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# Reimagining chemistry education for a sustainable future

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Chemistry education plays a critical role in preparing future scientists to address global sustainability challenges, yet traditional, instructor-focused pedagogies often obscure chemistry's societal impacts and limit students' sense of belonging and agency within chemistry. In this paper, we describe the implementation of *Reimagining Chemistry*, a course developed through a student-directed independent study, which contextualizes chemistry within social, environmental, and ethical frameworks aligned with the United Nations Sustainable Development Goals. Grounded in Culturally Sustaining Pedagogy (CSP) and the framework of Rightful Presence, *Reimagining Chemistry* emphasizes student voice, collaborative knowledge-building, and community-engaged projects that empower students as changemakers. Using surveys, observations, student reflections, and project outcomes from two course offerings, we examined student motivations, learning experiences, and the evolution of the course across its iterations. Students demonstrated significant engagement, broadened their perspectives on chemistry's role in society, and produced projects addressing educational equity, environmental justice, and local community engagement. Achieving a sustainable future requires chemistry education that not only develops technical competence, but guides and empowers all students to critically engage. This curriculum provides a model for chemistry educators seeking to foster inclusive learning environments that connect chemical education to global and community impact.

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### Sustainability spotlight

Chemistry education must explicitly center chemistry as a discipline that empowers diverse students as problem solvers to address sustainability in their communities. This work details the development of a course that addresses UN SDG 4 by encouraging students to critically engage with chemistry as a discipline that can address global sustainability challenges. *Reimagining Chemistry* is a course that centers student voices, allowing them to develop a strong sense of belonging in chemistry and reauthor the rights to their education. It engages students as partners in changemaking, as they apply their learning to a final project that reimagines an aspect of chemistry in their local community. *Reimagining Chemistry* was developed as part of an anti-racism effort, and it also addresses UN SDGs 5 and 10 by incorporating feminism and anti-racism as strong themes throughout.

## 1 Introduction

Chemists and related STEM professionals play essential roles in tackling major sustainability challenges facing our world, including pollution, climate change, and rising energy demands.[1] The United Nations Sustainable Development Goals (UN SDGs) are a blueprint for current and future world prosperity and peace, and will only be achieved through global partnership.[2] Chemistry education must empower students with the scientific knowledge and skills required to address the SDGs. Furthermore, chemistry classrooms are important places to discuss chemistry's role in designing a sustainable future. Our role as educators is to address UN SDG 4 by ensuring "inclusive and equitable quality education and promote lifelong learning opportunities for all".[3] To address UN SDG 4, chemistry educators must create classrooms where all students see themselves as problem-solvers who can use their chemistry knowledge and skills to address sustainability. UN SDG 4 is critical for achieving UN SDGs 10 and which are to "reduce inequality within and among countries" and "achieve gender equality and empower all women and girls", respectively.[3]

A crucial component of a contemporary chemistry classroom must be contextualizing course content. Students must be explicitly shown the relevance and power of chemistry in addressing the crises facing our world. Personally relevant course content not only improves learning outcomes, but helps students develop a sense of belonging in STEM and inspires them to enter the chemistry workforce as a way to serve their communities.[4,5] This is especially important for students with identities historically marginalized in STEM, and critical for

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achieving UN SDGs 5 and 10.[6–9] However, many chemistry classrooms adopt instructor-focused pedagogies that do not contribute to achieving this goal more than superficially, instead focusing on content without providing context.[10]

A modern chemistry classroom must also train students as problem solvers who can apply their learning to diverse challenges. Chemistry education already aims to train students in the scientific method, guiding them in developing the essential comprehension and skills to ask and answer important questions through experimentation. However, particularly in introductory classes, the problem identification and question generation phases of the scientific method are often overlooked. This results in students not considering careers in chemistry as a way to solve critical problems and care for the world.[11]

This is compounded by students' lived experiences in which chemistry has historically contributed to global challenges before being used to address them. Additionally, some students may experience implicit or explicit messaging that they do not belong in chemistry, which is reinforced by the lack of diverse representation in chemistry classrooms, faculty, and in leadership positions in the field.[12–14]

In chemistry classrooms, the focus on content without context, the absence of explicit discussion of how chemistry can address global challenges, and the lack of visible diversity has resulted in decreasing numbers of students pursuing chemistry careers.[15] Many chemistry educators have begun to adjust their pedagogical practices to address these issues and help develop a more diverse, service-oriented, and collaborative chemistry workforce. Importantly, many chemistry educators in higher education are incorporating more active learning and student-centered pedagogies into their teaching.[16] These approaches increase engagement, which results in the development of self-efficacy and more valuable long-term learning outcomes.[17,18]

