



SHAPING THE NEXT GENERATION OF **GREEN CHEMISTS**

How Beyond Benign's Green Chemistry Education
Awards support campus transformations
for a more sustainable future.

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INTRODUCTION

As the community of educators and institutions integrating green chemistry grows, more students are learning a sustainable approach to science. These students represent the next generation of innovators, environmental stewards, and scientists who will use their green chemistry skills and lived experiences to address local and global sustainability challenges.

Beyond Benign provides educators with the tools, training, and support needed to integrate green chemistry in their classrooms and labs. As part of this mission, Beyond Benign and partners developed the [Green Chemistry Education Awards](#) for K-12 and higher education. The awards for higher education provide funding and guidance for educators at [Green Chemistry Commitment](#) (GCC) signer institutions as they embark on projects such as curriculum redesign, outreach activities, collaborations, and awareness initiatives.

Three of the 2023-2024 recipients are GCC Signer Minority Serving Institutions (MSIs), which are bringing green chemistry to diverse student populations. By expanding green chemistry use on these three campuses, the awards give more students an opportunity to develop critical thinking skills and deepen their awareness of sustainable practices—tools they can carry into their professional work.

The following is a portfolio of stories with three educators leading these initiatives. They share updates on how they are expanding the use of green chemistry principles to help prepare the next generation of world-class chemists with the skills to create innovative environmental solutions.



Q&A WITH

DR. ROBERT IAFE

How California State University San Marcos Is Taking Steps Toward a Green Chemistry Minor

Award recipient Dr. Robert G. Iafe, Associate Professor at [California State University San Marcos](https://www.csusm.edu), says the green chemistry initiative has helped students develop a new sense of purpose and enthusiasm. “While we expected the green chemistry courses to be academically engaging, we didn’t fully anticipate how deeply students would connect with the broader themes of sustainability and social responsibility,” he says. “Many of our students come from communities that are disproportionately impacted by environmental issues, so when they see chemistry as a means of creating safer materials, cleaner technologies, and more equitable systems, it becomes more than just a course—it becomes personally meaningful and empowering.

In the Q&A below, Robert discusses progress on the university’s efforts to develop a green chemistry minor, highlights from a recent green chemistry event on campus, and other reflections.

CAN YOU PROVIDE A BRIEF OVERVIEW OF YOUR PROJECT, INCLUDING THE KEY OBJECTIVES YOU AIMED TO ACHIEVE WITH THE FUNDING AND ANY SIGNIFICANT OUTCOMES OR MILESTONES YOU HAVE REACHED SO FAR?

Our project is focused on establishing a Green Chemistry minor within the Department of Chemistry and Biochemistry at California State University San Marcos (CSUSM). The initiative is built around three core objectives. First, we’re developing Green Chemistry and Toxicology courses that are thoughtfully designed to meet the needs of our diverse student body, particularly as an MSI with a large population

of first-generation Hispanic students. Second, we’re implementing both qualitative and quantitative assessment strategies to better understand how these courses influence student success, persistence, and self-efficacy. And third, we’re working to increase campus and community engagement by hosting public seminars that feature leaders in the field of green chemistry. These events aim to raise awareness about sustainable chemistry and introduce students to related career pathways.

We’ve already made substantial progress. We’ve piloted the initial versions of both the Green Chemistry and Toxicology courses and submitted them for formal inclusion in the undergraduate curriculum. In parallel, we’ve submitted a proposal for the Green Chemistry minor itself, which is currently making its way through the university’s curriculum approval process.

One of the highlights so far has been the Green Chemistry Symposium we hosted on March 21, 2025. It was an exciting milestone for us. We welcomed guest speakers from Thermo Fisher Scientific and Beyond Benign, who shared insights on green chemistry technologies and professional pathways with an audience of over 130 undergraduate and graduate students. The event also included a pedagogy workshop that brought together faculty from CSUSM as well as neighboring institutions like SDSU and USD. Events like this really help build momentum—not just around curriculum development, but around a broader culture of sustainability and innovation on campus.

