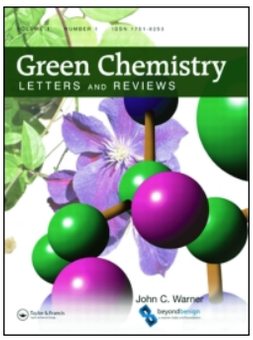
# The Green Chemistry Initiative's contributions to education at the University of Toronto and beyond



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**ABSTRACT**

The Green Chemistry Initiative (GCI) is a student-led group founded in 2012 with the primary mission of promoting green chemistry education at the University of Toronto. In order to achieve this, the GCI's activities have included undergraduate curriculum development, arrangement of an external speaker seminar series, and organization of an annual three-day symposium along with biweekly trivia challenges. To broaden education beyond the Department of Chemistry, a successful YouTube video campaign articulating the Twelve Principles of Green Chemistry in an accessible manner has also been undertaken (acquiring over 40,000 views), in addition to monthly blog posts and conference/outreach presentations. Descriptions of these activities are discussed in this paper, along with the resulting impact they have had. Through such efforts, undergraduate and graduate students are showing a growing understanding of the relevance of green chemistry in today's world, with the GCI serving as a platform for similar groups to build upon across Canada.

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**KEYWORDS**
Green Chemistry Initiative; education; curriculum development; undergraduate/graduate; outreach

## Introduction

Over the past several decades, green chemistry has emerged as a prominent component of chemistry education and research. Many scientists prefer to think of green chemistry not as its own separate field of study, but as a tool to be applied to already-existing areas. In the seminal work of Anastas and Warner (*1*), the Twelve Principles of Green Chemistry describe various ways that chemists can minimize the environmental impact and hazards of their own research. During the last ten years, an increasing number of student-led groups and initiatives have been established to help promote green and sustainable chemistry (*2*). The Green Chemistry Initiative (GCI) is one such organization founded in 2012 by a group of graduate students in the Department of Chemistry at the University of Toronto (U of T) (*3*). These students were primarily motivated by a perceived gap in green chemistry education at both undergraduate and graduate levels throughout the department.

The three overarching and connected goals of the GCI are as follows: (i) to raise awareness about green chemistry within the U of T Department of Chemistry and beyond; (ii) to promote sustainable laboratory practices; and (iii) to decrease the environmental impact of chemistry

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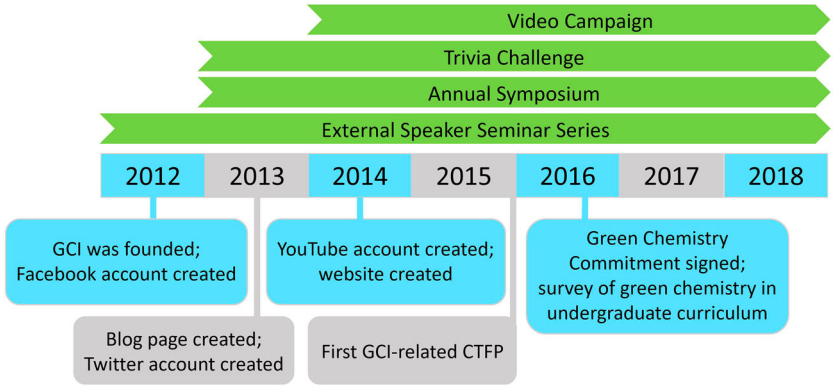



**Figure 1.** Timeline of select GCI projects from 2012 to 2018.

research. Since its inception, the GCI has flourished and grown to be one of Canada's leading student-run sustainable chemistry groups. In total, the GCI has had more than 60 members (undergraduate students, graduate students, and postdoctoral fellows). The membership has grown from eight students in 2012 to 20 in 2019. Of the current 20 members, 18 are graduate students and two are undergraduates. There are eight executive positions in the group: two co-chairs, treasurer, symposium coordinator, seminar series coordinator, social media coordinator, website coordinator, and secretary. The remaining "at-large" members take on varying roles in new and ongoing projects. The GCI obtains annual funding from several major sources, including the U of T Department of Chemistry (*4*), the Department of Chemistry graduate student-run ChemClub (*5*), and the U of T Environmental Resource Network (UTERN) (*6*). This funding is used to operate different initiatives in order to address the group's goals.

