



### What is Green Chemistry?

Green chemistry is the design of chemical products and processes that reduce and/or eliminate the use or generation of hazardous substances. This approach requires an open and interdisciplinary view of material and product design, applying the principle that it is better to consider waste and hazard prevention options during the design and development phase, rather than disposing, treating and handling waste and hazardous chemicals after a process or material has been developed.

The **Green Chemistry Commitment (GCC)** is helping to *transform chemistry education* in college and university chemistry departments that strive to:

- prepare world class chemists whose skills are well aligned with the needs of the planet and its inhabitants in the 21<sup>st</sup> century, and
- design and develop innovative, efficient, and environmentally sound solutions to the safety and effectiveness of chemical products and processes.

The Green Chemistry Commitment offers access to a broad and supportive community of chemistry experts and a flexible framework for green chemistry curriculum and training. With multiple pathways to the implementation of green chemistry education, the Green Chemistry Commitment sets a benchmark to track progress on specific learning and research objectives.

With the GCC, college and university faculty can band together to share resources and experience to shift how and what the next generation of chemists learn. Students will enter the workforce armed with the necessary skills, knowledge, and confidence to be leaders in making the principles of green chemistry standard practice in all fields and sub-disciplines of chemistry.

### Why introduce the Green Chemistry Commitment?

During the last 15 years, individual teachers, professors, and chemistry departments have introduced green chemistry concepts into lectures and lab activities, outreach initiatives, and some have even used green chemistry as the basis for academic research projects. The Green Chemistry Commitment seeks to build on the efforts of leaders in the field and systematically change chemistry education. The Green Chemistry Commitment aims to facilitate and support the development of a consortium program that unites the green chemistry community around shared goals and a common vision to:

- expand the community of green chemists
- grow departmental resources
- improve connections to industry and job opportunities in green chemistry
- affect systematic and lasting change in chemistry education

### Who is part of the Green Chemistry Commitment?



70 signers globally, including:  
64 in North America; and in the following countries: Brazil, Columbia, Thailand, Nigeria (2), Australia

**12 R1 Institutions**  
**9 R2 Institutions**  
**4 R3 Institutions**  
**40 PUI Institutions**  
**5 Community Colleges**

[See Who's Committed](#)

Colleges, universities, and industry leaders from around the world have signed the Green Chemistry Commitment for access to shared up-to-date resources, collaborative discussions and projects, improved curriculum, and accountability to track progress on specific learning and research goals.

The Green Chemistry Commitment is shaped and led by a Faculty Advisory Board comprised of faculty members of chemistry departments from across the United States, representing large and small academic institutions.

The supporting organization for the Green Chemistry Commitment is Beyond Benign ([www.beyondbenign.org](http://www.beyondbenign.org)), a non-profit organization dedicated to providing future and current scientists, educators and citizens with the tools to teach and learn about green chemistry in order to create a sustainable future.

Beyond Benign's vision is to revolutionize the way chemistry is taught to better prepare students to engage with their world while connecting chemistry, human health, and the environment. Beyond Benign is led by Dr. John Warner, a founder of the field of green chemistry and co-author of *Green Chemistry: Theory and Practice*, and Dr. Amy Cannon, the world's first PhD in green chemistry.

## The Green Chemistry Student Learning Objectives

GCC signers agree that upon graduation, all chemistry majors should be proficient in the following:

 **Theory:** Have a working knowledge of the Twelve Principles of Green Chemistry.

 **Laboratory Skills:** Possess the ability to assess chemical products and processes and design greener alternatives when appropriate.

 **Toxicology:** Have an understanding of the principles of toxicology, the molecular mechanisms of how chemicals affect human health and the environment, and the resources to identify and assess molecular hazards.

 **Application:** Be prepared to serve society in their professional capacity as scientists and professionals through the articulation, evaluation, and employment of methods and chemicals that are benign for human health and the environment.

