

A Cross-Disciplinary Sustainable Chemistry Summer Program

Dr Greg M. Swain



A CROSS-DISCIPLINARY SUSTAINABLE CHEMISTRY SUMMER PROGRAM

To protect Earth's environment and endangered species, chemists, material scientists and engineers will need to be more mindful of the substances they produce and use. To this end, **Dr Greg Swain**, Professor of Chemistry at Michigan State University, created the Cross-Disciplinary Training Program in Sustainable Chemistry and Chemical Processes. This innovative program teaches undergraduate chemistry students the importance of sustainable practices, while preparing them for their future careers.

Reducing Harmful Chemical Products and Processes

In recent years, a growing number of scientists, institutions and companies have been trying to increase the sustainability of their practices, to protect Earth's environment and biodiversity. This includes chemists – scientists who study chemical compounds, reactions, and processes.

Sustainable chemistry, also referred to as green chemistry, is a field that promotes the development and use of chemical products and processes that are safer, cleaner, healthier, and more environmentally friendly. There are several different ways in which chemistry can be made more sustainable.

Firstly, chemists can design and identify new chemical processes that maximise the amount of raw material that ends up in a product and minimise the amount of waste produced, particularly hazardous waste.

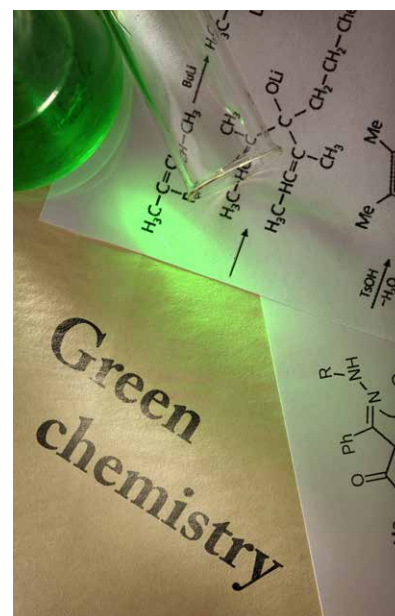
Chemists can also design and use more substances, including solvents, which are safe and environmentally

benign, with an eye towards reducing the global production and use of toxic chemicals. Finally, they can choose to use renewable energy sources and processes that are both safe and energy-efficient, to reduce energy consumption and the combustion of fossil fuels.

Combined, all these actions could pave the way towards more sustainable future, contributing to the reduction of harmful substances in the environment. Teaching future generations of chemists to be aware of how their practices impact the environment and to devise more sustainable processes is thus of vital importance, as it could contribute to the protection and preservation of our planet.

Training in Sustainable Chemistry and Chemical Processes

To best prepare undergraduate chemistry students for the professional challenges they will face in the future, Dr Swain created the Research Experience for Undergraduates (REU) site entitled Cross-Disciplinary Training in Sustainable Chemistry and Chemical Processes. The REU site was established in 2014 and continues to be funded by



the Division of Chemistry at the National Science Foundation (CHE-2150173).

The purpose of the NSF's REU programs is to support undergraduate students in meaningful, graduate-level research in topical areas supported by the agency. The MSU REU site is designed to teach students about green chemistry concepts, while also fostering their professional development and offering them the opportunity to gain valuable direct research experience.



The innovative program teaches participating students how sustainability concepts can be applied across a wide range of chemistry sub-fields, including analytical, biological, inorganic, organic, and physical chemistry. During the training period, students also gain hands-on research experience and develop laboratory skills, which provide them with tangible examples of how sustainable chemistry can be applied in research and development settings.

The program has five overarching goals. The first is to involve undergraduate students in graduate-level research focusing on sustainable chemistry and engineering. The second and third are to offer them positive mentoring experiences and equip them to succeed in graduate school. Finally, the program is designed to give the students a set of tools that they can use in experimental settings, significantly enhancing their professional development. Effective mentoring is a hallmark of the program. Students also receive education in responsible and ethical conduct of research and chemical hygiene and laboratory safety.

Participating students receive a stipend and are recruited on various platforms, including the National Science Foundation's REU website, the department's website, and other recruitment pipelines. As a result, the groups of participants have so far been highly diverse, with students from different academic and cultural backgrounds.

A Hands-On and Cross-Disciplinary Program

Two of the most notable aspects of the program developed by Dr Swain are its practical and cross-disciplinary nature. In contrast with many conventional summer programs, this training course offers students the opportunity to attain real, hands-on, research experiences that apply sustainable chemistry concepts across different sub-fields of chemistry and engineering.

The program starts in mid-May and includes 10 weeks of training in a laboratory setting, as well as specialised workshops, statistics training, ethics seminars and networking events. The students are also asked to complete weekly assignments, including conducting literature searches, reading journal articles, and completing short weekly progress reports. At the end of the program, students present the results of their study at two events: a university-wide research symposium (poster presentation) and a symposium organised by the university's Chemistry Department (oral presentation).

During the 10-week laboratory training, students are taught sustainable chemistry concepts and participate in the design and execution of a research experiment. Subsequently, they also analyse and interpret the data they collect, review past research in the same area, and write up their findings in a report.

The students also attend several activities focusing on sustainable chemistry concepts, as well as some workshops on statistics, literature reviews, ethics, and lab safety protocols. To teach green chemistry, Dr Swain and the other mentors involved in the project use a series of educational videos and materials created by the American Chemical Society's Green Chemistry Institute.

The faculty members teaching and mentoring the students throughout the program have different specialties and academic backgrounds, including analytical chemistry, physical chemistry, organic and inorganic chemistry, civil and environmental engineering, materials science, and chemical engineering. As a result, the students learn about how sustainable practices can be introduced in all these different fields, providing them with a broad knowledge of green chemistry.



