Curriculum

JMBE Journal of Microbiology & Biology Education

A Novel Undergraduate Seminar Course Celebrating Scientific Contributions by Scientists from Historically Marginalized Communities

Jesús A. Romo[a*] and Megan E. Rokop[b]
[a]*Department of Molecular Biology and Microbiology, Tufts University School of Medicine, Boston, Massachusetts, USA*
[b]*Honors College, University of Massachusetts Boston, Boston, Massachusetts, USA*

Scientific contributions by members from historically marginalized communities (HMCs) have been largely ignored, uncredited, and in some cases erased from history. This has contributed to science, technology, engineering, and math (STEM) curricula lacking diversity. In this study, we present an Honors seminar course aimed to highlight the discoveries of scientists from HMCs, centered around reading primary literature in a way that builds our students' research skills. The course provides students with opportunities for active learning, skill building, and mentorship that are key for persistence of students in the STEM "leaky pipeline." Students also read biographies of scientists from HMCs, interact with guest speakers, and choose scientists to highlight (in final papers and presentations) and publicize (through the creation of Wikipedia pages). Additionally, students use community-building methodologies to build a safe classroom and gain tools to have conversations about diversity, inequities, and intersectionality in STEM. In self-reporting surveys, 93.7% of students strongly agreed that their appreciation for marginalized scientists increased and 92.6% reported that the course met very well the goal of refining their research skills. These findings support the effectiveness of this novel course. We provide two lists (one of 137 scientists and one of 57 scientist biographies) that will allow faculty teaching a wide range of science classes to select examples of scientists and discoveries to highlight in their courses. This course represents a novel platform to diversify STEM curricula while engaging and empowering students from historically marginalized communities.

KEYWORDS diversifying STEM curricula, historically marginalized communities, reading primary literature, diversity in STEM, diverse scientists, diversity equity and inclusion (DEI)

INTRODUCTION

The contributions by historically marginalized scientists have largely been ignored, uncredited, or erased from history (1, 2). In addition, members from historically marginalized communities (HMCs) are vastly underrepresented in the scientific professions. This lack of recognition and lack of representation deeply impacts scientific research, science awards, scientific culture, and work environments in research and health care (2, 3). These issues also impact science education, leading to science that is taught from primarily Western and male-biased perspectives (4), resulting in a lack of representation in the science, technology, engineering, and math (STEM) curriculum.

This lack of representation has negatively impacted future career achievement gaps (3, 5–8) and retention (9) of students from marginalized communities in STEM. Issues with persistence in the "leaky STEM pipeline" disproportionately impact women and students from HMCs in STEM. Students from marginalized communities have reported an increase in their sense of belonging and persistence in STEM when they have mentors from diverse backgrounds and access to research opportunities (10–12). Students also persist in STEM when they engage in active learning, in classrooms that build research skills through hands-on activities and peer group discussions (13, 14).

In this study, we report the design and implementation of a seminar course entitled "Science in all Colors," taught during the Fall 2020 and Spring 2022 semesters at a highly diverse public university. We created an active learning-based class that builds research skills and introduces students to scientists from HMCs who have made key discoveries in a wide

Editor Betsy M. Martinez-Vaz, Hamline University
*Present address: Jesús A. Romo, Department of Molecular Microbiology and Immunology, The University of Texas at San Antonio, San Antonio, Texas, USA.
Address correspondence to Jesús A. Romo, Jesus.Romo@utsa.edu.
The authors declare no conflict of interest.
Received: 29 July 2022, Accepted: 3 October 2022,
Published: 31 October 2022

range of scientific disciplines. The course uses research paper discussions, guest speakers, and scientist biographies to bring attention to the research contributions of historically marginalized scientists. We discuss the implications of this work for all science courses. While not all science faculty have the flexibility to design an entire course about "science in all colors," all science faculty can think carefully about the cadre of scientists whose discoveries they highlight in their own courses and whether those scientists are representative of our students and our society.

