Sustainable Science Education

Paving the Way for Science of Sustainability in Secondary Education

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When people think about the science of sustainability, the fields of conservation and biology come to mind most often. General primary and secondary education has historically only taught sustainability through conservation in the Earth sciences curriculum, and indeed remains so in the *Next Generation Science Standards*. However, the real science of sustainability is rooted in the physical sciences, in green chemistry, physics, and engineering. Only in tertiary education do students receive any type of formal education about the science of sustainability, and even then, only the STEM students receive specialized instruction.

According to the U.S. Census Bureau and National Science Foundation, only 7% of the world's population and 38% of the United States's population attend college; the number of people who have access to any type of sustainability education is very low (U.S. Census Bureau 2017a). Further, only 40% of those people study a STEM field, which brings the maximum percentage of people worldwide who are exposed to the science of sustainability down to 2.8% of the world's population and 15% of the U.S. population (U.S. Census Bureau 2017b).

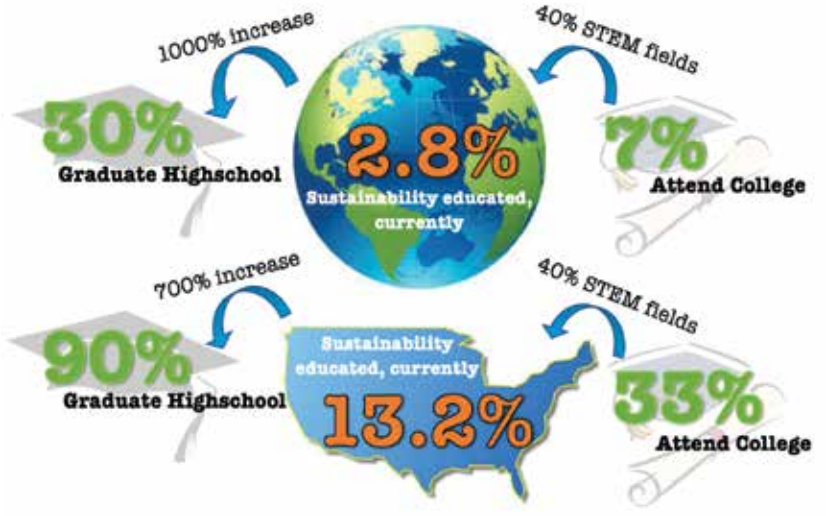
If less than 3% of the world's population understands the scientific considerations that go into creating sustainable practices, it is no wonder the planet's resources are being consumed at an alarming rate, and that many people do not believe that climate change is a relevant issue. Integrating sustainable science lessons into secondary education is the first step in building the general population's awareness of the science of sustainability. If 30% of the world's population and 90% of the U.S. population earned a high school diploma that includes sustainability topics, understanding of the science of sustainability could be increased by over 490% in the United States and 970% globally (National Science Board 2019).

To fully integrate science of sustainability into the secondary curriculum across the nation, adoption of sustainability-oriented educational standards must be considered and implemented. A few states have taken steps to do so. Washington has Education for Environment and Sustainability standards enacted across the state. Other states, like New York, suggest the implementation of green chemistry into the handling of chemicals within the classroom, but do not have formal education standards or emphasize teaching of green science concepts (See "On the web").

The few states with any sort of green science involvement are the exception

FIGURE 1

Representation of science sustainability education, based on current education models (orange) and what it could be if sustainability in science was introduced at the high school level (green).



Source: U.S. Census Bureau 2017.

to the rule, emphasizing how far behind the United States' K–12 educational system is concerning the science of sustainability, especially considering the high demand and impact such fields are having in research and industry.

Globally, sustainable science education mimics current trends within the United States. China and Malaysia have ramped up their focus on green chemistry education through the creation and output of university level classes, laboratory experiments, and publications. (Eilks and Zuin, 2018; Wang, Li, and He 2018) Additionally, only small trials of incorporating green science practices in secondary level laboratory experiments have been conducted, although results from Karpudewan and Kulandaisamy (2018) indicate that teachers find the material highly relevant and feasible to include in their classroom. However, no country has specifically incorporated sustainable science education into its curriculum—governments, journals, and schools simply suggest its implementation (Aparecida 2013).

One of the leading resources and agencies concerned with the science of sustainability, and notably the idea of green chemistry, is the American Chemical Society. Their Green Chemistry Education program has the mission statement: "Green chemistry education seeks to enhance chemists' understanding of the impacts of their design choices

FIGURE 2

Sustainable science and green chemistry resources for the classroom.