Going a step further, some educators have adopted Culturally Sustaining Pedagogy (CSP), including social or environmental-justice based frameworks.[19–29] CSP helps students see themselves in the field of chemistry, calling on them to engage in a loving critique of their education, the field, and the world around them. Classrooms using CSP can help students achieve a sense of Rightful Presence.[30] Rightful Presence is a framework that includes three tenets as defined by Calabrese Barton and Tan: the right to reauthor rights, making visible injustices/justices in the present while orienting towards new social futures, and a culture of disruption towards justice, where modes of power are called into question. Other educators have also incorporated service or community-based learning opportunities to train future chemists.[29,31,32]

This work details the implementation of a new course, *Reimagining Chemistry*, which emphasizes student voices while chemistry is discussed within its societal context. A key component of this course is a project that empowers students as changemakers by reimagining an aspect of chemistry on campus or in the local community. This course draws on the tenets of Rightful Presence[30] by disrupting guest–host dynamics found in traditional STEM classrooms, where students often take on the role of "guests", with little opportunity to decide or assert their rights to pedagogies and materials within their education. It also empowers students to challenge existing norms by making their lived experiences visible and integral to their learning. This course was designed as a part of an anti-racism effort and in partnership with students.[21] It was taught for the first time in Spring 2024. Through student and instructor feedback and structured reflection with students and teaching assistants in the course, several lessons were translated into changes for Spring 2025 to improve the course and achieve Rightful Presence. This course offers a model for how chemistry educators can advance inclusivity, belonging, and sustainability in STEM by centering student voices and supporting them as changemakers who use their chemistry education to better their communities.

# 2 Experimental

## 2.1 Course structure

*Reimagining Chemistry* was designed[21] as a small (25-student) discussion-based course featuring two major projects in addition to formative and summative assessments. The learning objectives and learning activities are shown in Fig. 1. This course aimed to expand student perspectives, develop an understanding of the societal context of chemistry, and identify areas of chemistry to reimagine on campus or in the local community. This course was developed as an elective targeted towards junior and senior students studying chemistry or related STEM fields. It was not required for any students, and was taken by 33 students in Year 1 and 23 in Year 2. These students were primarily junior and senior undergraduates obtaining degrees in Chemistry, Biochemistry, Neuroscience, Engineering, and Biology. For reference, our Chemistry and Biochemistry programs collectively graduate around 75 students per year across all undergraduate degrees. Detailed information including the syllabus, schedule, assignments and can be found in the SI.

*Reimagining Chemistry* was conceptualized using the framing and guiding questions defined in a student-directed independent study that was involved in designing this course.[21] This framing resulted in three distinct course phases: grounding, exploration, and action (Fig. 2).

The Grounding phase focuses on developing a set of shared norms and critical lenses. In the Exploration phase, case studies that highlight critical issues are discussed to contextualize chemistry within its past and present contributions to ongoing crises, both positive and negative. In the Action phase, students consider problems or issues they have encountered in chemistry that they want to investigate in their midterm projects and reimagine in their final projects. While students are not doing traditional wet-lab activities, they use the scientific method to participate in the scientific community by identifying problems and proposing literature-based solutions as changemakers. These projects are scaffolded, with check-points for peer and instructor feedback throughout the semester. At the end of the course, students share their final projects with the class, in a celebration of the progress made towards *Reimagining Chemistry*. Throughout the course, students reflect on their own personal experiences in STEM courses and STEM spaces more broadly, while also


Fig. 1 Learning objectives and activities for *Reimagining Chemistry*.

considering alternate perspectives. Detailed schedules of topics for each class meeting period can be found in the SI.

### 2.2 Pedagogical choices

This course is student-centered, which is critical to empowering students to make choices about their learning. Not only did this course come from a collaboration between students and faculty, but a majority of the course's topics, frameworks, and materials were designed in a student-led independent study.[21] Students were allowed to choose which materials they engaged with before class, while structuring in-class discussions to expose students to the ideas in all pre-class materials.

Additionally, the class meetings primarily involved instructor or peer-facilitated student discussion in small groups as a whole class, where students were engaging with each other around the course material. Students also made choices about assessments, including format and specific topic, provided it met the learning objectives. For example, in the Storytelling Assignment, students profiled a chemist and their work, using the critical lenses and their chemistry backgrounds. Students could pick chemists whose identities, research, or both were of interest to them and choose the project format, including a poster, essay, presentation, podcast, *etc.* The midterm and final projects were also student-driven. Students identified areas they were interested in addressing on

 