CAN YOU DESCRIBE THE PROCESS OF DEVELOPING THE GREEN CHEMISTRY MINOR AND HOW STUDENT FEEDBACK HAS SHAPED ITS CONTENT? APPROXIMATELY HOW MANY STUDENTS DO YOU ANTICIPATE THE GREEN CHEMISTRY MINOR AND ITS RELATED COURSES WILL REACH EACH YEAR?

The development of the Green Chemistry minor at CSUSM has truly been a collaborative and evolving effort. From the beginning, we prioritized both pedagogical integrity and student input. We started by piloting Green Chemistry and Toxicology courses using open-access resources from Beyond Benign, offering them initially as special topics courses. This allowed us to gather real-time feedback through course evaluations and student surveys. Faculty have been actively incorporating this feedback to improve course content, structure, and learning outcomes, especially to ensure the material resonates with our students, many of whom are first-generation college students and come from historically underrepresented backgrounds. Our goal has been to build a program that's not only academically rigorous but also personally meaningful and accessible.

Looking ahead, we anticipate that the Green Chemistry minor and its associated courses will engage approximately 40 students per year within five years of launch. Each course is expected to enroll around 20 students per semester, and we also foresee interest from students in related STEM disciplines like biology, biotechnology, kinesiology, and environmental science. Importantly, because green chemistry learning outcomes are being integrated across our broader curriculum, all Chemistry majors—not just those enrolled in the minor—will benefit from exposure to sustainable chemistry principles. We're really excited about the broader impact this initiative will have across our department and the university.

HOW DO YOU SEE THIS PROJECT PREPARING STUDENTS TO BE LEADERS IN THE SUSTAINABLE WORKFORCE OF THE FUTURE? HAVE YOU SEEN ANY SIGNS OF STUDENTS BEGINNING TO ENVISION THEIR ROLE IN SUSTAINABILITY-FOCUSED CAREERS?

This project was intentionally designed to equip our students with the skills and mindset needed to become leaders in the sustainable workforce. By embedding green chemistry principles throughout the undergraduate curriculum and offering hands-on, experiential learning opportunities, we're helping students make real-world connections to sustainability. Through specialized courses in Green Chemistry and Toxicology, students are gaining a solid foundation in designing safer chemicals, minimizing environmental impact,

and applying sustainability concepts to chemical processes—skills that are increasingly valued in sectors ranging from industry and government to academia.

Equally important, we've integrated culturally responsive pedagogy to ensure the curriculum feels relevant and empowering for our diverse student population. Our goal is to help students see themselves not just as future scientists, but as changemakers—individuals who can apply their knowledge to drive meaningful, sustainable solutions within their communities and beyond.

We're already seeing promising signs of impact. Beyond the strong turnout and enthusiasm at the Green Chemistry Symposium, we've noticed growing student interest in green chemistry-related research and activities. Students have begun inquiring about research opportunities in this area, and there has even been discussion about forming a student-led green advisory board, potentially in partnership with our American Chemical Society Student Chapter. We fully expect that as this momentum builds, we'll see an increase in student participation in sustainability-focused internships and programs, including NSF-REUs and industry collaborations. It's exciting to watch students start envisioning their roles in a more sustainable future.

HOW DO YOU PLAN TO MEASURE THE SUCCESS OF THE NEW COURSES AND THE OVERALL EFFECTIVENESS OF THE GREEN CHEMISTRY MINOR IN RETAINING STUDENTS IN CHEMISTRY RESEARCH?

We will assess the overall effectiveness of the Green Chemistry minor through a multi-faceted evaluation strategy that includes both qualitative and quantitative metrics. First, we will utilize student pre- and post-course surveys to gather feedback on student learning experiences, engagement, and perceived relevance of course content. This will help ensure that the curriculum is meeting the needs of our diverse student population and supporting their academic development.

Second, in collaboration with the Office of Institutional Planning and Analysis (IPA), we will conduct longitudinal data tracking to monitor key indicators of student success, including course performance, retention within the chemistry major, persistence in STEM pathways, and graduation rates. We will specifically analyze outcomes for students enrolled in the Green Chemistry courses and minor, with disaggregated data by demographic groups to assess equity in impact.