A timeline of select GCI projects (both annual and ongoing) which are discussed in this article is indicated in Figure 1. These initiatives all involve green chemistry education, address the three GCI goals, and can be separated into three categories based on the target audience: undergraduate students, graduate students, and the broader chemistry community. Each project is described in detail along with the impact they have had both inside and outside the Department of Chemistry where applicable, as examples of how students can successfully help spearhead the incorporation of green chemistry concepts into different aspects of education.

## Green chemistry educational initiatives for undergraduates at the University of Toronto

### *Curriculum development via the Chemistry Teaching Fellowship Program*

Since its launch in 2002, the U of T Chemistry Teaching Fellowship Program (CTFP) has been offered to graduate students and postdoctoral fellows on an annual basis (*7*). The objective of this program is to provide an exceptional learning experience in pedagogical tool development that directly enhances the quality of undergraduate instruction (*8*). The CTFP provides opportunities and funding to develop specific teaching initiatives for incorporation into the undergraduate chemistry curriculum. Through this program, several GCI members have successfully implemented green chemistry concepts into undergraduate classes, assignments, and teaching laboratories. As one example of this, Organic Synthesis Techniques (CHM 343H) is a third-year chemistry undergraduate course with an enrollment of 30–40 students per year (*9*,*10*). In 2014, a GCI member developed a novel assignment for CHM 343H that targets the use of industrial solvent and reagent selection guides (*11*–*14*). The aim is for students to learn how to effectively use published guides for greener solvents and reagents and to apply them to critically review a literature preparation of (+)-morphine (*15*). In this assignment, students identify hazardous reagents and solvents in the published synthesis of (+)-morphine and propose safer alternatives. A second assignment created for CHM 343H through the CTFP tasks students to design a synthetic route to a derivative of a reported organic molecule. The concept of life-cycle assessment (LCA) is introduced to broaden the consideration of the origin, use, and disposal of reagents involved in synthetic pathways. Instead of encouraging students to evaluate reactions solely on percentage yield, this assignment teaches the importance of considering the by-products and waste generated during organic transformations. Both of these assignments are available in the supplemental material accompanying this article and have been undertaken by over 100 chemistry program students over a period of three years. Based on the success of these two activities, a third CHM 343H assignment was devised in 2017 via the CTFP which connects practical and theoretical aspects of the course. Students are

required to undertake a Buchwald-Hartwig amination laboratory reaction to generate an aromatic amine, and compare the sustainability of their method with the sustainability of a nucleophilic aromatic substitution reaction that forms the same product (*16*). Feedback regarding the impact of all three assignments has been exceptionally positive, with many students appreciating the "real-world" application of green chemistry tools.

As a second example, Chemistry: Physical Principles (CHM 135H) and Introductory Organic Chemistry I (CHM 136H) are two U of T first-year undergraduate classes with a combined enrollment of 1600 life science and health science students per year. Content slides have been developed by a GCI member via the CTFP that highlight the Twelve Principles of Green Chemistry (including fundamental toxicology concepts), with a corresponding list of topics for the instructor to discuss with the class. This material will be implemented in each course during the near future. With a focus on real-world examples, these slides provide students with a means to visualize green chemistry approaches, which aids in knowledge retention. A sample slide for course CHM 135H describing use of supercritical carbon dioxide ($scCO_2$) as a solvent in the textile dyeing industry is shown in Figure 2. Both solvent recyclability and the application of carbon dioxide as a renewable feedstock are introduced, culminating with the decaffeination of coffee to provide contextualization. As these examples illustrate, the CTFP program has proved an effective mechanism to introduce green chemistry content into undergraduate curricula via collaboration with the GCI.

### *The Green Chemistry Commitment*

Beyond Benign is a 501c3 non-profit organization that develops and disseminates educational resources to empower educators, students, and the community at large to practice sustainability through chemistry (*17*). The Beyond Benign Green Chemistry Commitment (GCC) has emerged as a pledge for colleges and universities to prepare chemists whose skills are aligned with the needs of the planet and its inhabitants (*18*). In terms of undergraduate education, the GCC signatories agree to implement green chemistry student learning objectives into their courses and programs. In 2016, the GCI initiated and facilitated U of T in becoming the first Canadian institution to sign the GCC. GCI members participated in cataloguing and evaluating the Department of Chemistry's undergraduate curriculum for green chemistry and sustainability content, such that instructors may determine which courses to specifically improve upon. In the future, the GCI will continue to work within the framework of the GCC to positively impact the U of T undergraduate curriculum.