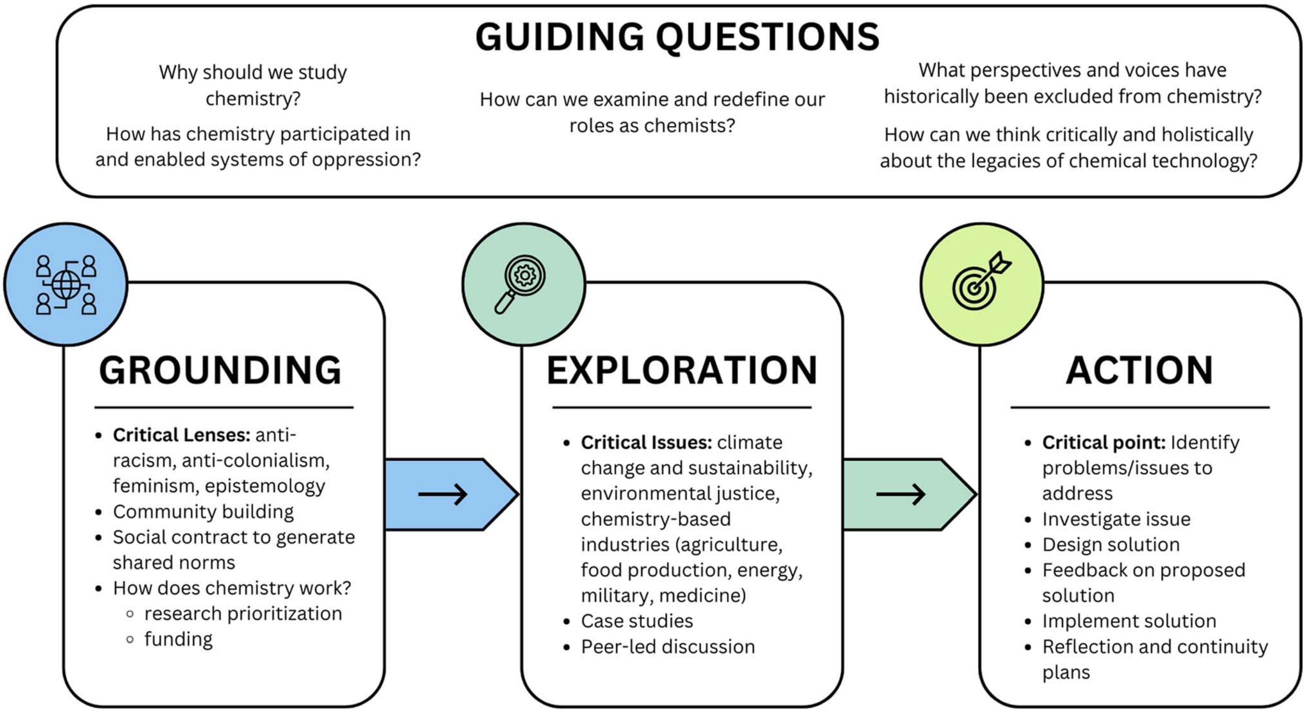


Fig. 2 *Reimagining Chemistry* course phases.

campus or locally, and interviewed stakeholders in a preliminary information-gathering phase. Then, they proposed ways to reimagine the problem addressed, with most students choosing to address issues related to STEM education, outreach, or the environment.

The second major choice was to discuss key topics that would be important for students' professional development. Topics that were relevant for students preparing to enter the workforce or graduate education included diversity in STEM, science funding, the environmental impacts of research, and the responsibilities of individual researchers.

### 2.3 Instructional team

The course was taught by a faculty member who was part of the original course design team and is an author of this article. The course was also supported by two undergraduate teaching assistants (UTAs). In Year 1 the UTAs were students who had participated in the student-directed independent study; in Year 2, they were students of the course in Year 1. The UTAs attended class, held office hours, provided feedback on assignments, assisted groups in locating resources for their projects, and consulted with groups throughout their projects.

## 3 Results and discussion

### 3.1 Student motivations for taking *Reimagining Chemistry*

At the beginning of the semester, students were given a survey to understand their motivations for taking the course. Motivations for taking the course typically fell into one of two categories: identity-based and professional or pre-professional interests and experiences. Most participants' motivations encompassed both of these categories; however, details of their lived experiences were different and deeply personal. In general, motivations can be summarized in Table 1.

### 3.2 Year 1 outcomes

In Spring 2024, 33 students enrolled in *Reimagining Chemistry*, 32 undergraduates and one graduate student. Of the undergraduate students, 30 were juniors or seniors, and two were sophomores. All students were majoring in a STEM field, and many were planning to enter medical or graduate school upon graduation or after taking a gap year. All students attended class regularly, participated in discussions, and completed all assignments throughout the semester, indicating a high level of engagement. Student projects were thoughtful, ambitious, and had excellent plans for continuity.