Intended audience

The course, "Diversity in the Scientific Fields: Science in All Colors," was designed and taught as an Honors seminar course in the Fall of 2020 and Spring of 2022. Our public university is the third most diverse 4-year college in the United States (15) and is classified as an R2 research institution by the Carnegie Classification of Institutions of Higher Education. Additionally, at the university, 66% are first-generation college students, 48% are Pell grant recipients, and 58% speak a language other than English at home (16). Therefore, this type of course serves a student population that would be significantly impacted both in and out of the classroom by the topics presented. The course enrollment consisted of a student population primarily composed of juniors and seniors (see Table S1 in the supplemental material). While the course focused on diversity in STEM, it was open to students from all majors. During the Fall 2020 and Spring 2022 semesters, 59.4% of students were pursuing a STEM-related degree (Table S1). A full list of student majors can be found in Table S2. While the course was designed for a virtual Honors seminar course environment and targeted at juniors and seniors, it can be easily adapted for in-person settings and for general courses of all sizes (see "Possible modifications," below).

Learning time

The course met twice a week for 1 hour 15 min synchronously for a total of 29 sessions. In total, of the 29 sessions, 4 were dedicated to gaining the required skills to read scientific papers, 8 to research paper discussions, 8 to discussing the scientist biographies, 5 to guest speakers, 3 to final presentations, and 1 to making Wikipedia pages.

Prerequisite student knowledge

While the course focused specifically on representation in STEM disciplines, accessibility of the material by students from a wide range of majors was at the core of the course design, and therefore no prerequisite knowledge was expected. The course was developed as an upper-level Honors seminar course. Students were required to have sophomore standing (as the course requires prior completion of two Honors courses), so that students had a certain level of experience with college-level critical thinking, critical reading, and critical writing.

Learning goals

The course had five main learning goals (LGs):

1. Analyze and discuss the work of historically marginalized members of the STEM community, their contributions, and challenges.
2. Meet with currently active scientists and see themselves represented in STEM.
3. Build key research skills by analyzing and discussing scientific manuscripts.
4. Utilize community-building methodologies to build a safe and welcoming class environment where all opinions and voices are welcomed.
5. Implement tools to have conversations about diversity, inequities, and intersectionality in STEM.

In Table 1, we describe how each learning goal was addressed by the activities in the course and the methodologies and tools used to achieve these learning goals.

PROCEDURE

Materials

The instructor must ensure the students have access to a computer, which will be used for a variety of activities throughout the course. Additionally, the students will need a free account with Perusall (www.Perusall.com) and access to the scientist biographies chosen for the semester. Alternatively, Perusall could be replaced with a different electronic discussion platform, such as Blackboard. If the instructor prefers Blackboard, they could have students annotate a manuscript or the instructor could leave questions throughout the manuscript so students can respond to them in a Blackboard discussion. Additionally, this could be done completely without technology by using small group activities discussing questions assigned before or during class which ask about the different components of the research paper to help guide and familiarize students with the structure of a research paper.

Student instructions

The course was divided into five activity units. These units, and the student assessments used within them, are briefly described below.

Research paper discussions. Students conducted four activities designed to help them develop the skill set to dissect scientific literature. Throughout the course, the students read a total of eight scientific papers and worked in teams to complete activities related to each during class. Additionally, students used the Perusall platform to read and answer questions about the paper before attending