## Green chemistry educational initiatives for graduate students at the University of Toronto

Since graduate students have different schedules and unique priorities, a different approach has been taken to educate this cohort of the Department of Chemistry. Rather than incorporating specific components directly

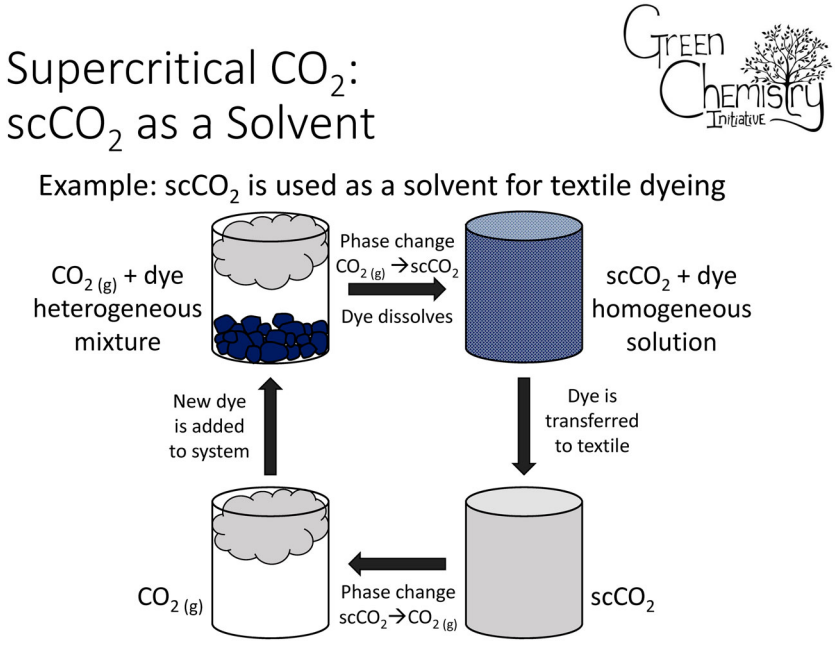



**Figure 2.** Sample CHM 135H class slide describing the use of $scCO_2$ as a solvent.

into courses, the hosting of events and projects that are related to graduate research has proved more effective in terms of informing students about different applications of green chemistry. Examples of activities include an external speaker seminar series, an annual symposium, and biweekly trivia challenges.

### External speaker seminar series

In 2012, one of the first projects the GCI undertook was organization of a seminar series involving green chemistry experts from outside the university. The series has become an annual event each subsequent academic year and consistently has at least 30 attendees per seminar. Growth has led to a minimum of six speakers per year who each give a one-hour seminar on their field of expertise. The topics of these presentations are all covered under the umbrella of green chemistry and sustainability, and have ranged from scientific policy to industrial research and educational concerns. During the last two years, the GCI seminar series coordinator has collaborated with the Department of Chemistry and the Women in Chemistry Toronto Chapter (WICTO) (*19*) to host a varied selection of speakers, leading to increased interest with a departmental attendance of over 100 faculty and students. Some past speakers have been Amy Cannon (Beyond Benign: "Green Chemistry Education: Techniques and Resources for K-12 through Higher Ed Programs"), Tom Baker (University of Ottawa: "Beyond Fossil Fuels: Turning Renewable Resources into Consumer Products through Catalysis"), Jane Wissinger (University of Minnesota: "Green Chemistry Curriculum Design, Implementation, and Rewards"), and Allison Paradise (My Green Lab: "Labs of the Future: Transforming Research Labs into Sustainable Spaces").

### Annual symposium

The GCI's annual three-day symposium was first held in 2013, and continues to be the biggest event organized by the group. It is held on the U of T campus, with a highlighted theme related to green chemistry and sustainable science. A new theme is proposed and voted on by the GCI members each year (Table 1).