At the end of the semester, students were asked in class which topics they most enjoyed learning about. Interestingly, there was a wide distribution of "favorites", without consensus. The most common topics that students described as the most impactful for them were learning about Superfund and researching Superfund sites, the use of chemistry in agriculture, nuclear chemistry and chemistry in warfare more generally, and the history of birth control development. A common sentiment was, "how have we not encountered such an important topic after making it this far in STEM?" Some students described a sense of surprise due to their lack of knowledge on a particular topic or its fraught history. This surprise prompted inner reflection on some students' privilege to be ignorant to such topics, but also the role of STEM education, including what was missing in their own undergraduate education.

Table 1 Selected quotes on student motivations for enrolling

| Motivation | Student quotes |
| --- | --- |
| Challenge perspective and facilitate growth | "I wondered if higher education STEM spaces were ready for critical, honest, likely controversial conversations around inequities, uncomfortable histories, and their own shortcomings." "This course offered a rare opportunity to question existing narratives in STEM and explore its broader societal impacts—an approach that deeply resonated with my lived experiences and aspirations." |
| Develop a holistic understanding of the ethical implications of chemical research and industry | "What drew me most to *Reimagining Chemistry* was its qualitative approach to a discipline that is often represented as purely empirical. I had never before seen chemistry discussed through a social lens, nor had I encountered a course that intertwined science with topics like race, socioeconomic disparity, and education inequities." "Topics like military chemistry and agricultural chemistry just weren't things I knew about, and I thought it would add a lot to my understanding of chemistry to also understand the real-world ways in which it is used" |
| Professional and personal development | "Ultimately, this course gave me the space to critically engage with chemistry in a way that mirrored my broader approach to science and medicine, which is one that acknowledges the historical and social contexts in which knowledge is produced and disseminated." "…I hoped to deepen my understanding of various contexts, histories, and narratives in chemistry that may be useful in curriculum development, lesson planning, and creating learning experiences that may be more engaging and empowering to students." "I wanted to take a step towards mitigating the harm I do to different communities during my studies and to open my eyes to inequalities that I might not have taken into consideration in the past." |
| Passion for making STEM more inclusive and accessible | "I feel an almost urgent desire to fill the (gradually shrinking) absence of conversations regarding race, gender, the environment, systems of oppression, and identity from chemistry/STEM spaces, and it felt exciting to see that I was far from alone in these feelings." "I realized that this course would approach chemical education from an anti-racist framework, and would investigate why black and brown students like myself were performing worse in college STEM courses." "…I was thinking really hard about how to create more equitable STEM learning environments that encourage all students to grow in their thinking. I just really wanted people to have positive experiences learning STEM subjects." |

### 3.3 Student projects

Student projects addressed a wide range of issues, but can be broadly categorized as addressing chemistry education, outreach, career preparation, environmental justice, green chemistry, and diversity, equity, and inclusion. Examples of specific projects are shown in Fig. 3, and a list of project descriptions is in the SI. Final projects involved a peer review/feedback process, and required students to submit continuity plans for ensuring that their projects were continued after the semester. Since many of the students in the course were graduating seniors, it was important to plan for continuity.

Student projects to develop instructional and career preparation resources for introductory STEM courses encountered resistance from faculty who teach these courses. In meetings where students interviewed faculty to help inform their projects, course instructors of large introductory courses in chemistry expressed hesitation at incorporating anything other than strictly "chemistry" content, feeling that it was not their place or style to discuss anything other than "the facts". They also expressed the sentiment that, by avoiding discussions of any people in chemistry or the societal context in which chemistry occurs, they were being "objective," thus allowing students to focus on engaging with the course content without anything else "getting in the way". This remained true even after individual conversations between students and instructors, where students indicated that representation or discussion of diversity in their introductory courses was something that they actively sought out. Additionally, instructors expressed hesitation to share career preparation resources, as they did not view their courses as vehicles for career information. To our knowledge, STEM careers are rarely discussed explicitly, even in higher level courses on our campus. Lastly, we observed that, although many educators expressed a commitment to supporting all students and were aware of equity gaps in general and in their own courses, they struggled to see how their pedagogical choices contributed to reinforcing or reducing these gaps.

