improve the outcomes or processes identified (*83*). Creating classroom and laboratory exercises that involve systems thinking analysis as part of the deliverable helps students identify their role in a bigger system as well as their opportunity for positive impact as career chemists, designers, etc. It also increases relevancy for students, important in particular for students of color and women (*28*), and provides context and purpose for their place in their communities as chemists.

## Conclusion

Innovative green and sustainable chemistry technologies have excellent potential to offer solutions to achieve equity and environmental justice. However, the STEM pipeline must be supported by a framework to facilitate the use of social and environmental justice for teaching and investigating chemistry as solutions to justice issues. Linking green and sustainable chemistry to equity and environmental justice has excellent potential to inspire a new audience of students to pursue STEM careers and to strengthen the pipeline through the engagement and retention of students of color and women. Considering aspects of identity, bias, inclusivity, community-centered research, guiding principles of social justice pedagogy, and systems thinking can guide faculty and staff toward supporting a justice-centered focus within curriculum that calls for consideration and protection of human and environmental health. It provides purpose, relevancy, and vision for chemistry students and their future careers as change agents.

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## Disclosure statement

No potential conflict of interest was reported by the authors.

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*Edward J. Brush* is a Professor of Chemistry and coordinator of Project GreenLab at Bridgewater State University. Project GreenLab is a regional center for Green Chemistry Education that focuses on curriculum development, research, and community outreach. Our partners include faculty and students at Bridgewater State University and regional colleges. Project GreenLab aims to educate the BSU and regional communities about green chemistry and the impacts of chemicals on human and environmental health. GreenLab offers professional development and hosts an annual Undergraduate Symposium on Sustainability and the Environment.

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