TABLE 1
Learning goals addressed by each activity unit

Activity unit	Learning goals addressed
Research paper discussions	LG 1: All papers chosen were authored by members of HMCs. LG 3: Students utilized a combination of Perusall, group discussions, and analysis of figures to learn how to dissect scientific papers. LG 4: Students worked in small groups, using guidelines for discussion and expectations of each other that they codeveloped, using POLS[a] after difficult conversations and using strategies like "step up step back." LG 5: Roughly half of the discussion of each paper was about the research studies and results, and half were about the life, career path, and challenges of the scientists.
Guest speakers	LG 1: Five scientists from diverse backgrounds each spent one full class period speaking with the students about their research and career paths. LG 2: Students interacted with five scientist presenters by introducing them, moderating the Q&A sessions, and networking with them after the class visits. LG 4: During Q&A sessions with the speakers, students used their discussion guidelines, POLS, and "step up step back" strategy. LG 5: Guest speakers' presentations were half about their research and half about their lives, career paths, and challenges.
Scientist biographies	LG 1: Biographies read covered the life story and work of two distinct scientists from HMCs. LG 4: During class discussions of the books, students used their discussion guidelines, POLS, and "step up step back" strategy. LG 5: Prompts for class discussions and written papers focused on the lives, career paths, and challenges of the scientists.
Final paper and presentation	LG 1: Students wrote a manuscript on the life of the scientist (half) and a minireview of their research (half). LG 3: Students wrote a detailed minireview with figures about the work of the scientist of their choice. LG 4: During Q&A sessions after each presentation, students used their discussion guidelines, POLS, and "step up step back" strategy. LG 5: Half of each final paper and presentation focused on the life, career path, and challenges of the scientist.
Wikipedia pages	LG 1: Students gathered information about the life and work of a scientist of their choice. LG 4: In small groups in which they designed the Wikipedia pages, students used their discussion guidelines, POLS, and "step up step back" strategy.

[a]POLS, places of love and support.

class. Students were assessed in this unit based on their participation in Perusall and on the reflections they wrote in one minute papers at the end of each class session.

Guest speakers. The students met with five guest speakers throughout the course. A group of four students was assigned to each scientist. The students researched the scientist, prepared an introduction, and crafted a set of 10 questions related to their trajectory, challenges, research, and tips for students. During the speaker session, the assigned student group introduced the speaker and moderated the question and answer (Q&A) session after the speaker presentation. Students wrote reflections on each guest speaker through the one minute paper assessment at the end of each class.

Scientist biographies. Throughout the course, the students read two scientist biographies. In small groups, the students discussed prompts designed by the instructor. After each biography, the students completed a two-page paper following prompts created by the instructor related to the life of the scientist and their work.

Final paper and presentation. At the end of the semester, each student gave a 10-min presentation about the life and research of a scientist of their choice. The students then wrote a 15-page final paper about the life of the scientist and a minireview of the scientist's research and contributions.

Wikipedia pages. At the beginning of the semester, students were assigned small groups and asked to choose a scientist to create a Wikipedia page on the final day of class. Throughout the term, students gathered information about the scientist and watched Wikipedia tutorial videos. In the last class period, they worked as a team to create and submit a Wikipedia page.

Faculty instructions

On the first day of class, students were provided an overview of the course goals, five activity units, tools used throughout, and expectations. An outline of the course and all assignments and activities are provided in Appendix S2 in

TABLE 2
Examples of activities conducted to teach students how to read scientific literature

Activity	Reference
Asking scientific questions	HHMI Biointeractive (http://www.biointeractive.org)
Winging it: analyzing a scientific paper	HHMI Biointeractive (http://www.biointeractive.org)
Research paper discussion: Helen Rodriguez-Trías	38
Research paper discussion: Vivien Thomas	39
Research paper discussion: Carlos Juan Finlay	40
Research paper discussion: Ben Barres	41

the supplemental material. All five activity units were aligned to the main LGs for the course; a list of specific activities within each unit and how they addressed each learning goal are presented in Table 1. The five activity units are described in detail below.

Throughout all five of these units, students used community-building methodologies to build a safe and welcoming class environment where all opinions and voices were welcomed, and they implemented tools to have conversations about diversity, inequities, and intersectionality in STEM. We understand that not all faculty are trained to lead discussions around diversity, equity, and inclusion (DEI) in the classroom. We encourage all faculty interested in teaching a similar course or a course containing similar topics to seek training, guidance, and useful resources through the DEI office at their institution.

Research paper discussions. Eight sessions in the course were run like journal club discussions. Examples of papers covered are listed in Table 2, and full lesson plans for two example discussions are included in Appendix S3. While experience reading scientific literature is helpful, it is not necessary, as students work through a variety of activities at the beginning of the semester to learn how to properly identify the different sections of a paper and extract the most important information (Table 2). The papers selected for the course increase in difficulty as the semester progresses to continue to challenge the students. Therefore, it is important to select papers that appeal to a wide range of majors and contain minimal jargon (see Appendix S4 for additional papers used in the course). Indeed, previous studies have reported more successful journal club sessions and an increase in student motivation when papers are selected thoughtfully (17).