### 3.4 Lessons learned in Year 1

As part of the process of preparing a manuscript detailing the development of this course,[21] instructors (2), UTAs (2), and Year 1 students (5) completed structured written reflections (see SI

 

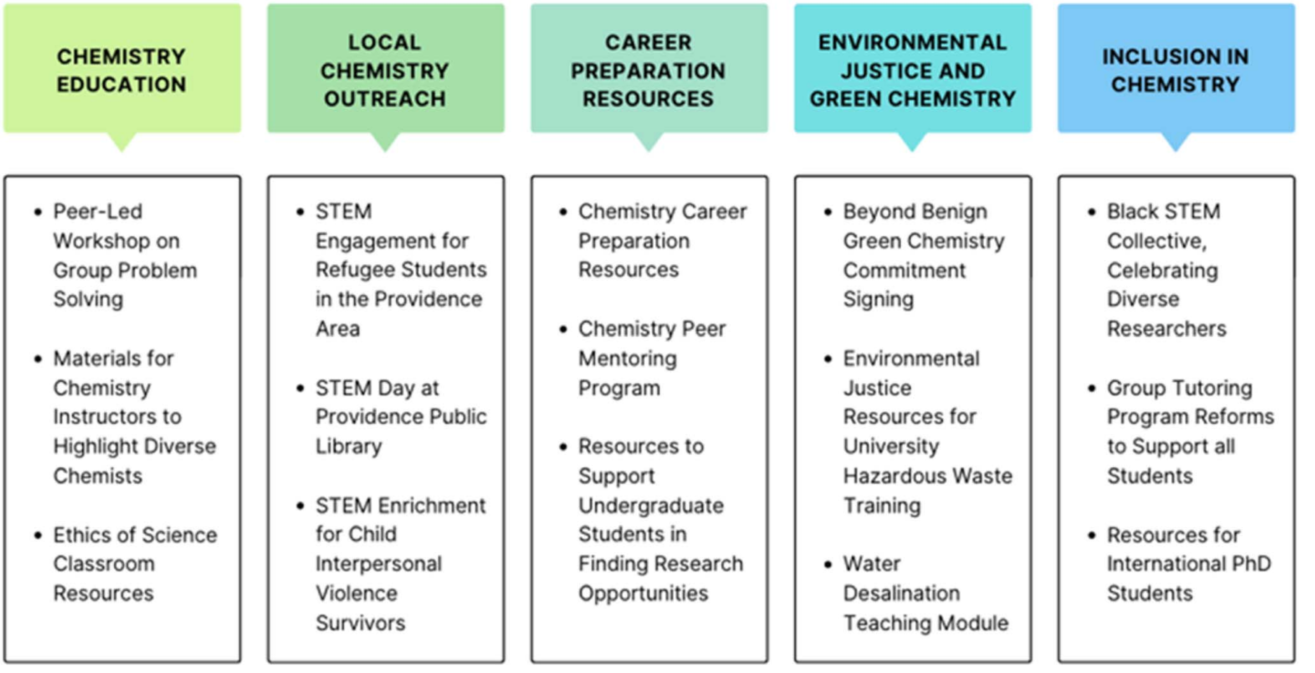


Fig. 3 Student project themes and examples.

for questions) followed up by focused conversations. Based on these reflections and conversations, three important lessons were learned in the first iteration of this course.

**3.4.1 Lesson 1: it was easy to default to norms found in other STEM courses.** The class struggled to challenge campus norms for student–teacher interaction within STEM courses. Introductory STEM courses on our campus are typically large lectures, in which communication flows between instructor and students with minimal student-to-student dialogue. This meant that although students came into *Reimagining Chemistry* with some understanding of equity and inclusion in STEM spaces, the course's attempt to practice Rightful Presence[25] through a non-traditional classroom environment felt unfamiliar and initially uncomfortable. In Year 1, day-to-day in-class interactions tended to reflect traditional STEM classroom dynamics between students and teachers, where students primarily engaged with the instructor *versus* one another. The instructor felt pressure to make the course conform to STEM class norms, including using traditional in-person timed assessments to avoid the course being viewed as out of place in the curriculum. This forced the course to conform to norms in the department and STEM more broadly that were irrelevant to the learning outcomes in this class.

Some of this stemmed from the physical space, which included background noise and inflexible seating that limited peer interactions. However, students and teachers brought learned norms about how communication "should" work in STEM classrooms. Without intentional disruption of the guest–host framework, students defaulted to interacting with the instructor and a set group of peers, and engaging less with peers they did not know. This is common in lecture courses, but is not conducive to vibrant discussion. This reinforced instructor authority and limited student-driven conversations.

Furthermore, members of the student body share a university-wide culture shaped by imposter syndrome[33] and fear of failure. Many students arrive on campus having achieved high levels of success in high school, which was obtained by becoming a "professional student". This contributes to a culture where learning is less of a process of mistake making and exploration, but instead a perfection-based pathway to perceived "success". As a result, the risk-taking, collaboration, difficult discussions, and disruptions of guest–host framing necessary for this type of class are not only atypical in STEM classes, but can feel contradictory to what it means to be a "successful" student.