“Our goal is to help students see themselves not just as future scientists, but as changemakers—individuals who can apply their knowledge to drive meaningful, sustainable solutions within their communities and beyond.”



More than 200 students gathered at CSUSM in March 2025 for a green chemistry outreach event organized by the university's Chemistry and Biochemistry Department. This gathering exemplifies CSUSM's ongoing efforts to integrate green chemistry into student research, lab instruction, and community outreach.

Third, we will collect data on student involvement in research, internships, and co-curricular opportunities related to sustainability and green chemistry. We anticipate that the integration of green chemistry content will increase student interest in pursuing independent research, summer programs, and career pathways aligned with sustainability.

And finally, the number of students declaring the Green Chemistry minor and continued enrollment trends will serve as key indicators of institutional impact. These metrics, along with follow-up surveys post-graduation, will help us evaluate the program's success in preparing students for sustainability-focused careers and retaining them in chemistry research.

WHAT ARE YOUR HOPES FOR THE FUTURE OF THE GREEN CHEMISTRY PROGRAM AT CSUSM AND ITS POTENTIAL IMPACT ON STUDENTS AND THE WIDER COMMUNITY?

Our long-term vision for the Green Chemistry program is to establish it as a leading model for inclusive, sustainability-focused STEM education in the region. We see CSUSM becoming a regional hub for green chemistry education, particularly among MSIs, by offering a curriculum that goes beyond technical training to also foster environmental responsibility and social consciousness in the next generation of scientists.

Looking ahead, we hope to expand the program's impact by integrating green chemistry principles throughout the broader chemistry curriculum, encouraging interdisciplinary collaboration, and building strong partnerships with local industries, environmental organizations, and K-12 schools. The Green Chemistry minor is designed not just as a set of courses, but as a launchpad—supporting students as they pursue research, graduate education, and careers in areas like renewable energy, sustainable manufacturing, public health, and environmental policy.

For our students, we believe that early, meaningful exposure to real-world applications of green chemistry—combined with opportunities to connect with professionals in the field—will build both their confidence and their sense of purpose. It's about helping them see themselves in sustainability-focused careers and supporting their long-term academic and professional success.

Beyond the campus, we're also focused on community impact. Events like our Green Chemistry Symposium are just one example of how we hope to elevate environmental awareness and sustainability literacy across the region. Ultimately, our goal is to create a ripple effect, preparing graduates who are not only well-trained scientists but also empowered to lead positive change in their communities and within the global chemical industry.

YOUR UNIVERSITY-WIDE GREEN CHEMISTRY SEMINAR FEATURED SPEAKERS FROM THERMOFISHER AND BEYOND BENIGN AND DREW STRONG ATTENDANCE. WHAT WAS THE INTENDED GOAL OF THE EVENT, AND WHAT KIND OF IMPACT DID IT HAVE ON STUDENTS AND THE BROADER CAMPUS COMMUNITY?

The primary goal of the university-wide Green Chemistry Seminar was to elevate awareness of green chemistry principles and their real-world applications, while also inspiring students to consider sustainability-focused career paths. By featuring speakers from Thermo Fisher Scientific and Beyond Benign—leaders in both industry and education—we aimed to bridge the gap between classroom learning and professional practice. These speakers not only introduced cutting-edge technologies and sustainability initiatives but also shared their personal career journeys, offering students valuable insight into pathways they may not have previously considered.

The impact was immediate and energizing. With over 130 students, faculty, and community members in attendance, the event sparked meaningful conversations around the role of chemistry in building a more sustainable future. Students left the seminar asking thoughtful questions about internships, research opportunities, and how they might apply green chemistry in their own academic work. Additionally, the event included a pedagogy workshop attended by faculty from CSUSM and neighboring institutions, which helped foster collaboration and expand the reach of green chemistry education beyond our campus. Overall, the seminar not only reinforced the importance of sustainability within the sciences but also helped establish CSUSM's identity as a major contributor in green chemistry education across the region.