PROGRAM/SPONSOR	CONTENT AVAILABLE	TARGET AUDIENCE	WEBSITE
Green Chemistry Institute (GCI)	Lab Manuals/ Textbooks/ Videos/ Activities	Undergraduate/ Graduate	*www.acs.org/content/acs/en/greenchemistry/students-educators.html*
Environmental Protection Agency Green Chemistry	Articles/ Green Chemistry Challenge	Public/ Researchers	*www.epa.gov/greenchemistry*
Michigan Green Chemistry Clearing House	Textbooks/Lectures/ Activities / Experiments	Public/ Undergraduate/ Graduate	*www.migreenchemistry.org*
Yale Center for Green Chemistry and Engineering	Activities	High School/ Undergraduate/ Graduate	*https://greenchemistry.yale.edu/education/high-school/teachers*
New York State Department of Environmental Conservation	Laboratory Experiments	High School	*www.dec.ny.gov/education/104714.html*
Beyond Benign	Activities /Laboratory Experiments	High School/ Undergraduate/ Graduate	*www.beyondbenign.org/cur-high-school/*
Green Chemistry Education Network (GC Ed Net)	Mentorship/Webinars/ Education Seminars	Educators/ Undergraduate/ Graduate	*http://cmetim.ning.com*
Greener Education Materials for Chemists (GEMS)	Activities/Experiments/ Textbooks	Undergraduate/ Graduate	*http://greenchem.uoregon.edu/gems.html* (site currently down)

and experiments." This is a problematic statement, because of a single word: *Chemists*. If a big difference is to be made in achieving sustainability, the word *chemists* needs to be changed to *society's* or *students*. Highly trained chemists are the ones with the knowledge to design new solutions to our problems. But it is students who provide the curiosity and excitement to look at the problem of sustainability differently.

Early introduction to some of the basic concepts of sustainable science such as energy conservation and cost, atom economy, and 12 principles of green chemistry will help invite students into a field they may never have known existed, and pave the way for the future generations to come up with their own creative solutions to the sustainability problems.

As a trained research chemist, I have seen the incredible ingenuity of the people around me. However, I did not have the opportunity to take a sustainability in chemistry course until the last semester of my master's degree program, or even know that it was a field of chemistry until my fifth year of higher education. An earlier introduction to sustainability in science would have changed the way I viewed my work and thought of the chemical processes I learned about and used daily. As a preservice teacher I have the ability to address that gap.

One important way we can introduce these concepts earlier is to add sustainable science into official state standards for the physical sciences, or modify existing standards to specifically address green practices. By becoming the first country to require green science education, we would gain two key benefits. First, we provide our students with knowledge that will allow them to jump ahead in tertiary education, industry, and experience. Second, by creating an official structure for sustainability education, we create openings for additional training, funding, and support by those focused on sustainable science in industry and government. This will help counter the extra effort it will take for teachers to implement the changes at first, and pave the way for continued support of science education in the future.

By implementing changes to education standards, we challenge the perceived notion that the science of sustainability can only be taught to and practiced by people who are already familiar with the physical sciences. Instead, teaching green science alongside basic chemistry and physics will serve to make environmentally conscious science a habit, rather than an effort, and a citizen movement, rather than a professional think tank.

To support teachers in meeting this educational need, policy makers and administrators should consult with green science professionals and instructors from industry and academia to understand what the current green science developments are. Then, a collaboration with both experienced and new educators from all disciplines, including chemistry, physics, and engineering, can help provide phrasing for standards that both are achievable by teachers and relevant enough to give students an entry into current scientific developments in the areas of sustainability practices. Please contact the author for suggested sustainability-oriented standards.

Until such time as sustainability standards can be adopted, a list of Green Chemistry engineering resources—including links to sustainability-specific lessons and laboratory experiments available for immediate implementation in the classroom—may be found in Figure 2. *Lessons from Beyond Benign* and the New York State Department of Environmental Conservation are recommended as good introductory resources. ■

ON THE WEB

American Chemical Society Green Chemistry: *www.acs.org/content/acs/en/greenchemistry/students-educators.html*

Green Chemistry (New York State Department of Environmental Conservation): *www.dec.ny.gov/education/77750.html*

State of Washington, Office of Superintendent of Public Instruction: *www.k12.wa.us/student-success/resources-subject-area/environment-sustainability/resources-and-research*

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