Networking and Professional Development

In addition to completing the 10 weeks of core training activities and working on their research projects, students participating in the Cross-Disciplinary Training Program in Sustainable Chemistry and Chemical Processes are also offered the opportunity to attend valuable networking events and professional development classes.

For instance, during their first week of training, the students attend a workshop that teaches them how to write a resume, cover letter, and personal statement. The skills they acquire during this workshop can assist them in applying for jobs and post-graduate education.

Every Wednesday, students also attend a presentation given by faculty members, as well as scientists working at General Motors and the Dow Chemical Company – a materials science company based in Michigan. During these presentations, the industrial scientists first discuss purposeful research projects and then also speak about internship opportunities at their companies, offering tips that could aid the students' professional development.

During the program, students have the opportunity to attend various networking events, including a networking picnic, student-faculty networking dinners, and Q&A sessions focusing on graduate courses, post-graduate courses, and career paths. These networking activities are organised by the Undergraduate Research Office at Michigan State University. Finally, one day of the program is dedicated to a field trip to the Dow Chemical Company, where the students can observe some of the sustainable processes implemented by Dow.

Evaluating of the Program's Impact

Dr Swain is evaluating the outcomes of the program through a series of assignments and surveys. As part of their training, all students are expected to prepare a research abstract, write weekly research progress reports, prepare oral and poster presentations for the two research symposiums, and write a personal statement. These assignments can be used to assess what the students learned during the program and provide feedback to the students on their writing style.

To better tailor the program to the students' needs, Dr Swain also asks them to complete a three-part questionnaire mid-way into the program, asking them to provide feedback on what aspects they find useful and what parts are more challenging. Their responses are discussed with mentors and used to tailor specific aspects of the program to individual students' needs.

At the end of the program, participants also complete three different exit surveys. The first includes 20 questions asking them to share their feedback about components of the program, while the second is specifically designed to compare the program's performance to that of other summer programs offered at Michigan State University. Finally, the students complete a self-assessment questionnaire, which asks them what they learned during the program.

The feedback and data that Dr Swain has collected so far is very positive and encouraging, as most participating students reported that they learned a great deal from the program. A majority of the students felt that the program was very interesting and useful, particularly the sustainable chemistry research and professional development opportunities. The program has provided them with valuable laboratory training, soft skills development and improved their overall confidence about their abilities as a researcher.

Moving Towards a Greener Future

The Cross-Disciplinary Training Program in Sustainable Chemistry and Chemical Processes is a remarkable example of how undergraduate chemistry students can be introduced to more sustainable research and development practices, while also acquiring valuable professional and academic skills. In the future, the program could inspire other universities and colleges to develop more academic chemistry courses with a focus on sustainability.

Combined, these programs could have transformative effects on existing chemical processes and practices, through the training of responsible chemists who are mindful of how their work impacts their environment. This could contribute to the reduction of environmentally harmful activities, thus supporting global efforts to tackle pollution, climate change and natural resource depletion.

'The incorporation of green chemistry principles into the research activities will equip and inspire a next-generation of chemists to solve the greatest sustainability challenges facing our planet,' says Dr Swain. 'This training will benefit society through safer laboratories and laboratory practices, reduced volume, and toxicity of chemical waste, and educating engaged and inspired students on how they can be better stewards of the environment in their research activities.'



Meet the researcher

Dr Greg M. Swain
Chemistry Department
Michigan State University
East Lansing, MI
USA

Dr Greg M. Swain is a Professor of Chemistry and member of the Neuroscience Program at Michigan State University (MSU). He is the former Director of the Graduate Neuroscience Program and the current Responsible and Ethical Conduct of Research Education Coordinator in MSU's Graduate School. He holds a BA in Chemistry from University of Texas at Dallas and a PhD in Analytical Chemistry from University of Kansas. Before he started working at MSU, Dr Swain was an Associate Professor and Associate Department Head in the Department of Chemistry and Biochemistry at Utah State University. In the early stages of his career, he also worked as a Reservoir Chemist and a Research Chemist in industry. Dr Swain's research group at MSU is well-known for the study of electrochemical reactions at conductive diamond and diamond-like carbon thin-film electrodes, as well as the application of these electrodes in electroanalysis, spectroelectrochemistry, neuroanalytical chemistry and biomedical diagnostic devices. Over the course of his career, Dr Swain has published over 200 scientific papers in renowned scientific journals. He also serves as Editor-in-Chief of the journal, *Electroanalysis* (Wiley).

CONTACT

E: swain@chemistry.msu.edu
T: <https://grad.msu.edu/staff/swain>

KEY COLLABORATORS

Dr Gary Blanchard and Dr Ruth Smith (Professors of Analytical Chemistry)
Dr Marcos Dantus and Dr Angela Wilson (Professors of Physical Chemistry)
Dr James Jackson and Dr Robert Maleczka (Professors of Organic Chemistry)
Dr Karen Draths (Assistant Professor of Organic Chemistry)
Dr Tom Hamann and Dr Milton Smith (Professor of Inorganic Chemistry)
Dr Selvan Demir and Dr Seokhyoung Kim (Assistant Professors of Inorganic Chemistry)
Dr Vlad Tarabara (Professor of Civil and Environmental Engineering)
Dr Robert Ferrier (Assistant Professor of Chemical Engineering and Materials Science)

FUNDING

This research was supported by a grant from the National Science Foundation (#CHE-2150173). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.



MICHIGAN STATE
UNIVERSITY