WHY WAS THIS FUNDING CRITICAL TO THE SUCCESS OF YOUR PROJECT? WERE THERE BARRIERS YOU WERE FACING THAT THIS SUPPORT HELPED YOU OVERCOME—EITHER FOR YOU, YOUR STUDENTS, OR YOUR INSTITUTION?

This funding played a pivotal role in the success of our project. As a primarily undergraduate, teaching-focused institution, CSUSM can face structural and financial challenges when it comes to launching new academic initiatives—especially those that demand significant faculty time for curriculum development, student assessment, and community outreach. The support from this award helped us overcome several of those key challenges. It allowed us to thoughtfully develop and adapt Green Chemistry and Toxicology courses using Beyond Benign's open-access resources, while tailoring the content to resonate with our diverse student body. It also gave us the capacity to implement robust assessment strategies, both qualitative and quantitative, that simply would not have been feasible without this dedicated funding.

Perhaps just as importantly, the award made it possible for us to host our first Green Chemistry Symposium by providing funding for guest speakers—something that many Primarily Undergraduate Institutions typically cannot support due to limited resources for honoraria and travel. Bringing in nationally recognized leaders from Thermo Fisher Scientific and Beyond Benign created a unique and impactful experience for our students and faculty, fostering excitement and deeper engagement with sustainability-focused careers and research. Ultimately, this funding removed critical financial and logistical barriers and enabled us to bring our vision for green chemistry at CSUSM to life in a way that is both inclusive and forward-looking.



Q&A WITH

**DR. ADALGISA
BATISTA PARRA**

How Green Chemistry at Pontifical Catholic University Is Planting the Seeds for a More Sustainable Future

Award recipient Dr. Adalgisa Batista Parra, Professor of Chemistry and Organic Chemistry Researcher at [Pontifical Catholic University of Puerto Rico](#), says green chemistry sparked meaningful discussions among students about their role in shaping a more sustainable future. “What began as a curriculum redesign became an opportunity to reflect on our values, our impact, and the kind of legacy we want to leave for our students,” she says. “This project is about more than just redesigning lab experiments—it’s about planting the seeds of a cultural shift toward sustainability in science education and beyond.”

In the Q&A below, Adalgisa shares more about her green chemistry efforts and how they have influenced her instruction, her students, and her university colleagues.

CAN YOU PROVIDE A BRIEF OVERVIEW OF YOUR PROJECT, INCLUDING THE KEY OBJECTIVES YOU AIMED TO ACHIEVE WITH THE FUNDING AND ANY SIGNIFICANT OUTCOMES OR MILESTONES YOU HAVE REACHED SO FAR?

Our project centers on redesigning the undergraduate organic chemistry laboratory curriculum to incorporate green chemistry principles with the goal of aligning instruction with emerging trends in sustainable chemistry education while actively reducing environmental impact.

With the support of funding, our primary objectives are to:

- implement greener synthesis routes to promote sustainability,
- adopt safer solvents to minimize health and environmental risks, and
- reduce chemical waste through optimized experimental procedures.

These changes were piloted with a select group of students to evaluate effectiveness and feasibility. Currently, the changes are being implemented in the organic chemistry laboratory curriculum.

SIGNIFICANT MILESTONES ACHIEVED TO DATE INCLUDE:

- The completion of a pilot redesign for several laboratory experiments using safer solvents and greener synthetic techniques.
- The collection of baseline data on waste output and solvent usage, which will inform future impact assessments.
- The development of new student learning outcomes emphasizing sustainability, green chemistry practices, and responsible chemical handling.

WHAT MOTIVATED THE REDESIGN OF THE ORGANIC CHEMISTRY LABORATORY CURRICULUM TO INCORPORATE GREEN CHEMISTRY PRINCIPLES, AND HOW DOES IT DIFFER FROM THE PREVIOUS CURRICULUM?