**“The goal of Green Chemistry is for the term to disappear and it simply becomes how we practice chemistry.”**  
*John C. Warner Co-author of “Green Chemistry: Theory and Practice” and Co-founder of Beyond Benign*

## Resources and Opportunities for GCC Signers



Contribute to Collective Voice



Track Progress



Shape the Commitment



Collaborative Working Groups



Professional Development



Green Chemistry Curriculum



Access GCC Member Benefits



Networking and Collaborations

## What GCC Signers Are Saying

**“Green Chemistry represents an essential way of thinking, being underpinned by a set of principles and practices that positively impact all aspects of chemistry education and research”**

*Quote from Professor Andy Dicks University of Toronto*

**“The time is ripe to make Green Chemistry principles part of the norm in our curricula. Our students appear to be very receptive to our moves in this direction.”**

*Quote from Michelle Fry, Department Chair Bradley University*

**“The Green Chemistry Commitment gave us the curricular foundation, support, confidence and networking opportunities we needed to build our program”** *Quote from Nick Kingsley, Jessica Tischler, Department of Chemistry University of Michigan – Flint*

**“Integration of green chemistry concepts into the chemistry curriculum challenges our students to make these practices common place in the chemical laboratory. Additionally, the implementation of green chemistry practices saves both the environment and departmental resources.”**

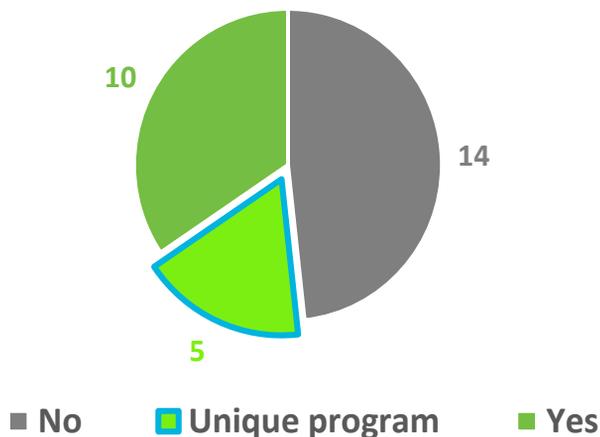
*Quote from Aaron Amick, Associate Professor of Chemistry at Washington College*



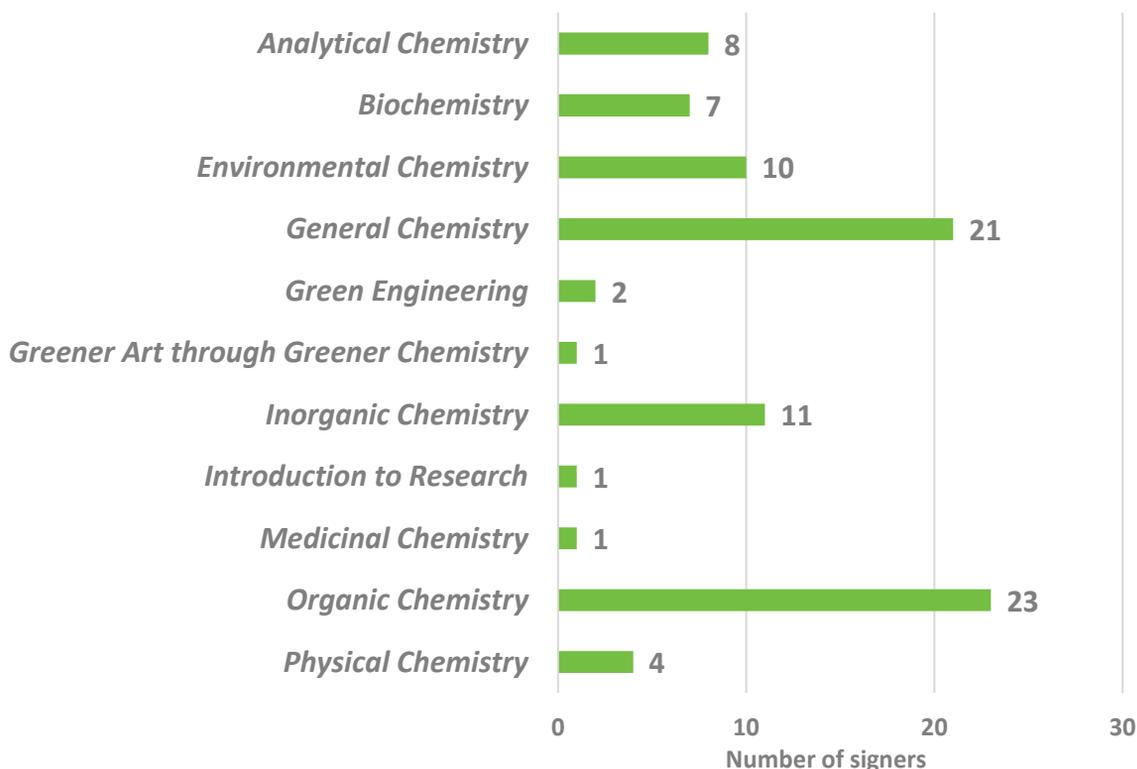
## The Green Chemistry Commitment – Programs and Courses