The first four class sessions of the semester were devoted to building the skills needed in advance of the research paper discussions. During the first session, students played a role in setting course, instructor, and classmate expectations, setting individual goals for the class, and discussing how to create welcoming environments to have discussions about intersectionality. The next three sessions included an introduction to reading scientific papers, process-oriented guided inquiry learning (POGIL) (18), and two activities from the Howard Hughes Medical Institute (HHMI) Biointeractive, "Asking Scientific Questions and Winging It: Analyzing a Scientific Paper," (http://www.biointeractive.org). Concepts and tools from these four sessions were utilized throughout the rest of the course. A step-by-step description of these introductory sessions can be found in Appendix S4.

Guest speakers. To give students the opportunity to see themselves represented in the sciences and expand their mentoring and professional network, they met with five guest speakers throughout the course. All the scientists were from diverse backgrounds and active leaders in STEM. Speakers gave talks divided into two sections: (i) a general overview of their research and (ii) their career trajectory, challenges, and successes in STEM. Their talks were followed by a Q&A session moderated solely by students, and afterward students were responsible for sending an email to the speaker to reflect what they learned and to grow their network. Students were assessed on their moderation of the talk and the reflections they provided in their email to the speaker and daily one minute paper reflections.

Scientist biographies. To take a deeper look into the experience of scientists from marginalized communities, the course incorporated two scientist biographies (Table S3). A list of 57 options (books, plays, and films) are available in Appendix S5. Assignment prompts and grading rubrics are included in Appendix S6. An example of one of the two guided book discussions is provided in Appendix S7.

Final paper and presentation. For their final paper and presentation, students were instructed to choose a scientist, either from the list provided by the instructor (see the list of scientists in the supplemental material) or one of their choosing. The students then were given guidelines to create a 10-min presentation and a 15-page final paper that covered the scientist's life and research. Assignment prompts and rubrics are included in Appendix S8 in the supplemental material.

Wikipedia pages. In the context of our course, this portion was intended to help students appreciate the impact of giving back to the community and increase the visibility of marginalized scientists. Students were instructed to gather as much information as possible about the scientist and bring it to class on the day of the final session. Additionally, students were provided tutorial materials on

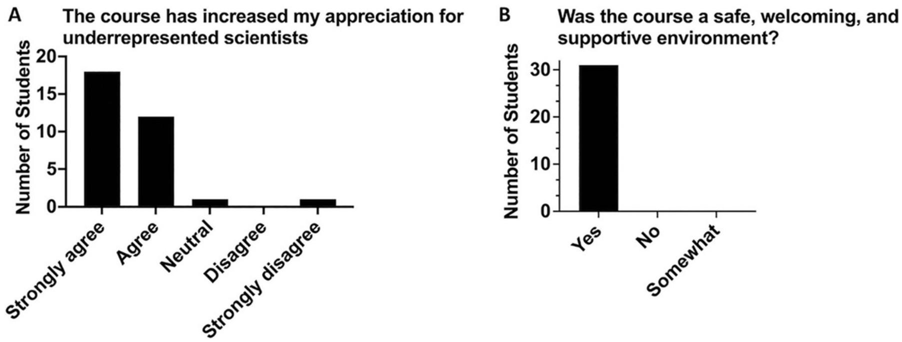

FIG 1. Student self-reporting on diversity, equity, and inclusion in the classroom. Students were administered a postcourse survey. (A) Most students (93.7%) strongly agreed or agreed that the course increased their appreciation for underrepresented scientists. (B) All students (100%) felt the course and virtual classroom environment was safe, welcoming, and supportive.

how to create a Wikipedia page. During the final 3 hour session, students worked with their groups to create and submit Wikipedia pages. Examples of Wikipedia pages created by students are presented in Table S4.