The primary motivation for redesigning the organic chemistry laboratory curriculum was the growing need to align educational practices with the principles of green and sustainable chemistry. Traditional laboratory experiments often rely on hazardous solvents, generate significant chemical waste, and lack emphasis on environmental responsibility. As chemistry evolves to address global environmental challenges, it is essential that our teaching laboratories reflect these priorities and prepare students for a future where sustainability is integral to scientific practice. Additional motivators included:

- Limited student exposure to environmentally responsible techniques and real-world applications of green chemistry.
- A desire to reduce the environmental footprint of the teaching laboratory and model more sustainable behavior within the academic setting.

The redesigned organic chemistry laboratory curriculum differs significantly from the previous version by shifting the focus toward sustainability, safety, and real-world relevance. Whereas the traditional curriculum relied heavily on hazardous solvents and reagents, the updated version introduces greener, safer alternatives that reduce health and environmental risks. The new approach emphasizes sustainability metrics, such as atom economy and waste reduction, alongside reaction success. Students now engage in experiments that are optimized not only for chemical outcomes but also for minimizing waste and maximizing efficiency.

WHAT FEEDBACK HAVE YOU RECEIVED FROM STUDENTS PARTICIPATING IN THE PILOT TESTING OF GREENER SYNTHETIC ROUTES, AND HOW HAS THIS INFLUENCED THE CURRICULUM?

Feedback from students participating in the pilot testing of greener synthetic routes has been overwhelmingly positive

and insightful. Many students expressed appreciation for working with safer, less toxic materials, noting that it made the lab environment feel more secure and modern. Several also shared that learning about the environmental impact of chemical processes made the course more meaningful and relevant to current global challenges.

As a result of this feedback, the curriculum will be refined to include more structured opportunities for students to analyze the environmental impact of each experiment. We will also develop supporting materials to better explain green chemistry principles and ensure students can connect theory with practice.

HOW DO YOU SEE THIS PROJECT PREPARING STUDENTS TO BE LEADERS IN THE SUSTAINABLE WORKFORCE OF THE FUTURE? HAVE YOU SEEN ANY SIGNS OF STUDENTS BEGINNING TO ENVISION THEIR ROLE IN SUSTAINABILITY-FOCUSED CAREERS?

This project is equipping students with the mindset and skills needed to become leaders in a sustainability-focused workforce. By integrating green chemistry principles into their lab experiences, students are learning to prioritize environmental responsibility alongside scientific rigor. They are not just memorizing reactions—they're critically evaluating the impact of their work, exploring alternatives, and thinking innovatively about how chemistry can contribute to a more sustainable world.

We've already seen encouraging signs that students are beginning to envision themselves in sustainability-driven roles. Some have expressed interest in pursuing careers in environmental science or regulatory policy. Others have mentioned how this experience reshaped their understanding of chemistry's role in solving real-world problems, inspiring them to look for research or industry opportunities aligned with sustainability.

Overall, the project is doing more than teaching chemistry—it's helping to shape responsible, forward-thinking scientists who understand that sustainable practices are not just an option, but a necessity for the future of science and society.

“What began as a curriculum redesign became an opportunity to reflect on our values, our impact, and the kind of legacy we want to leave for our students. This project is about more than just redesigning lab experiments—it’s about planting the seeds of a cultural shift toward sustainability in science education and beyond.”

CAN YOU SHARE ANY EARLY DATA OR INSIGHTS RELATED TO WASTE REDUCTION, SOLVENT USE, OR OTHER ENVIRONMENTAL BENEFITS OF THE GREENER PROCEDURES? HOW DO THESE RESULTS REINFORCE THE VALUE OF INTEGRATING GREEN CHEMISTRY INTO UNDERGRADUATE LABS?

Preliminary data from the pilot implementation of greener synthetic procedures shows promising environmental benefits. For example, in one redesigned experiment, we replaced toluene with water, a significantly safer solvent. In another case, the total mass of chemical waste generated per student was cut by more than 95% compared to the traditional version of the same experiment. These early results reinforce the value of integrating green chemistry into undergraduate labs by demonstrating that sustainability and scientific integrity can go hand-in-hand. Students still meet learning objectives and achieve strong outcomes, but in a way that aligns with modern environmental standards. Moreover, the measurable reductions in hazardous waste and solvent use highlight how small curricular changes can have a meaningful cumulative impact when scaled across multiple lab sections and semesters.