52% of signing universities have either a standalone Green Chemistry course or a unique program, such as a dedicated Minor or Major. The 48% of signers that do not have a standalone course are able to incorporate Green Chemistry principles in varied and unique ways, such as Engineering, Art, Policy and Research classes.

*Do you have a standalone Green Chemistry course at your institution?*



*What courses introduce Green Chemistry as a discussion point at your institution?*

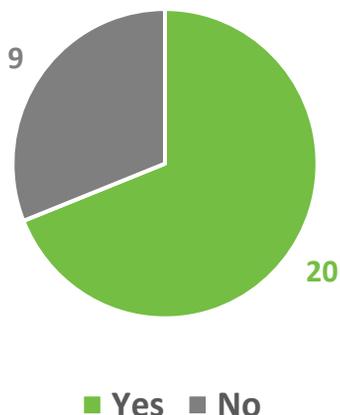




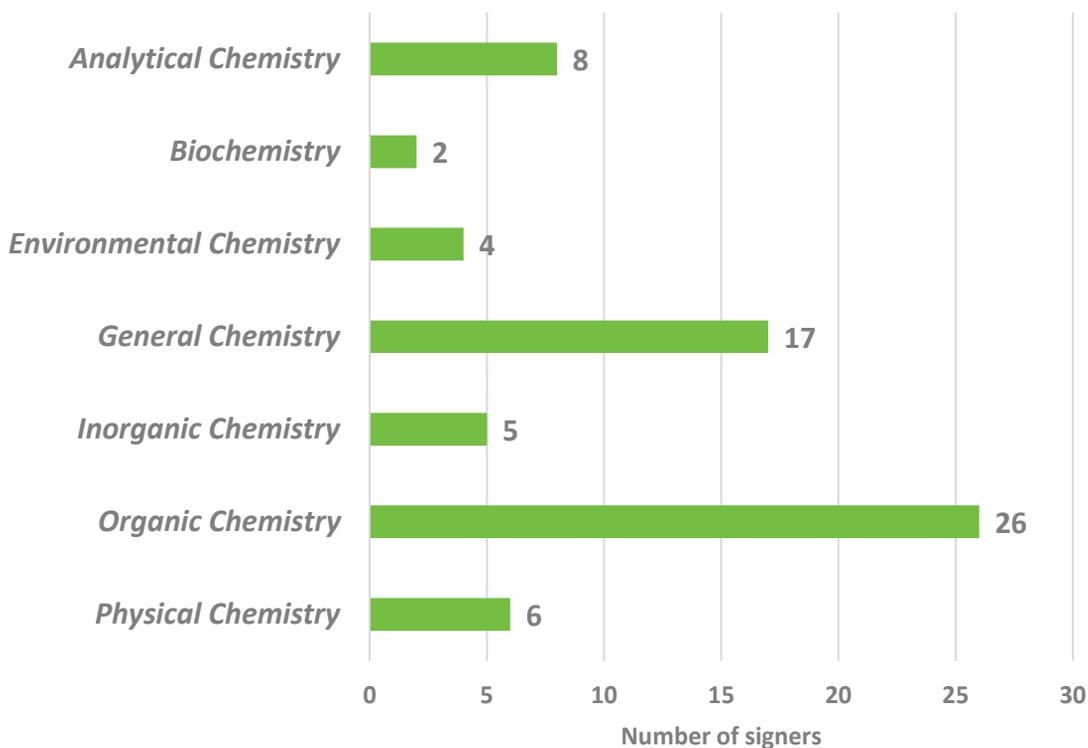
## The Green Chemistry Commitment – Laboratories

The GCC program connects with both research and non-research institutions; 69% of signers have active research groups performing green chemistry. Non-research institutions are more focused on curriculum development and outreach efforts in their communities.