**3.4.2 Lesson 2: this course experience depends intimately on the student population and their experiences, interests, and goals.** Students came into the classroom with a variety of experiences, cultures, and previous coursework. This meant that students had varying levels of pre-existing knowledge about course topics. This multitude of perspectives is necessary to create the pluralistic classroom culture we envision for chemistry as a discipline. However, this sometimes resulted in friction during discussions. There were several instances where there were only one or a handful of students who had a similar shared lived experience around a particular issue. Similarly, in many cases students' sense of surprise about different topics was not widespread, but limited to students who had the privilege to be unaware of certain histories, injustices, and the state of the current STEM landscape. Students from marginalized groups sometimes needed to remind their peers of inequities they face. At times students over-generalized the experiences of marginalized groups, forcing marginalized students to take on the burdensome role of educating their peers. Additionally, students more familiar with the anti-imperialist frameworks introduced in the class sometimes felt like the course topics were "common sense," slipping into the audience during discussions rather than being active participants.

The instructor also came into the class with her own set of lived experiences. Reflecting on the class, she recognized the difficulty of moderating discussions, and balancing being an ally while acknowledging the limitations of her lived experiences. Ultimately, producing discussions that both incorporate the pluralistic perspectives of the class and center marginalized experiences requires added effort by the students and instructor.

At the beginning of each semester, time was devoted to developing a social contract that outlined the norms and expectations for in-class discussions. This included not requiring every student to weigh in on every issue and allowing students the opportunity to leave the room if any discussion topic became too much for them. While this provided clear expectations for all students, there were still times where discussions had to be redirected by the instructor, not due to mal-intent, but rather due to a lack of awareness.

That being said, the productivity of in-class discourse also relies on the variety of lived experiences of participants. The diverse backgrounds of students allowed for unique perspectives on topics from students who could serve as primary sources for topics in the class. The instructor tried to encourage multiple perspectives by redirecting conversation when necessary, encouraging students to build off of or challenge each other's ideas, and trying to ensure that talking time was not being consumed by only a small group of outgoing students. Several discussions lasted long after class ended, and provided new perspectives that participants had not considered. Many students did eventually break pre-existing social circles to come together for final projects and develop new, sustainable ideas for improvements in their local community. Students also developed new relationships through *Reimagining Chemistry*. These relationships were formed with peers, faculty, staff, and other people across campus that students had interacted with as part of their projects. In addition to diverse student participation, the instructor was able to secure a merged lesson with another course and a speaker from industry to further broaden perspectives and understanding for students.

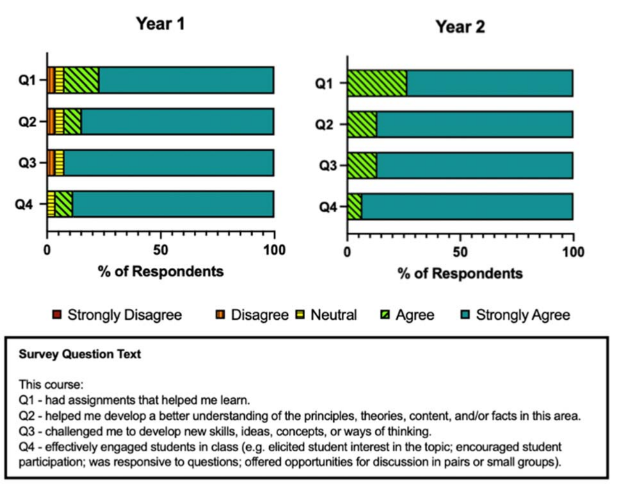


Fig. 4 Selected course feedback data for Years 1 and 2.

**3.4.3 Lesson 3: challenging the status quo in a meaningful way is difficult and gives rise to resistance.** The project component of this course works toward a Rightful Presence-based vision of chemistry by allowing students to make current and historical injustices within chemistry visible and re-write what engaging with chemistry at Brown looks like.[30] While anticipated, it became clear that making meaningful change is challenging. Students encountered challenges before, during, and after their projects.

Before starting projects, some students struggled to select topics that both felt personally meaningful and could lead to realistic changes with the department. Even if a student found a desirable topic, they may not have been able to find other students interested in working on that topic. This was especially true for students who had less previous experience with course topics, since many students who had experience came into the class with a project topic in mind.

During the final project, some students encountered defensiveness and resistance from members of the chemistry community. Many students were caught off guard by these responses and felt discouraged from having further discussions. Rather than leave students to take on a difficult conversation alone, the instructor joined to support them. In these moments, students and instructor were no longer positioned as guests and host, but rather as partners in change-making.