The symposia have garnered national attention through the Chemical Institute of Canada featuring and promoting the 2015 and 2018 editions (*20*,*21*). Participants are largely graduate students from across Canada, with the number of attendees rising from 25 in 2013 to 83 in 2018. At the beginning of each symposium, there is a two-hour green chemistry "crash course" to introduce fundamental concepts to the audience. Following this are talks and discussion panels led by invited speakers who come from academia, industry, or government sectors. Some speakers from past symposia include John Warner (Warner-Babcock Institute for Green Chemistry, Beyond Benign), Philip Jessop (Green-Centre Canada, Queen's University), and Frank Gu (University of Waterloo).

**Table 1.** GCI annual symposium titles and topics.

| Year | Symposium title | Main topics |
|---|---|---|
| 2013 | Future Leaders in Green Chemistry | solvent selection, LCA |
| 2014 | Next Steps in Green Chemistry Research | toxicology, environmental fate of chemicals, creating a green chemistry student group |
| 2015 | Green Chemistry Applied in Industry | photovoltaics, ink printing, continuous flow chemistry |
| 2016 | Innovations in Chemistry Towards Sustainable Urban Living | textile dyeing, aerospace materials, crop protection |
| 2017 | Recent Advances in Sustainable Chemistry | water desalination, workplace safety, climate change |
| 2018 | Green By Design: Advances in Chemistry and Engineering | microbial engineering, wastewater treatment, biomass conversion |

Each symposium provides participants with a chance to learn about research from differing fields with the unifying theme of green chemistry. For instance, previous topics have included polymers, agriculture, pesticides, solar cells, nanochemistry and science policy. The invited speakers are available throughout the whole symposium to afford multiple networking opportunities. In addition to the talks, there is a two-hour workshop in which all the registrants and speakers are divided into small groups and participate first-hand in a workshop on a green chemistry concept. As an example, the 2018 symposium workshop topic was a case study involving LCA challenges related to biomass conversion. Students explored how each stage in a LCA supply chain may require a unique approach to yield better results. Finally, a panel discussion is held at the end of the symposium where four of the invited speakers discuss relevant topics with respect to their field and the theme of the symposium.

### Trivia challenge

In an alternative and ongoing way to engage departmental members, the GCI hosts a trivia challenge where two multiple-choice questions are sent via email to all departmental graduate students and postdoctoral fellows every two weeks. The theme of the questions has varied from green chemistry solvent guides, toxicity of certain chemicals, recycling of materials, and sustainability metrics to questions about relevant literature papers. Questions are written in a way such that basic chemistry should be sufficient to logically deduce a possible answer based on the information provided. A sample question and answer are presented in Figure 3. Typically,