### *Any active research groups performing Green Chemistry in the lab?*



### *Have Green Chemistry principles & practices been implemented in the teaching laboratory?*



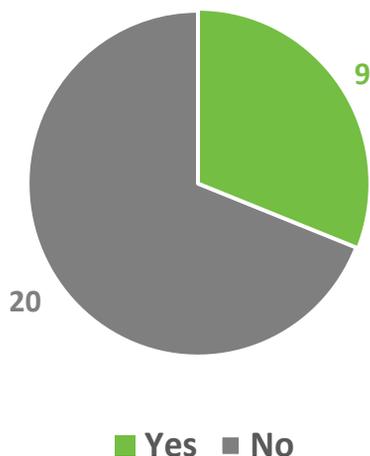


## The Green Chemistry Commitment – Toxicology

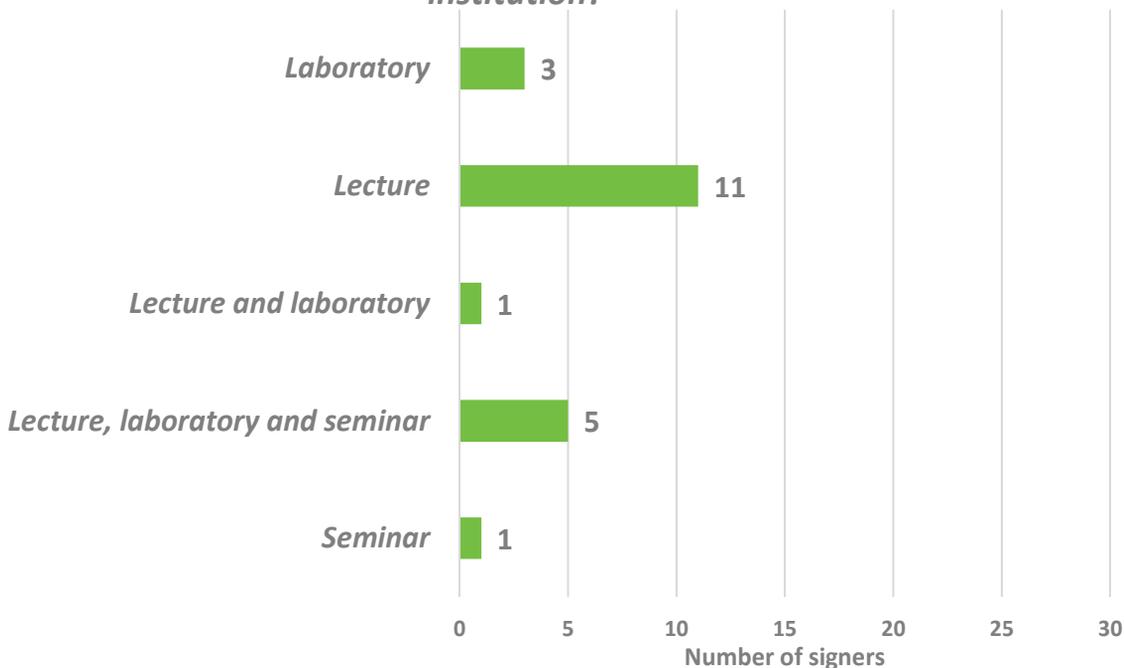
“Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.”

– David Constable, PhD.