After the course ended, students also faced practical challenges implementing the innovations designed in their final projects. These included scheduling conflicts, lack of interest from stakeholders, and lack of time amidst other school work. This meant that some final project products were not actually used after the class concluded or were only implemented superficially.

### 3.5 Changes and outcomes for Year 2

The major changes made for Year 2 were designed to:

(1) Intentionally disrupt guest–host dynamics by establishing classroom norms and encouraging student discussion.

(2) Allow students more choice in the topics that were explored in class.

(3) Support students in navigating the friction they might encounter in their final projects.

**3.5.1 Disrupting guest–host dynamics.** Classroom and disciplinary norms that have been internalized must be deliberately acknowledged, and class community and dynamics (ones that are engaged, sincere, and dynamic, as opposed to disengaged, superficial, and stagnant) must be actively named, co-created, and upheld. The way this was achieved in Year 2 was by asking students to reflect on their previous STEM classes. By naming the expectations imposed in other classes, students and instructors can discuss how the rights afforded to students can be expanded to include more student–student interactions. Similarly, taking time to identify Brown's academic culture could allow students to deconstruct their ideas of what success might look like and rewrite what it means within their lives. This allowed the class to reimagine what a chemistry class can look like, one where students and teachers share discursive power.

To foster more student–student interactions in class, we introduced a peer-led discussion assignment, the use of pre-class online discussion boards, and a digital collaborative whiteboard (Miroboard) to hold students accountable during in-class discussions and decrease the time the instructor spent lecturing. The digital collaborative whiteboard was set up with specific questions that each small group would record their discussions on, and use to share from with the whole class. This ensure that student discussions were more focused, because they had a specific output to produce. The digital whiteboard was projected during small and large group discussions and referred to by students and instructors. An example template whiteboard is included in the SI. All of these changes resulted in increased student–student engagement during discussions.

**3.5.2 Fostering student choice.** To allow students more choice in the ways they engaged with course material and discussions, course topics were reordered, the pace was adjusted, and new assignments were developed. The topics at the beginning of the course were reordered to decrease redundancy based on how discussions unfolded in Year 1. Less class time was spent discussing the critical lenses and pre-reading was encouraged by the use of online discussion boards, both of which allowed for discussion of a wider range of topics. Another important decision was to remove the use of quizzes, which were included in Year 1 and did not encourage students to engage with the course content in a critical and meaningful way. Two different assignments were introduced to meet the learning objectives of the course. The first was a Superfund Case Study Assignment, in which students researched and presented information about an Environmental Protection Agency (EPA) Superfund site of their choice. The second was a peer-led discussion assignment where students had to select a topic to lead a class conversation on, including designing their own discussion questions and activities before class. These changes allowed students to explore topics of their choice more deeply, as well as redirected course accountability to the participants, rather than just the instructor.

**3.5.3 Supporting student projects.** Several changes were made to better support students in their projects. First, the timeline of the final project was expanded, allowing students more time to explore project topics. Secondly, more in-class time was dedicated to final project ideation. This allowed students to find peers with similar interests and consider the practicality of each idea. Third, we shared student projects from Year 1 to outline expectations regarding the scope and scale of projects. In Year 2, class time was also dedicated to preparing students for resistance and practical challenges in their projects.

By discussing Year 1 projects, students gained an understanding of previous efforts to make change within and outside of chemistry and where and why projects were met with resistance. This allowed students to proactively anticipate challenges that might arise in their projects. Additionally, the instructor and UTAs who completed projects in Year 1 were better able to connect students with community members who might support specific projects. As this course iterates, there will be more project examples to serve as inspiration and build from, creating a sustainable way to use small projects to drive larger initiatives that are too ambitious for one semester.

### 3.6 Year 2 outcomes

The changes to the course topic schedule and use of different assignments were successful in terms of exposing students to more topics and allowing them more choice in pursuing topics based on their interests. On course feedback surveys sent out by the university, a larger percentage of students selected "Agree" and "Strongly Agree" in Year 2 than Year 1 for questions pertaining to assignment usefulness for learning (Q1 – 100% *vs.* 92%), developing an understanding of the course material (Q2 – 100% *vs.* 92%), and broadening ways of thinking (Q3 – 100% *vs.* 92%) (Fig. 4). The course feedback also showed that students in Year 2 were more likely to select "Strongly Agree" for a (Q4 – 92% *vs.* 88%) about the amount of engagement in discussion with peers in class. This suggests that the changes made to increase student–student interaction in class by enhancing discussion were successful. Course feedback surveys in Years 1 and 2 had response rates of 88% (29/33 students) and 78% (18/23 students, respectively).