Suggestions for determining student learning

Assessments of student learning were completed using postcourse surveys (Fig. 1 and 2), and also with all assignments presented here. In the research paper discussion unit, students completed two HHMI activities related to reading scientific papers and asking scientific questions (Table 2), a Perusall activity answering questions about each of the eight assigned research papers, and eight small group discussions about the papers. In the guest speaker unit, students were assigned to moderate a discussion with a guest speaker. In the scientist biographies unit, students wrote 2-page papers for each book about challenges encountered by scientists living in different periods and from different cultures. In the final paper and presentation unit, students wrote and presented about a scientist of their choosing. And in the Wikipedia pages unit, students created a Wikipedia page for a marginalized scientist. Together, the five activity units accomplished the learning goals of the course (Table 1). Importantly, students were encouraged to reflect throughout each activity unit by writing one minute papers at the end of each class session. A list of sample prompts for these one minute papers can be found in Appendix S9.

Sample data

This report describes the course during the Fall 2020 and Spring 2022 semesters. The material was consistent during both semesters, but changes included the scientists highlighted during the course and the scientists selected by students for their oral presentations and their Wikipedia pages. For the research paper discussion unit, the students completed two HHMI Biointeractive activities and read a total of eight research papers. A small sample of some of the papers can be found in Table 2. For the scientist biographies unit, the students read the two books in Table S3. For additional suggestions on scientist biographies (books, films, and plays), see Appendix S5 for a list of 57 options. For the final paper and presentation unit, students selected a scientist from the list given by the instructor (see the list of scientists in the supplemental material) or from elsewhere. A sample subset of scientists discussed in the course can be found in Table 3. For the Wikipedia pages unit, students worked in teams to gather information

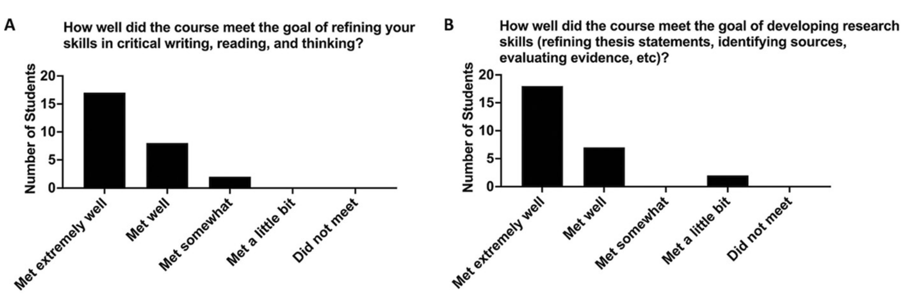

FIG 2. Student self-reporting on research skills acquired. Students were administered a postcourse survey. (A) Most students (92.6%) stated that the course met extremely well or well the goal of refining their skills in critical writing, reading, and thinking. (B) Similarly, 92.6% stated that the course met extremely well or well the goal of refining their research skills.

TABLE 3
Sample of the scientist database created for the course

Scientist	Field	Discovery
Dorothy Crowfoot Hodgkin	Chemistry/Biochemistry	A chemist who won the Nobel Prize for using X-rays to solve the first protein structure (pepsin)
Ellen Ochoa	Physics/Engineering	An engineer who was the director of the Johnson Space Center and the first Hispanic woman to go to space
Gladys West	Math/Computer Science	A mathematician who played a key role in developing GPS
James Miranda Steuart Barry	Biology/Medicine	A military surgeon who assumed a male identity to become the first female doctor in the United Kingdom
Luis Walter Alvarez	Physics/Engineering	A particle physicist who discovered a large number of resonance states
Marie Maynard Daly	Chemistry/Biochemistry	A chemist who first discovered the link between cholesterol, hypertension, and atherosclerosis and the first African American woman to earn a PhD in chemistry in the United States
Mario J. Molina	Environment/Ecology	A chemist who won the Nobel Prize for discovering that chlorofluorocarbon compounds damage the ozone layer
Sister Mary Kenneth Keller	Math/Computer Science	A computer scientist (and nun) who helped developed the language BASIC and was the first person to earn a PhD in computer science in the United States
Tu Youyou	Chemistry/Biochemistry	A chemist who won the Nobel Prize for discovering artemisinin as a treatment for malaria
Vivien Thomas	Biology/Medicine	A medical school faculty member who pioneered the main techniques for modern heart surgery

about a scientist of their choice and created a Wikipedia page during the last class session. Examples of Wikipedia pages created by the students in the course can be found in Table S4.