*Do you have a stand-alone Toxicology course at your institution?*



*What courses contain toxicology as a discussion point at your institution?*

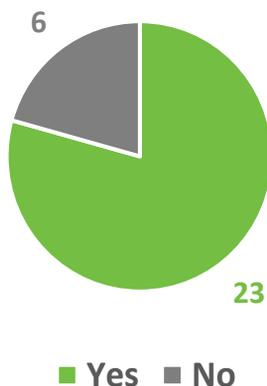




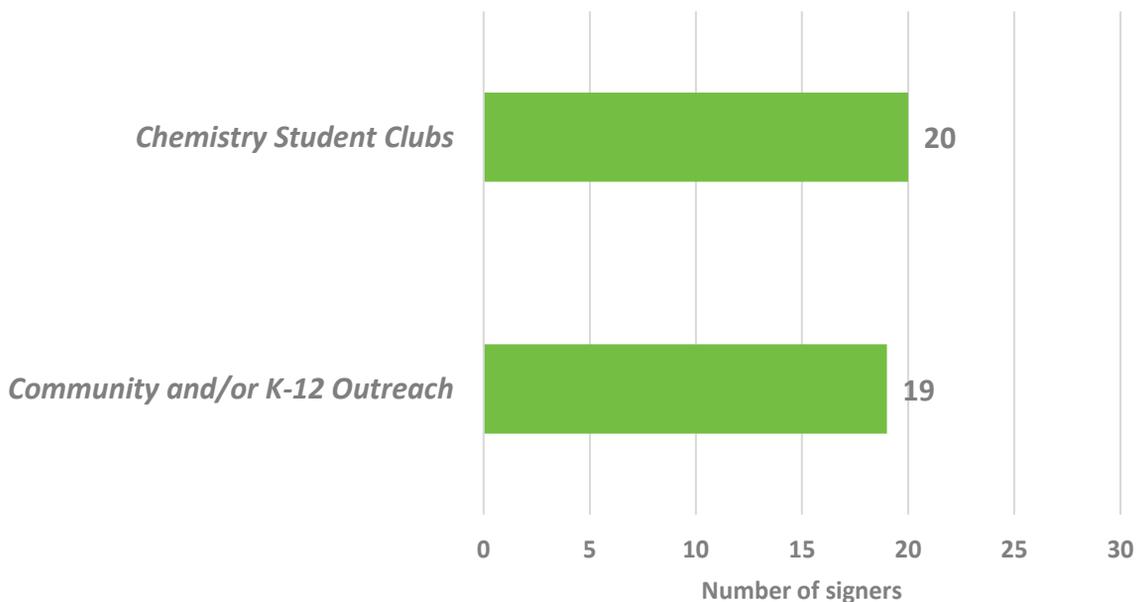
## The Green Chemistry Commitment – Student Engagement

Engaging the student body is a crucial component in the success of the Green Chemistry Commitment program. 79% of signers use interdisciplinary courses to deliver Green Chemistry information of students, and over two thirds of signers are active in outreach programs in their communities, often through student clubs.

*Do you offer additional courses, seminars, or content within existing courses in Environmental Science, Sustainability, or other related subjects?*



*Does your department organize/participate in any of the follow that incorporate & promote Green Chemistry?*





## The Green Chemistry Commitment – Next Steps

The GCC program is subject to continuous improvements based on feedback from signers. Reiterative enhancements of the program will be achieved expedited data and feedback acquisition pipeline, emerging connections with student leaders in Green Chemistry, continued remote support for signers in place of conferences and publication in academic journals.

### Expedited feedback acquisition

- **Challenge:** Current strategy of long-form responses yields 50% signer responses – including follow up email communications.
- **Opportunity:** Roll out of Google forms survey as a short-form version of signers' responses to efficiently collect data necessary to quantify metrics of success of GCC program.
- Increase the number of responses from signing universities.
- Retain a voluntary long-form response program to easily identify and communicate with GCC leaders.

### Identifying and connecting with student advocates

- **Challenge:** Current feedback is received exclusively from one or two professors from each department.
- **Opportunity:** Collection of information from student “on the ground” will serve to provide a more complete and rich profile of the university's efforts in the GCC program.
- Establishment of relationships with emerging student leaders in the Green Chemistry field
- Obtain key information overlooked by academic staff.

### Continue support of signers in the time of COVID-19

- **Challenge:** The effects of the COVID-19 pandemic on travel and conferences have resulted in the cancellation of regional and national meetings.
- **Opportunity:** The implementation of strong online content including meetings, roundtables, networking sessions, webinars, and more.
- Remotely strengthen relationships between signing universities and Beyond Benign by continuing to foster an environment of support and collaboration.