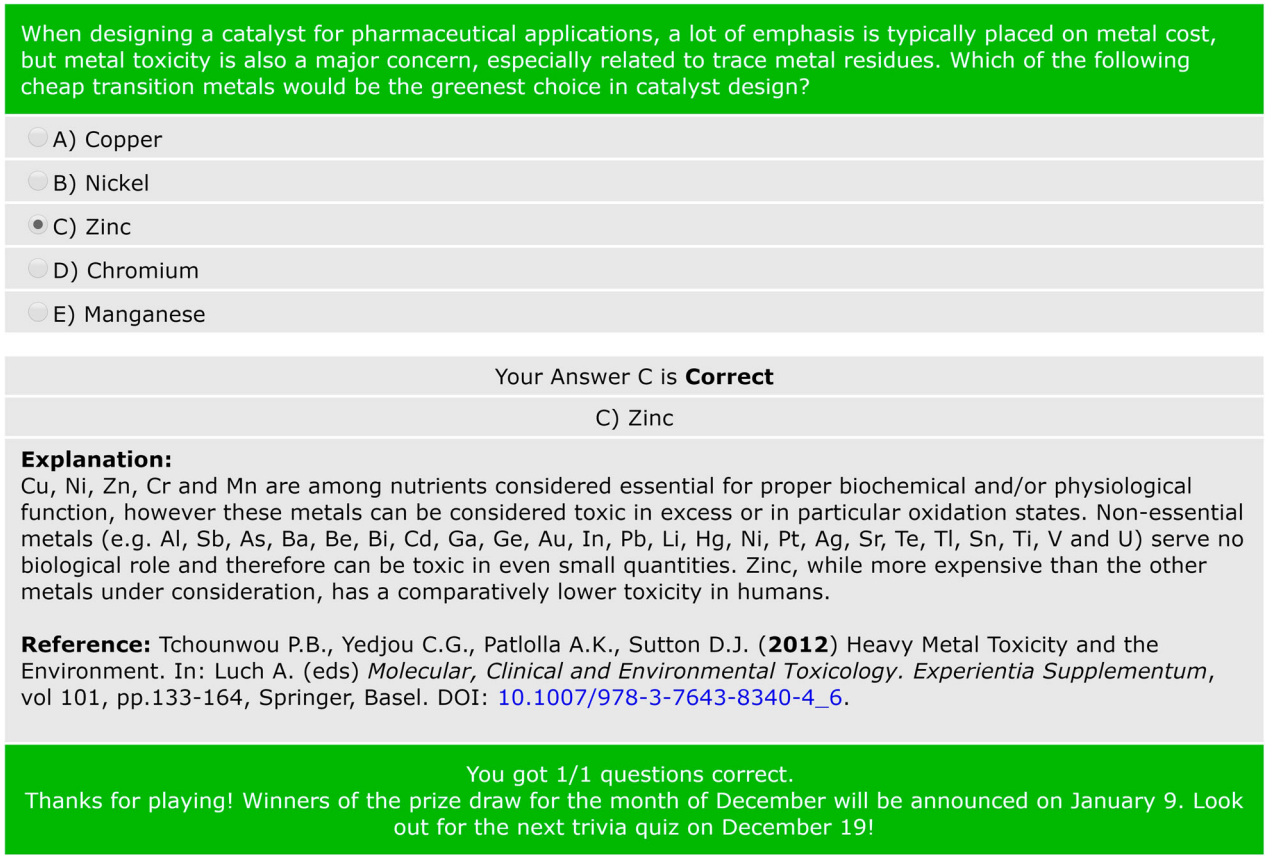



**Figure 3.** Example of a GCI trivia challenge question and answer.

25 people participate each time by answering the questions through an online link provided by the GCI. For each question that a particular person answers correctly, their name gets placed in a prize pool. At the end of every month the GCI draws three names from the pool and the three winners receive a $5 coffee gift card as a prize. After the draw takes place, the prize pool is emptied and reset for the following month.

## Educational resources for the broader chemistry community

To expand the reach of green chemistry education outside the Department of Chemistry, the GCI has developed resources that are both readily available online and designed to be used from the early stages of grade school chemistry through higher education. Two such initiatives are the Twelve Principles of Green Chemistry video campaign and monthly blog posts.

### *The Twelve Principles of Green Chemistry video campaign*

The GCI envisioned an innovative pedagogical approach for explaining the Twelve Principles of Green Chemistry through an open access YouTube video series (*22*) (www.youtube.com/user/GreenChemUofT). The three- to four-minute videos summarize each of the principles using an appropriate analogy to effectively communicate how to make more sustainable chemistry decisions. Scripts were written to present broadly accessible content to a science literate audience. The most impactful video thus far has been the one highlighting Principle #2: Atom Economy, with approximately 9000 views to date (*23*) (www.youtube.com/watch?v=plbmxQLa_-M). Atom economy is the measurement of the percentage of atoms from the reactants which are incorporated into the desired product during a chemical transformation. In this video, each atom is associated with a specific Canadian coin to visualize the synthesis of ibuprofen through two different synthetic protocols. As each synthesis proceeds, any "wasted" atom (coin) is placed in the waste collection pile. Summation of the coin waste demonstrates that the modern synthetic protocol for ibuprofen is significantly more atom economical than the original one.

The video campaign has also highlighted the replacement of bio-accumulative fluorosurfactants in fire extinguishers (Principle #4: Designing Safer Chemicals), use of solvent selection guides for column chromatography

(Principle #5: Safer Solvents and Auxiliaries), mitigation of protecting groups as demonstrated with Lego™ (Principle #8: Reduce Derivatives), and biodegradation of detergents (Principle #10: Design for Degradation). The video series has to date accumulated over 40,000 views on YouTube (spanning 71 countries) and has 269 subscribers. As one viewer has written: "... (the videos are) very informative and easy to understand. You guys are doing an amazing job promoting Green Chemistry."