Safety issues

There are no safety issues associated with the course or any of the individual activities.

DISCUSSION

Field testing

Field testing was conducted by teaching the course to students in two different semesters (Fall 2020 and Spring 2022) and administering the standard postcourse evaluation survey used by the Honors College at our university. This study was deemed to have "exempt" status (protocol 3303) by the University of Massachusetts Boston IRB Committee. Our course evaluation surveys included several quantitative questions (see Fig. 1 and 2 for the wording of the questions analyzed in this study) and four open-ended response questions about what the students liked about the course and felt they gained from it (see Table S5 in the supplemental material for question wording). Of the 32 students who took the class, between 26 and 28 students answered each of these four open-response questions, providing a total of 109 short answers. The response rate was high (87.5%) because, while the final course evaluation survey was optional, we provided dedicated time in the final class session to complete the survey. We categorized 100 of the 109 students' short answers into themes; the other 9 short answers were too general to categorize (e.g., "Everything was amazing"). We assigned one theme to each of the five main learning goals of the course (LG 1 through LG 5), and we added two other additional themes that we found were represented multiple times: impacting interest in science careers and appreciating the active learning focus of the course (i.e., that it emphasized discussion and writing, rather than lectures and exams). From the 100 short answers, we identified 125 themed passages (as some short answers combined multiple themes). Table S5 shows the distribution in frequencies of the themes we identified in the student quotes. Table 4 contains a list of nine

TABLE 4
Student quotes from answers to open-ended course evaluation survey questions

Learning goal(s) addressed	Representative student quote
LG 1, LG 5	"This course has most definitely contributed in my growth as I learned so much about scientists from diverse backgrounds. I learned both about these specific scientists' very important discoveries, as well as more broadly how history and academia in America is undeniably overlooks minority individuals' and groups' contributions to their fields."
LG 1	"Professor Romo took an immense amount of time crafting this course around many different fields of study and subjects to give us a wider view of the history of minority and marginalized scientists. He pulled from many different resources. From published academic papers to popular news video clips, we were able to discuss with one another with different tools."
LG 3, LG 5	"This course has added to my experience with research papers and my understanding of how to read them best. Also working with others and having important discussions about diversity in science."
LG 1, LG 4	"The course is very eye-opening and allowed me to learn about many inspiring underrepresented scientists. What I like the best about Dr. Romo is that he has done a great job in creating a safe space for students to engage. He encourages everyone to participate."
LG 2, LG 3	"This course has played a huge role in my searching for underrepresented scientist stories to learn and gain inspiration from them. It has also taught me the importance of representation as well. The last most impactful thing was learning to read scientific articles."
LG 3, LG 5	"I have grown so much in terms of being a scientist. I have also appreciated more sciences and diversity in STEM."
LG 5	"It has made me realize about underrepresented scientists in the field of science. It has shed light on the discrimination and biases that are in our community. It has definitely changed my view towards many things, education, medical career, science, college and even personal life choices."
LG 4	"It inspired me to think differently and think about topics I had not before, especially talking to my peers about topics I do not discuss in other classes."
LG 2	"My favorite part of the course are the guest speakers and learning about these real scientists who love their job and career. It is really motivating and inspiring to see that people can love their job and pursue happiness at the same time."

representative student quotes that we chose to highlight; we chose these particular quotes so that each LG theme was represented in Table 4 at least twice.

Evidence of student learning

Data were collected using postcourse evaluation surveys to determine if the course met its five main learning goals. Student comments were categorized into three distinct categories: diversity, equity, and inclusion (LGs 1, 2, 4, and 5), research skills (LG 3), and other additional themes identified as occurring frequently in the student quotes (appreciation for active learning and impacting career interests).