### Publication on long-term impact of GCC

- **Challenge:** Collection of sufficient high-quality data towards academic publication.
- **Opportunity:** Expedited feedback collection, input from student advocates and maintaining online support will work towards the achievement of this goal.
- A peer-reviewed publication solidifies the strengths of the GCC program and the benefits of signing.
- Increased number of signing universities.



UNIVERSITY OF  
**TORONTO**

## The University of Toronto

**A student-led effort** — The Green Chemistry Initiative at the University of Toronto is a student-led group devoted to the promotion of sustainable practices in the chemical sciences. The GCI was founded in 2012 by a group of graduate students looking to learn more about Green Chemistry and how it could be applied to their research and in the chemistry community in creative and engaging ways. The GCI hosts an annual symposium which includes speakers from academia, industry and government, networking sessions, case studies and a poster session. In 2017, the GCI hosted their annual symposium as part of the CCCE, Canada's largest chemistry meeting. Currently, the executive student members of the GCI are working with newly-formed GCI groups at the University of British Columbia and Dalhousie University to establish a Canada-wide partnership of student groups in the planning of meetings at national conferences.

Closer to home, the GCI spearheaded the acquisition of a solvent recycling system for the chemistry research laboratories – today, the department recycles most of the acetone waste generated in the department and returns it to the research groups for free. To strengthen ties to their community, executive members of the GCI have participated as judges in local elementary school science fairs and organized community trash pick up events in partnership with Shoreline Cleanup. This latter event brought together GCI members with the community to pick up over 30 pounds of garbage from a local park. These efforts were recently shared in a blog post authored by the Chemical Institute of Canada.

Members of the GCI have successfully implemented Green Chemistry concepts into various classes, assignments, and organic and inorganic teaching laboratories. This has often been achieved via the well-established Chemistry Teaching Fellowship Program (CTFP) offered by the Department of Chemistry, which bring together a graduate student with a faculty member and provides associated funding to engage in pedagogical improvements to the undergraduate student experience. In addition, members of the GCI annually attend Introductory Chemistry co-curricular mentorship sessions to speak about their work and emphasize the culture of departmental “green thinking”. Although the GCI has been a traditionally graduate student organization, active recruitment of undergraduate students has led to increased membership and visibility in the Department. Next year, the GCI will have the first undergraduate students holding executive positions.

The GCI has been prolific in their online outreach. The group has published an open-access YouTube video series explaining the 12 Principles of Green Chemistry through everyday analogies and has accumulated over 40,000 views spanning over 70 countries. Monthly blog posts have ensured that the GCI have significant visibility and encouraged other similar student groups to develop. Promoting guest blog contributors from other universities serves to increase the GCI's network of Green Chemists.

## Why does the University of Toronto participate in the Green Chemistry Commitment?

### Teaching the new generation of chemists

Of the 29 past GCI members who have now graduated from the University of Toronto, 10 have continued to directly apply green chemistry and/or sustainability concepts in their current jobs.

### To be at the cutting edge of creating new green chemistry educational materials

A top priority for the University of Toronto has been to expose the undergraduate chemistry student body to Green Chemistry in the reaching laboratories. Students explore green halogen sources, recyclable content in consumer goods, solvent and catalyst recyclability, microwave synthesis and the many of the Principles of Green Chemistry including waste prevention, atom economy, and design for energy efficiency.



## Bradley University

***Green Chemistry education and outreach are a labor of love*** — A long legacy of outreach in the Mund-Lagowski Department of Chemistry and Biochemistry at Bradley University is still alive today. By putting on emphasis on the importance of experiential learning, students learn important skills outside the classroom by being involved in scientific demonstrations in their communities.

When John Warner recently visited Bradley University to give the Kolb lecture, it was easy for the Department to recognize the importance of the Green Chemistry Commitment. This sparked an interest within the Department, and led to participation in the conference at the Beyond Benign headquarters in November. The Chemistry and Biochemistry faculty are particularly motivated by the positive philosophy of the Green Chemistry Commitment and dedicated to training a new generation of chemists with a greater awareness of personal and environmental safety in mind. “Every faculty member agreed verbally to include green chemistry initiatives. Our curricula are being re-worked to include more green chemistry” say Professors Dean Campbell and Michelle Fry.