### Monthly blog posts

The GCI has maintained an active blog since 2013, posting material once per month on average (*24*). To ensure a fresh perspective, the blog is written by members who have different chemistry and engineering backgrounds, allowing followers to keep up to date on various topics and GCI projects such as the Twelve Principles of Green Chemistry video campaign. The blog provides GCI members with an opportunity to explore a topic of interest to them and to gain experience communicating to a general audience in a clear and effective way. A blog post on Principle #9: Catalysis is shown in Figure 4 (*25*). Research-related posts help GCI members keep abreast of new developments in a different way to scientific journals, and profile researchers working to make products and processes more sustainable (e.g. an eco-friendly extraction of pectin and *d*-limonene from lemon peels (*25*,*26*)).

To date, there are 69 blog posts available online which have had over 90,000 views and over 59,000 visitors from 173 countries. The most-read posts (apart from those accompanying the GCI video campaign) are "Proper Chemical Waste Disposal: Posters & Memes," "Going Green on a Large Scale: The 12 Principles of Green Engineering," and "No-Mess Composting with the Greenlid" as these are of interest to a wide audience. To further increase the impact of the blog, recent efforts have been made to author posts in collaboration with other student green chemistry groups. A recent post written by a member of GreenChem UBC at the University of British Columbia has inspired this group to start up a blog series themselves. In addition, a recent collaboration with the Gainesville ToxSquad (a Florida student-

JUNE 24, 2017 BY GREENCHEMUOFT

## Green Chemistry Principle #9: Catalysis

**By Alex Waked, Member-at-Large for the GCI**

*9. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.*

In stoichiometric reactions, the reaction can often be very slow, may require significant energy input in the form of heat, or may produce unwanted byproducts that could be harmful to the environment or cost lots of money to dispose of. Most chemical processes employing catalysts are able to bypass these drawbacks.

A catalyst is a reagent that participates in a chemical reaction, yet remains unchanged after the reaction is complete. The way they typically work is by lowering the energy barrier of a given reaction by interacting with specific locations on the reactants, as demonstrated in Figure 1 below. The reactants are represented by the red and blue objects, and the catalyst by the green one. Without the catalyst, the reactants cannot react with each other to form the desired product. However, once the catalyst interacts with them, the reactants become compatible and can subsequently react together. The desired product is released and the catalyst is regenerated to continue interacting with the remaining reactants to produce more product.

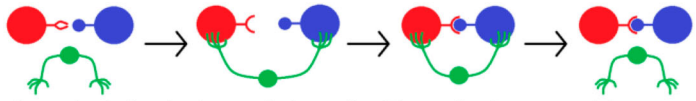
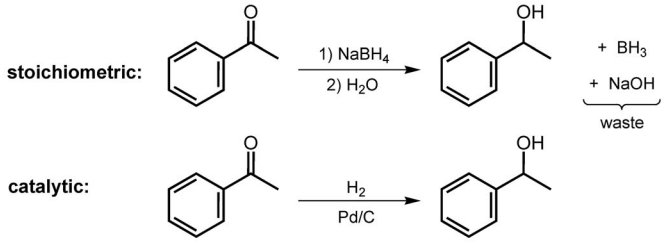


Figure 1. Graphic of a catalyst's function in a catalytic reaction. The catalyst is green, and the reactants are red and blue.

In other words, a catalyst can be thought of as a key that can unlock specific keyholes, where a keyhole represents a particular chemical reaction. One common example of a catalytic reaction that is taught in introductory organic chemistry is the hydrogenation of ketones (Scheme 1). The stoichiometric reaction involves the addition of sodium borohydride, followed by addition of water. In this reaction, borane ($BH_3$) and sodium hydroxide are (formally) generated as waste. By simply employing palladium on carbon as a catalyst, the ketone can react directly with $H_2$ to generate the same desired product without producing any waste.




Scheme 1. Stoichiometric vs. catalytic reduction of a ketone.

**Figure 4.** A GCI blog post regarding Principle #9: Catalysis.

run organization similar to the GCI) has helped include more consideration of toxicology that has previously been outside of the GCI members' expertise. Collaborating on blog posts has been a straightforward way for the GCI to form relationships and share knowledge with sustainability-focused groups across North America.