HOW DO YOU PLAN TO SHARE THE COMPREHENSIVE REPORT WITH UNIVERSITY STAKEHOLDERS, AND WHAT IMPACT DO YOU HOPE IT WILL HAVE ON BROADER UNIVERSITY PRACTICES?

We plan to share the comprehensive report through a combination of formal and informal channels. This includes presenting key findings at departmental meetings, curriculum committee sessions, and university-wide faculty development workshops. A digital version of the report will be made available through the university's internal repository and shared directly with administrators and faculty. A snapshot of this work was presented during the in-person 2025 Green Chemistry Commitment Summit on June 22nd in Pittsburgh, Pennsylvania.

The goal is not only to showcase the pilot's success but also to initiate broader conversations about integrating sustainability across science education. We hope the report will inspire other departments to adopt similar practices, encourage investment in sustainable lab infrastructure, and strengthen the university's overall commitment to environmental responsibility. Ultimately, we envision this project serving as a model for curriculum innovation, reinforcing the university's leadership in both academic excellence and sustainable practices.

HOW DO YOU HOPE THIS PROJECT SHIFTS THE CULTURE AROUND SUSTAINABILITY—NOT JUST IN YOUR DEPARTMENT, BUT ACROSS THE UNIVERSITY? HAVE YOU SEEN EARLY SIGNS OF THAT SHIFT ALREADY?

By integrating green chemistry into our program's curriculum, we aim to model how environmental responsibility can be embedded into academic practices without compromising educational quality. We hope this initiative encourages other programs to evaluate their own practices through a sustainability lens—whether in teaching, research, procurement, or waste management. Our vision is to help foster a university-wide mindset where sustainability is not seen as an add-on, but as a core value guiding decisions and innovation across disciplines.

We've already seen early signs of this shift. Faculty from other science programs have expressed interest in our green chemistry strategies. Additionally, students are exploring how to apply green principles in other academic settings and how they can apply green principles in other courses and research projects, showing that the impact is already expanding beyond the lab.

In the long term, we hope this project contributes to a broader institutional culture that prioritizes environmental stewardship, interdisciplinary collaboration, and the preparation of students to be leaders in a sustainable future.

“By integrating green chemistry into our program's curriculum, we aim to model how environmental responsibility can be embedded into academic practices without compromising educational quality. We hope this initiative encourages other programs to evaluate their own practices through a sustainability lens—whether in teaching, research, procurement, or waste management.”

WHY WAS THIS FUNDING CRITICAL TO THE SUCCESS OF YOUR PROJECT? WERE THERE BARRIERS YOU WERE FACING THAT THIS SUPPORT HELPED YOU OVERCOME—EITHER FOR YOU, YOUR STUDENTS, OR YOUR INSTITUTION?

This funding was essential to the success of our project, enabling us to overcome key barriers that had previously limited our ability to modernize the organic chemistry lab curriculum. Prior to this support, we faced significant resource constraints—from the cost of safer, greener reagents and solvents, to the need for updated lab equipment and training materials.

The grant allowed us to pilot greener experiments without compromising instructional quality, and to collect baseline data on environmental impact—something we hadn't had the capacity to do before. It also supported faculty development, helping instructors gain the knowledge and confidence needed to implement and teach green chemistry principles effectively.

For our students, the funding made it possible to gain hands-on experience with modern, sustainable lab techniques—an opportunity they wouldn't have had under the traditional curriculum. More broadly, it gave our institution a model for what a sustainable lab redesign can look like, helping us take the first step toward long-term, campus-wide transformation.

IS THERE ANYTHING ELSE YOU'D LIKE TO SHARE ABOUT YOUR EXPERIENCE WITH THIS GRANT—SOMETHING UNEXPECTED, PERSONALLY MEANINGFUL, OR SOMETHING YOU LEARNED ALONG THE WAY?