Bradley University has a long history of reaching out to the community through a variety of events. Since the 1970s, the Department of Chemistry and Biochemistry has hosted a High School Chemistry Contest that involves visiting high school students competing on a written chemistry exam and attending a chemistry demonstration show. The faculty have also worked with Bradley University Undergraduate Chapter of the American Chemical Society on the Demo Crew project. Students and faculty in this project have been involved in over 300 outreach events, bringing science to over 32,000 participants since 2007. The Department works to bring aspects of Green and Environmental Chemistry into these events in multiple ways. Top priorities are to maximize safety and minimize environmental hazards associated with the experiments. This includes using lower acid and base concentration and minimizing the use of heavy metals. Discussions of past and present environmental issues such as increasing atmospheric carbon dioxide concentration, ocean acidification, microplastics pollution, and radium contamination of watch-dial painters working with phosphorescent paint have been incorporated into the demonstrations.

To departments looking to join the Green Chemistry Commitment, and improve or start their Green Chemistry outreach efforts, Dean Campbell says: “Use outreach to connect the promise green chemistry offers for solving major issues we as a society face to engage students. Show funding agencies the importance of doing outreach. Local schools love to have university students give demonstrations and its a great place to start your outreach efforts!”

### Why does Bradley University participate in the Green Chemistry Commitment?

#### A way to minimize hazards and recycle reagents

Armed with the Green Chemistry Commitment, hazards have been significantly minimized in the Department of Chemistry and Biochemistry. Highly toxic substances like arsenic, tin, ammonium sulfide, and thioacetamide have been removed from teaching labs and commonplace lab materials such as copper sulfate, dry ice, metal beads, buffer and EDTA solutions are recovered and reused in other experiments.

#### A legacy of outreach

The Department of Chemistry at Bradley University has maintained an open mind when it comes to new ways of teaching their undergraduate students, and outreach has always been held in high regard. This culture is key for sustainable community engagement efforts. “Departmental and institutional support should recognize the value and the importance of outreach – it is a labor of love. Outreach events serve as a chemical education research tool.”



## University of Michigan – Flint

***Green Chemistry education and outreach are a labor of love*** — After becoming a Green Chemistry Commitment signer in 2017, the Department of Chemistry at UM-Flint launched the first Bachelor of Science in Green Chemistry program in 2018. This is the first and only undergraduate program focusing on Green Chemistry in the United States. The program provides students a core chemistry education with exposure to diverse fields such as sustainable design, life-cycle analysis, toxicology, and electives centered around environmental justice. UM-Flint sees the value in training their students as Green Chemists as the chemical industry looks to hire graduates with the skills to solve complex problems related to sustainability. Professors Nick Kingsley and Jessica Tischler say: “Getting students interested in green chemistry has been the easy part. Many students are very passionate about environmental issues and are eager to learn and find more ways to be involved.”

A major strength of the Department of Chemistry at UM-Flint is its student group, who recently received the ACS Green Chapter Awards (2017-18 and 2018-19). This group of dedicated students made it a goal to win it again the following year – and did. In fact, the Chemistry Club at UM-Flint has received a Chapter Award for the last 18 years, nine of which were outstanding. The Demo Squad, the outreach group within the Chemistry Club, is very active and performs a variety of K-12 outreach events as well as events for pre-K and University-age students. For many years and in line with the Green Chemistry Principles, UM-Flint focused on establishing a culture of safety while performing demos, both for students performing them and for the audience. In line with these efforts, the students must complete a risk assessment form before performing any demos and must obtain any additional safety training as required by the assessment, such as cryogen training. They discuss what safety measures are being taken and why it reduces the risk and actively seek substitutions wherever possible to reduce risks. In the 2018-2019 school year, the Chemistry Club developed an hour-long Green Demo program for elementary and middle school students. Existing experiments recommended by Beyond Benign such as the biomimicry match game, Sharklet, and ocean acidification were modified for different grade-levels and a nanomaterials section was added to the program. An overview of this program was presented at the Spring ACS National Meeting in 2019. The Club hope to continue adding to their Green Demo program and be recognized as an ACS Green Student Chapter.