### *Conferences and educational outreach*

In order to disseminate information about different initiatives, GCI members have presented talks at numerous academic conferences in the chemistry education sector. As examples, at the 2016 Canadian Chemistry Conference and Exhibition (CCCE) a presentation entitled "Can't Teach Old Dogs New Tricks? Campaigns to Change Habits in Research Laboratories" was given on altering the work habits of graduate students at U of T. In 2018, a second presentation was given at the CCCE highlighting the GCI's efforts regarding the Twelve Principles of Green Chemistry video campaign. In addition, as part of the 100th CCCE in 2017, the GCI organized a one-and-a-half-day symposium entitled "Recent Advances in Sustainable Chemistry." At this event, invited speakers included Robin Rogers (McGill University), David Bergbreiter (Texas A&M University), and Sir Martyn Poliakoff (University of Nottingham). At the 45th annual College Chemistry Canada conference in 2018, a presentation on the GCI CTFP projects discussed in this article was made. GCI members were also invited to teach a three-hour class for Perspectives in Biological and Chemical Sciences with a Focus on Sustainability (BH800) at Wilfrid Laurier University where green chemistry concepts and their application in graduate student research was discussed.

The GCI has additionally had occasion to give public talks, such as a presentation entitled "Promoting Sustainable Practices in the Laboratory" given for the Wannabe Toxic Free program offered by Women's Healthy Environments Network. Here, the Twelve Principles were discussed with a focus on the relevance to the Canadian Environmental Protection Act. Each year, the GCI participates in Science Rendezvous, a coast-to-coast open house and festival in Canada which celebrates feats of science and engineering (*27*). In Toronto, this day-long event attracts hundreds of visitors and science enthusiasts. During Science Rendezvous, GCI members run family-friendly, interactive green chemistry demonstrations. Past demonstrations have included building a solar cell made with blackberries (*28*) and running a green iodine clock reaction (*29*).

## Preparation for a career in green chemistry

The knowledge and skillset acquired through volunteering in the GCI extends beyond the years spent as a graduate student in the Department of Chemistry. As members graduate and join the workforce, alumni impart their perspectives in sustainability to a variety of chemical industries which focus on solving real-world issues. For example, one past GCI member is now a material innovation engineer at Patagonia, an active wear apparel manufacturer and distributor with the mission statement "Build the best product, cause no unnecessary harm, use business to inspire and implement solutions to environmental crisis" (*30*). Another is a development scientist at GreenCentre Canada, a vital link to commercialize sustainable academic discoveries (*31*). Towards the growth of green chemistry education, a third past member is currently a program manager at My Green Lab, a company focused on reducing waste and energy consumption in research laboratories through various nationwide initiatives (*32*). A fourth person is a chemistry specialist at TopHat, a Toronto-based company that has developed an all-in-one teaching platform including interactive materials for college and university courses, some of which feature green chemistry content (*33*). In total, of the 29 past GCI members that have now graduated from the University of Toronto, approximately ten have continued to directly apply green chemistry and/or sustainability concepts in their current job positions.

## Conclusion

Since its inception in 2012, the GCI has grown into a prominent student group in the Department of Chemistry at U of T, and is recognized as a leading Canadian green chemistry organization. The GCI has focused on working together with faculty, staff and students in the department to implement initiatives in the laboratory and in the classroom. Educational projects have been targeted towards undergraduate and graduate students, as well as the chemistry community at large. Development of course content through the CTFP program and the GCC, education through seminars, symposia, and trivia, as well as communication through videos, blog posts, conferences, and outreach efforts have all proven successful to introduce and discuss green chemistry concepts.

Many of the activities described in this article are ongoing and will continue as the GCI moves forward. Building on the success of the GCI's first seven years, future initiatives will attempt to increase impact at the University of Toronto and within the community at large. To do so, three key goals have been set out. Firstly, to encourage a greater number of chemistry graduate students to participate in different activities,

especially those who have difficulty connecting their research to the concepts of sustainability and green chemistry. Secondly, to improve collaborations with engineering graduate students to include an applied view of sustainability, and to strengthen connections between chemists and engineers. Finally, to expand the educational initiatives outside U of T, with a specific focus on outreach activities for secondary school students. The GCI will strive to continually improve upon and encourage broader education and application of green chemistry principles and sustainable practices to reduce the environmental impact of research.

## Acknowledgments

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## Disclosure statement

No potential conflict of interest was reported by the authors.

## Notes on contributors

*Alexander E. Waked* is currently a Ph.D. candidate at the University of Toronto and has been co-chair of the GCI since 2017. After obtaining his Bachelor of Science in Chemistry at McGill University in 2014, he began graduate studies in the field of main group chemistry synthesizing nitrogen-, sulfur-, and phosphorus-based Lewis acid catalysts for organic transformations.