It was incredibly rewarding to see students not only adapt to the new experiments but also ask more thoughtful questions, show greater environmental awareness, and express genuine excitement about being part of a positive change. It reminded us that when given the tools and the context, students rise to the occasion—they want to do work that matters.

Along the way, we also learned that change is possible, even in well-established systems, when you have the right support, clear goals, and a shared sense of purpose. This grant didn't just fund a project—it empowered a shift in mindset that we hope will continue to grow across our department and beyond.



GUTTMAN
COMMUNITY COLLEGE



Q&A WITH

DR. JIHYUN KIM

How Green Chemistry at Stella and Charles Guttman Community College Is Nurturing Innovation and a Sustainability-Minded Workforce

Award recipient Dr. Jihyun (Ji) Kim, Associate Professor of Chemistry at [Stella and Charles Guttman Community College](#), says the green chemistry concepts helped students see how chemistry can be a tool for environmental responsibility. “One of the most encouraging outcomes of this project was the level of student engagement with green chemistry concepts, particularly as they connected sustainability to real-world issues,” Ji says. “One student reflected on how using dried orange peels as a catalyst opened their eyes to the value of reusing food waste and sparked curiosity about other potential applications of natural materials in chemistry.”

In the Q&A below, Ji discusses how green chemistry education has helped students deepen their critical thinking skills and consider sustainability-focused career opportunities.

CAN YOU PROVIDE A BRIEF OVERVIEW OF YOUR PROJECT, INCLUDING THE KEY OBJECTIVES YOU AIMED TO ACHIEVE WITH THE FUNDING AND ANY SIGNIFICANT OUTCOMES OR MILESTONES YOU HAVE REACHED SO FAR?

This project focused on redesigning a classic organic chemistry experiment—the synthesis of cyclohexene—to emphasize green chemistry principles and provide a safer, more sustainable laboratory experience for students at a resource-limited two-year college.

With support from the funding, the key objectives were to:

- reduce chemical waste and hazards using microscale techniques,
- introduce students to environmentally friendly alternatives to traditional reagents, and
- align experimental design with the 12 Principles of Green Chemistry.

Students explored alternative catalysts such as Amberlyst-15 and dried orange peels in place of conventional acids like phosphoric acid. The activity incorporated pre-laboratory research, group collaboration, and critical evaluation of chemical choices. Outcomes included increased student awareness of sustainability in chemistry, hands-on experience with safer materials, and thoughtful reflection on the environmental and health impacts of chemical practices. The use of microscale kits reduced waste and exposure risks, while also addressing institutional limitations like limited fume hood access.

Overall, the project served as a successful model for incorporating green chemistry into the undergraduate laboratory curriculum and highlighted opportunities for further research in sustainable lab practices.



Beyond Benign Co-Founder and Executive Director, Dr. Amy Cannon, visited Guttman Community College in September 2024. Here, Amy is pictured in the lab with Ji, students, and the microscale glassware kits.

WHAT IMPACT HAVE THE MICROSCALE GLASSWARE KITS HAD ON STUDENT LEARNING OR ENGAGEMENT IN THE LAB? HOW HAVE STUDENTS RESPONDED TO THIS SHIFT IN HANDS-ON EXPERIENCE?

The introduction of microscale glassware kits had a notable positive impact on student learning and engagement in the laboratory. Survey results indicated that most students felt confident using the microscale setup, with approximately 88% expressing comfort with performing microscale experiments. The kits allowed students to carry out organic synthesis using significantly reduced quantities of chemicals, aligning with green chemistry principles while minimizing safety risks and waste production.

Qualitative feedback from student reflections also highlighted the appeal of the hands-on experience. Students appreciated the accessibility and manageability of the equipment, especially in a setting with limited fume hood access. While a small percentage (12%) reported some discomfort or challenges—suggesting the need for additional scaffolding or practice—the overall response was positive.

The microscale kits enabled students to focus more on experimental design, sustainability, and chemical safety, making the lab experience more meaningful and aligned with real-world applications of green chemistry.