There were noticeable changes in final projects between Years 1 and 2, both in terms of topics and quality. In Year 1 more projects were focused on addressing diversity, equity, and inclusion (45% (5/11 total projects) *versus* 28% (2/7 total projects)), while more projects in Year 2 were focused on chemistry education (45% (5/11 total projects) *versus* 57% (4/7 total projects)). We speculate that this might be due to a changing political landscape both nationally and institutionally between 2024 and 2025. We also noticed that students in Year 1 had a greater sense of responsibility towards ensuring that this course was offered again, which included making sure it was perceived as rigorous. Finally, students in Year 2 had seen what students in Year 1 had accomplished in their projects and could use their work as an example to build from. Overall, the projects in both years were thoughtful and addressed important topics, but the topics addressed were variable.

## 4 Conclusions

*Reimagining Chemistry* successfully contextualized chemistry and empowered students to make meaningful contributions to reimagining chemistry in their communities. The pedagogical choices were designed to achieve Rightful Presence by making visible the political struggles inherent in chemistry, allowing students to make choices about their learning, prioritizing student–student interactions, and engaging students as changemakers.[30] Reflecting on the first iteration of this course provided the teaching team with valuable lessons about how to help students in this course achieve the learning goals and achieve Rightful Presence.

In only two years, student work produced as part of the projects in this course has had a meaningful impact on the Chemistry Department. For example, as part of a student project in Year 1, students established a Peer Mentoring program that is in its second year and pairs junior and senior Chemistry and Biochemistry students with first- and second-year students. This program has doubled in size between the first and second year it was offered. As another example, there have been long term changes made to the university peer tutoring program based on meetings and recommendations from a student project in this class.

While meaningful changes were made from Year 1 to 2, there are still areas for improvement in terms of encouraging student engagement, fostering classroom discussion, and supporting student projects. In future iterations, we will include exit assignments at the end of each major topic that require students to think critically about how their experiences inform how they engage with course topics. For example, an exit assignment on decolonization in chemistry might ask students what Brown and their high school have done to acknowledge and sustain Indigenous lifeways and critically reflect on what those institutions should continue or do differently. This assignment would also ask students to consider what decolonization might look like in their personal lives, allowing them both to assess their previous biases and imagine anti-imperialist futures. We hope that these assignments will help students identify how their experiences affect their engagement with the course topics and inspire more thoughtful discussions.

We also plan to incorporate more community-building activities at the beginning of the course. This would entail purposefully and repeatedly mixing up discussion groups, providing students time to introduce themselves to new groups, and thus adding opportunities for students to connect over shared interests. We hope that by doing this, we can foster a classroom community built on trust and respect, and make students feel more comfortable engaging in difficult conversations. We also plan to reframe office hours as a space for more student–student interactions by holding themed office hours on specific topics throughout the semester. Finally, the teaching staff plans to more explicitly model inclusive language and name over-generalizations and misrepresentations of marginalized groups when they occur. We aim to shift the burden of educating non-marginalized students away from their marginalized peers, creating a more equitable classroom environment.

*Reimagining Chemistry* is an example of a course that engages students in thinking critically about all of the complex relationships between science and society. Such courses not only directly address issues related to inclusion and belonging in STEM, but also provide valuable learning experiences where students can explore their interests and see examples of how chemistry can address pressing global sustainability challenges. A pedagogical approach that incorporates the tenets of Rightful Presence or related ideas in Culturally Sustaining Pedagogy is an essential component of valuing students' unique identities and empowering them as lifelong learners who will use their training in STEM to address the problems facing their communities. Developing courses that allow students to use their voices to reimagine areas of chemistry for sustainability and inclusion will be essential to achieving the UN Sustainable Development Goals, particularly Goals 4, 5, and 10.

## Author contributions

Conceptualization: J. Morin, R. Tobias, A. Nemerovski, M. Collins, A. Ryu, A. Sojka, E. Louthain; investigation/methodology: J. Morin, M. Collins, S. Bella, E. Louthain; visualization: J. Morin, R. Tobias; writing – original draft: J. Morin, R. Tobias, A. Nemerovski, S. Bella, M. Collins, A. Ryu, A. Sojka, E. Louthain; writing – review and editing – J. Morin, M. Collins, A. Nemerovski, S. Bella.

## Conflicts of interest

There are no conflicts to declare.

## Data availability

No software or code have been included. Survey data from students and individual reflections from students and instructional staff were collected. The relevant survey data is presented in Fig. 4 and in the article text. This data was added to the supplementary information (SI) in Tables S1 and S2. The reflection questions are shown in the SI on page 25, but individual reflections are only summarized in the article due to their personal nature. Supplementary information: a syllabus, detailed course schedule, assignment template and rubrics, summaries of student projects, and a template for the digital whiteboard tool used in class. See DOI: https://doi.org/10.1039/d5su00963d.

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