*Karl Z. Demmans* is currently a postdoctoral fellow in the CSICOMP NMR facilities at the University of Toronto. He obtained his doctorate working in the field of inorganic chemistry by synthesizing iron and manganese catalysts for the asymmetric transfer hydrogenation of ketones. He was involved with the GCI from 2013 to 2018, holding several executive positions including that of co-chair.

*Rachel F. Hems* is an environmental chemistry Ph.D. candidate at the University of Toronto. She obtained her Bachelor of Science in Chemistry at the University of Guelph. Her work focuses on atmospheric chemistry, specifically investigating organic oxidation reactions that occur in cloud water. She has been volunteering with the GCI since 2015 and has held multiple executive roles, including that of co-chair since 2018.

*Dr. Laura M. Reyes* obtained her B.Sc. at York University in 2011 followed by her Ph.D. at the University of Toronto in 2017, where she worked with Geoffrey Ozin to research the surface chemistry of photocatalytic nanomaterials for CO2 utilization. She was also a founding member of the GCI and involved in its establishment and growth through several roles including co-chair. She currently works at the Chemical Institute of Canada and organizes the technical programming for its two annual conferences.

*Dr. Ian Mallov* is a research chemist for Inkbox Ink in Toronto. He was raised in Truro, Nova Scotia, and holds a Ph.D. in synthetic inorganic chemistry from the University of Toronto. He was a founding member and former co-chair of the GCI during his Ph.D. studies. He is currently a member of the Green Team at Inkbox working to minimize the company's environmental footprint.

*Erika N. Daley* is currently the Scientific Programs Manager at the Resource Management Group, Inc. in California, and the Director of Sustainable Science Groups for the Network of Early-Career Sustainable Scientists and Engineers (NESSE). She served as the co-chair of the GCI during her graduate studies with Doug Stephan at the University of Toronto from 2014 to 2015. Erika obtained her B.Sc. from Mount Allison University under the supervision of Steve Westcott which is where her passion for green chemistry began.

*Dr. Laura Hoch* is currently a Materials Innovation Engineer at Patagonia, where she is responsible for the identification and development of novel and sustainable chemistry and textile technologies. Prior to this position she worked as a Technical Fellow for the Green Chemistry and Commerce Council (GC3). She holds a Ph.D. in the area of inorganic materials chemistry from the University of Toronto and was one of the co-founders of the GCI in 2012.

*Dr. Melanie L. Mastronardi* completed her doctorate at the University of Toronto in 2015 after obtaining her B.Sc. in Chemistry at the University of Ottawa. Her Ph.D. research focused on the synthesis, size separation, and characterization of silicon nanocrystals. She was one of the co-founders of the GCI in 2012 and was actively involved with the group during her time at the University of Toronto, holding various positions including the role of chair.

*Dr. Brian De La Franier* is currently a postdoctoral fellow in Chemistry at the University of Toronto, where he previously earned his Bachelor of Science in Biological Chemistry and his Ph.D. in the field of bioanalytical chemistry. He currently studies anti-fouling coatings for use in catheters to reduce patient infections. He was the website developer and video campaign director for the GCI from 2014 to 2018 and is currently a member at large.

*Dr. Nadine Borduas-Dedekind* is an SNSF Ambizione Fellow in the Department of Environmental Systems Science at ETH Zurich where she leads a group in organic aerosol chemistry. She completed her Ph.D. as a Vanier Scholar at the University of Toronto in 2015, working on the oxidative fate of organic nitrogen in the atmosphere. She was one of the founding members of the GCI in 2012 and was involved with the organization until 2015.

*Andrew P. Dicks* holds the title of Professor, Teaching Stream in the Department of Chemistry at the University of Toronto. After undergraduate and graduate study in the United Kingdom, he was hired as a faculty member in 2001 and soon developed an interest in designing novel undergraduate laboratory experiments, particularly those showcasing green chemistry principles. He has edited a book as an instructor resource for teaching green chemistry ("Green Organic Chemistry in Lecture and Laboratory"), and in 2014 he was co-chair of the 23rd IUPAC International Conference on Chemistry Education which was held in Toronto. He has acted as a faculty advisor to the Green Chemistry Initiative since 2012.

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