Diversity, equity, and inclusion. To assess whether the course met its learning goals relating to diversity, equity, and inclusion (LG 1, 2, 4, and 5), we analyzed student responses to two quantitative survey questions (Fig. 1) and four open-response questions (Table S5). When asked if their appreciation for scientists from HMCs increased after taking the course, 93.7% of students strongly agreed or agreed (Fig. 1A). Moreover, when asked if the course was a safe, welcoming, and supportive environment for discussion, 100% of students answered "Yes" (Fig. 1B). These data significantly support the impact of the course goals related to DEI. To accomplish this classroom environment, a variety of tools were implemented throughout the course (Table 5). Briefly, the most valuable tools that contributed to the classroom environment included the concept of "step up step back," which was used throughout the course to remind students to allow all voices to be heard and not dominate discussions. The concept of "Places of Love and Support" (POLS) was utilized weekly (using stickies via Google Slides) to give students a space to show support and appreciation for the rest of their classmates after difficult conversations in the classroom. Moreover, the use of

TABLE 5
Tools utilized throughout the course

Strategy	Purpose	Frequency
Breakout rooms	Increase participation and small group discussions	Every session
POGIL-like structure	Maintain pace and organization	Every session
Perusall	Guide students through scientific literature	Before discussing a paper (10 times total)
Google Docs	Organization and guidance for activities	Every session
Places of love and support	Allow students to support each other with anonymous comments	Weekly
One-minute papers	Allow students to provide anonymous feedback and identify gaps in knowledge	Every session
Step up step back	Allow students to share the spotlight	Every session
Guest speakers	Allow students to hear the perspectives and research of current scientists from marginalized communities	Monthly
Student presentations	Give each student a choice of one scientist for which they will analyze their work and career	End of semester
Wikipedia pages	To create a tangible student-generated product that brings attention to discoveries by scientists from HMCs	End of semester

breakout rooms allowed for students who usually do not participate to have a smaller space for discussion, which significantly increased participation and comfort in sharing personal anecdotes. Finally, all small group work utilized a simplified version of process-oriented guided inquiry learning to maintain structure and give each student a distinct responsibility during the discussions. A large number of students commented in the open-ended survey questions about how much they learned related to DEI themes (Table S5). A list of student quotes from the postcourse surveys can be found in Table 4, including two representative quotes relating to DEI: "The course is very eye-opening and allowed me to learn about many inspiring underrepresented scientists. What I like the best about Dr. Romo is that he has done a great job in creating a safe space for students to engage. He encourages everyone to participate." and "This course has played a huge role in my searching for underrepresented scientist stories to learn and gain inspiration from them. It has also taught me the importance of representation as well."

Research skills. To assess whether the course met its learning goal relating to building research skills (LG 3), we analyzed student responses to two quantitative survey questions (Fig. 2) and four open-response questions (Table S5). When asked how well the course refined their skills in critical writing, reading, and thinking, 92.6% of students responded that the course met this goal extremely well or well (Fig. 2A). Similarly, when asked how well the course met the goal of developing research skills (such as refining thesis statements, identifying sources, and evaluating evidence), 92.6% students responded that the course met their goal very well or well (Fig. 2B). Taken together, these data suggest that the course significantly contributed to building research skills. A tool that significantly contributed to this was the social reading platform Perusall, which allowed students to digitally annotate a research paper posted by the instructor that contained directed questions about different sections of the papers (Table 5). A large number of students commented in the open-ended survey questions about how the course built their research skills (Table S5). Two representative student quotes were the following: "This course has added to my experience with research papers and my understanding of how to read them best," and "I have grown so much in terms of being a scientist" (Table 4).

Other additional themes. Two additional themes were identified frequently in the student quotes from the open-response survey questions: appreciating the active learning focus of the course and impacting interest in science careers. A substantial number of students mentioned their appreciation for the fact that the course emphasized group discussions and writing assignments, rather than lectures and exams (Table S5). In addition, while impacting interest in science careers was not a main course goal (as the course was designed for both STEM majors and nonmajors), a handful of students commented on impacts on their career goals in the postcourse survey responses (Table S5). For example, one student commented that the course "has amplified my interest in pursuing academic science and academic mentoring. I have wanted to pursue a PhD however I now have a greater appreciation for the process and the contributions that scientists can make." A tool that contributed to career development was the guest speaker presentations (Table 5), which allowed students to meet potential mentors and expand their network in ways that have been shown to impact retention in STEM, especially among students from HMCs (19, 20).