To departments looking to sign the Green Chemistry Commitment, Nick and Jessica have words of advice: “Be bold and innovative in your conversations. Go to ACS, GC&E, and BCCE meetings if you can and seek out the Green Chemistry education community. Get comfortable with self-promoting. Engage with faculty at campus-wide teaching and learning events. It’s a lot of figuring it out as you go.”

### Why does University of Michigan – Flint participate in the Green Chemistry Commitment?

#### Leading the way in Green Chemistry education

Students at UM-Flint can get exposed to Green Chemistry principles related to sustainability, environmental justice and systems thinking across many different departments including, English, Sociology, Engineering, and Geography Planning and Environment. To broaden the program opportunities for students, UM-Flint is in the process of developing a Green Chemistry track to their Bachelor of Arts degree.

#### Be your own Green

Regarding signing the Green Chemistry Commitment, Nick and Jessica say: “You don’t have to have all the answers to start! Departments should realize that every step moving forward in Green Chemistry is important and everyone is doing unique things in green chemistry.”



## Washington College

**What do students really want to know?** — Washington College has developed a unique and fluid curriculum that changes and adapts to students' interests. Professors Anne Marteel-Parrish and Aaron Amick seek to train chemistry students in ways that are important and impactful to them. From *"Art in the Anthropocene"* to *"Science Policy"*, green chemistry is taught in interdisciplinary courses within the Department of Chemistry at Washington College so that upon graduation, students will enter the work force with diverse knowledge and practice in green chemistry and aware of fulfilling career paths in this field.

Anne Marteel-Parrish has been teaching the Green Chemistry course at Washington College for 15 years. At its inception in 2005, it was one of only 12 Green Chemistry courses taught in the US. Since then, it has been continuously revised and improved with feedback from the student body. Partnering with Aaron Amick, Green Chemistry principles were shared with students in General and Organic Chemistry laboratories. Now, the Green Chemistry principles are the driving force in the laboratory component of the "Chemistry of the Elements" course which has replaced the foundational and traditional Inorganic Chemistry course. Today, all chemistry labs at Washington College are 100% paperless. Looking to provide students with unique educational experiences outside of the natural sciences, Anne co-teaches a cross-disciplinary course "Art in the Anthropocene: Greener Art through Greener Chemistry" with Heather Harvey in the Art and Art History Department at Washington College. Anne is also a founding member of the Green Chemistry Commitment Advisory Board at Beyond Benign.

Washington College is devoted to community outreach. All interested chemistry students regularly teach and help children K-12 with experiments, using the Beyond Benign website for content and ideas. Participation in outreach events is an essential component of the implementation of green chemistry in the curriculum. Experiments that feature green chemistry principles, such as making art with paints derived from fruits, vegetables, and spices are especially interesting to young students. Building and nurturing relationships with teachers in the community is important for the success of outreach programs.

To departments looking to sign the GCC and improve their green chemistry education and outreach efforts, Anne says "Start small. Perform slow and incremental changes to the curriculum and get constant feedback and input from students." Aaron adds "Go for it. You don't know what is going to happen, but just start."

## Why does the Washington College participate in the Green Chemistry Commitment?

### Community engagement is an essential skill for chemistry students

Both faculty and students believe that the promotion of green chemistry principles is important and should be an integral component of a chemistry education. Students teach younger students about green chemistry and in so doing, they solidify their own understanding of and passion for the subject. Beyond Benign provides essential content for success in this area and signing onto the GCC is another step towards promoting incorporation of green chemistry into the general community.

### A resource for other institutions looking to teach green chemistry

Many faculty and departments are interested in implementing greener practices in their teaching, service and research. The Commitment provides a resource for faculty and departments who are looking to adopt green chemistry principles and practice. The Commitment helps to connect them with likeminded institutions that are currently implementing green chemistry. This can be an invaluable resource for institutions who are new to the field and who are beginning to engage faculty and administrators.