WHAT METHODS ARE YOU USING TO ASSESS STUDENT UNDERSTANDING OF THE 12 PRINCIPLES OF GREEN CHEMISTRY, AND WHAT HAVE YOU FOUND EFFECTIVE?

Student understanding of the 12 Principles of Green Chemistry was assessed through a combination of pre-laboratory activities, collaborative discussions, lab reports, and post-activity reflections. During a dedicated pre-lab session, students reviewed the principles and discussed how they related to the planned experiment. Each group was tasked with aligning their chosen modifications—such as the use of Amberlyst-15 or dried orange peels—with specific principles, fostering intentional connections between theory and practice.

As part of their lab reports, students were required to identify and justify which green chemistry principles their

“This project empowers students to think critically about sustainability in chemical practice, fostering awareness of eco-conscious decision-making.”

experimental design addressed. The class collectively concluded that their approaches satisfied at least six of the 12 principles, demonstrating a strong grasp of the framework and its practical applications.

WHAT CHALLENGES HAVE YOU ENCOUNTERED DURING THE IMPLEMENTATION OF NEW EXPERIMENTAL PROCEDURES, AND HOW HAVE YOU ADDRESSED THEM?

Several challenges emerged during the implementation of the redesigned experimental procedures. One primary challenge was the use of microscale glassware kits, which, while aligned with green chemistry goals, required students to adapt to working with smaller quantities and more precise techniques. Some students initially struggled with unfamiliar equipment and the level of care needed for accurate handling. To address this, additional guidance was provided during the pre-lab sessions, and the instructor demonstrated proper technique to build student confidence.

Another challenge involved managing expectations around reaction yields. Because the focus of the activity was on sustainability rather than maximizing product yield, students needed support in understanding the trade-offs between greener methods and traditional efficiency. This was addressed through guided discussions and reflection prompts that emphasized process over outcome.

HOW DO YOU SEE THIS PROJECT PREPARING STUDENTS TO BE LEADERS IN THE SUSTAINABLE WORKFORCE OF THE FUTURE? HAVE YOU SEEN ANY SIGNS OF STUDENTS BEGINNING TO ENVISION THEIR ROLE IN SUSTAINABILITY-FOCUSED CAREERS?

This project empowers students to think critically about sustainability in chemical practice, fostering awareness of eco-conscious decision-making. Through hands-on experience

with green chemistry, many began envisioning their role in solving environmental challenges. Some even expressed interest in sustainability-focused careers, signaling early leadership potential in the green workforce.

WHY WAS THIS FUNDING CRITICAL TO THE SUCCESS OF YOUR PROJECT? WERE THERE BARRIERS YOU WERE FACING THAT THIS SUPPORT HELPED YOU OVERCOME—EITHER FOR YOU, YOUR STUDENTS, OR YOUR INSTITUTION?

This funding was critical in enabling the implementation of a redesigned, sustainability-focused lab activity at a resource-limited two-year college. With limited access to fume hoods and traditional lab infrastructure, the support allowed us to purchase microscale kits and eco-friendly reagents that aligned with green chemistry principles. It also supported curriculum development time to create engaging, accessible materials tailored to our diverse student population. Without this funding, hands-on experience with safer, more sustainable methods would not have been feasible. It helped overcome institutional barriers, expanded learning opportunities for students, and laid the groundwork for integrating sustainability into our STEM curriculum.

IS THERE ANYTHING ELSE YOU'D LIKE TO SHARE ABOUT YOUR EXPERIENCE WITH THIS GRANT—SOMETHING UNEXPECTED, PERSONALLY MEANINGFUL, OR SOMETHING YOU LEARNED ALONG THE WAY?

This grant reaffirmed the power of innovation in resource-limited settings. An unexpected outcome was how deeply students connected with sustainability when given ownership of their learning. Watching them think critically, collaborate, and make environmentally conscious choices was incredibly meaningful—and reminded me why inclusive, hands-on science education truly matters.

Thank you to these educators for empowering the next generation of scientists, innovators, and environmental stewards.