Taken together, these data strongly support that this novel course met its five main learning goals, including celebrating the contributions of marginalized scientists, learning how to have difficult conversations about diversity, equity, and intersectionality in STEM, and building students' research skills.

Possible modifications

The course was designed to be highly flexible and can be modified in a variety of ways. First, the course was taught virtually due to the COVID-19 pandemic, but all the activities can be easily modified for in-person instruction. Second, different scientists can be chosen for each of the course activities. For the research paper discussions, guest speakers, and scientist biographies, each faculty member can choose any papers, speakers, or biographies that align with their course goals and topics. For the final papers and presentations and the Wikipedia pages, students can choose any scientist whose discoveries, life, and career paths interest them most (see the list of scientists in Appendix S5).

Another possible modification could be to create a class with the same central theme of this course but with a somewhat different structure or focus. For example, while we did not encounter in the literature any other examples of full 3-credit courses with our main theme, we did find syllabi for two different 1-unit freshman seminar courses that highlighted scientific discoveries made by scientists from historically marginalized groups (21, 22). Full 3-credit courses do exist that are focused on women in science (23, 24), and full 3-credit courses also exist that are focused on highlighting scientific discoveries, although not with the focus on scientists from HMCs (25, 26).

We recognize that not all faculty or departments have the curricular flexibility to design a full course entirely on the topic of this course. Therefore, another possible modification is to embed a unit about diverse scientists within a larger class. This model has been used successfully in a Science, Ethics, and Society course (27) and in a large introductory biology course (28).

Even when it is not logistically feasible to incorporate a unit on "Science in all Colors" into a science course, it is still possible to incorporate one assignment or activity that promotes student discussion of diverse scientists and their key discoveries. For example, courses that focus on analysis of primary literature can use the process of paper selection to ensure that the authors represented in the course reflect the diversity of students and trainees (17, 29, 30). The same goal can be accomplished for courses that incorporate inviting guest speakers (19, 20). Any course can incorporate an individual assignment that focuses on diverse scientists, such as a writing assignment in which students craft Wikipedia pages or other similar short-format biographies (31, 32). Any course can incorporate an individual reading assignment that is a biography of a scientist from an HMC, either incorporating a full-length book (33, 34) or even short biographies (35, 36). As a resource for faculty who want to incorporate a biography (a book, film, or play) into their course, see the list of 57 possible options in Appendix S5.

Some science faculty may feel that it is challenging to incorporate a new reading or writing assignment into an already-packed course syllabus, and yet fortunately there is a straightforward way to ensure that diverse scientists are represented, recognized, and highlighted in every science course. Every science course involves some mention of scientists and key discoveries, among the collection of lessons, activities, or lectures created for the course. Each of us can do our part to ensure that we are recognizing the contributions of scientists from historically marginalized groups, by looking at the cadre of scientists and discoveries we choose to mention in each of our classes and asking ourselves if these scientists are representative of our students and our society. Resources exist to aid science faculty in identifying scientists from a wide range of backgrounds who have made key discoveries in their respective scientific fields (21, 37). In this study, we have provided a list of 137 scientists, binned into 5 general categories: biology/medicine, chemistry/biochemistry, environment/ecology, math/computer science, and physics/engineering (see Appendix S5). We encourage science faculty from all disciplines to utilize these available resources when selecting scientists and discoveries to highlight in their courses, and we welcome suggestions for expanding this list of inspiring trailblazers across scientific fields.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.4 MB.
SUPPLEMENTAL FILE 2, XLSX file, 0.02 MB.

ACKNOWLEDGMENTS

We thank Claire Moore, Mitch McVey, and Jordan Wilkinson at Tufts University for support and training for J.A.R. through the IRACDA program. We also thank the Honors College at the University of Massachusetts Boston for financial support for J.A.R. during the Spring 2022 semester. J.A.R. was supported as a postdoctoral scholar and M.E.R. as a faculty member by the Tufts IRACDA program at Tufts University School of Medicine (grant K12GM133314).

We have no conflicts of interest to declare.

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