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A framework for educating and empowering students by teaching about history and consequences of bias in STEM

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One sentence summary: The authors present one model for teaching a universal course for participants of all professional stages to address racism, bias, and exclusion in STEM, and discuss the literature around these issues and why it is important to teach courses like these.
Editor: Antentor Hinton

Abstract

Racism and bias are pervasive in society—and science, technology, engineering, and mathematics (STEM) fields are not immune to these issues. It is imperative that we educate ourselves and our students about the history and consequences of this bias in STEM, investigate the research showing bias toward marginalized groups, understand how to interpret misuses of science in perpetuating bias, and identify advances and solutions to overcome racism and bias throughout our professional and personal lives. Here, we present one model for teaching a universal course for participants of all professional stages to address these issues and initiate solutions. As very few institutions require students to enroll in courses on racism and bias in STEM or even offer such courses, our curriculum could be used as a blueprint for implementation across institutions. Ultimately, institutions and academic disciplines can incorporate this important material with more region and/or discipline specific studies of bias.

Keywords: racism, bias, STEM, solutions, dialogue, inclusive pedagogy, diversity, equity, inclusion

Introduction

Science has a legacy of racism and white supremacy that continues to impact participation of underrepresented and marginalized groups today, including underrepresented identities in gender, sexual orientation, disabilities, socioeconomic status, race, and ethnicities, both as scientists and as subjects of research studies (e.g. Graves 2019, O'Brien et al. 2020). The resulting lack of diversity in STEM represents a loss of talent and novel contributions to scientific fields (Campbell et al. 2013, AlShebli et al. 2018). Furthermore, science is conducted by scientists who view each aspect of the scientific process through the lens of their social and political values. A lack of diversity among scientists may perpetuate discriminatory funding practices that exclude, or favor, disproportionately represented groups (Hoppe et al. 2019). Additionally, it leads to negative long-term impacts on the recruitment and retention of people from marginalized backgrounds across all career stages (Elliott et al. 1996, Whittaker and Montgomery 2012, Whittaker et al. 2015).

Furthermore, we know that an individual's intersectionality—how any and all of one's identities and their interactions—can lead to multiple factors of advantage and disadvantage, and for many minoritized identities this can lead to compounding effects of oppression and discrimination (Crenshaw 1989). For these reasons, it is imperative for educators and stakeholders to take steps to create communities that support diversity (representation of all identities and differences), equity (fairness in access to opportunity, information, and resources), and inclusion (promotion of a culture of belonging), collectively known as DEI, within STEM spaces (Ford Foundation 2021).

Educating the next generation of scientists about the role science has played in, first, perpetuating racism and biases toward marginalized groups; and second, about how to recognize the impacts of biases on scientific research is a critical step toward cultivating and empowering communities to reduce, limit, and ultimately eliminate bias, racism, and exclusion. Combined, these efforts will ensure that we have the highest scientific impact and most robust and creative STEM teams across multiple disciplines.

The American Association for the Advancement of Science's *Vision and Change* report (2011) calls for biology educators to emphasize the relationship between biology and society in the undergraduate classroom. Within discipline-specific curricula (e.g. biology, chemistry, engineering, physics, and so on), discussing the legacy and current ramifications of biases is relevant to students' identities and to issues that continue to affect their lives and communities. Courses that teach about intergroup biases could encourage responsible future collection, interpretation, and distribution of data by scientists and the public, strengthening the impact of foundational scientific research and its broader applications to our lives.

Within higher education, over the past few years curricular materials have begun to be developed that incorporate these topics into classroom content, lesson plans, or even whole curriculum devoted to exploring with students that race is not a biological but rather a socio-political construct, and that racism has real impacts for people (Hubbard 2017, Bhagia et al. 2020, Reese 2020, Fred Hutchinson Cancer Research Center Science Education Partnership 2021). For example, while higher education curricula teach about the history of explicit bias through racist acts and policies, implicit bias toward underrepresented identities is more common, with compounding effects on an individual, and it is rarely taught in curriculum. But what is implicit bias? The Perception Institute (Perception Institute 2021) defines implicit bias as an action/perception in which 'we have attitudes toward people or associate stereotypes with them without our conscious knowledge.' The subconscious association of certain identities with stereotypes comes from historical reinforcement of specific views, whether from the teachings of the household, broader community, or popular culture, and these views carry over into the academic sphere (Perception Institute 2021). Despite the data showing that bias occurs and persists broadly in STEM and within biology as a field, only 4% of biology majors are required to take courses that study the ethical, social, and legal issues that arise in STEM fields and research (Booth and Garrett 2004). This means that most biologists and students from related fields currently do not receive training about their own biases or widespread biases in STEM.

Furthermore, while the materials and recommendations from these courses are a critical first step in addressing curricular needs, they often focus only on reducing racial biases. Few courses have emerged to educate STEM professionals about the data on diversity in STEM, biases toward marginalized groups, or how to best support marginalized individuals in a way that respects intersectionality (e.g. intersection of race, class, gender, and so on). Additionally, past courses rarely address privilege of participant/instructor identities and how those biases affect course engagement for the participant and/or through interaction with other course participants. We developed the *Diversity, Equity, and Inclusion in STEM: The Science Behind Bias seminar* at Cornell University as a course to meet these needs (see Supplementary File 1 for a syllabus used in the teaching of the course). In this seminar, participants from multiple professional stages (undergraduate and graduate students, postdoctoral associates, and faculty) met weekly, with the overall goal of exploring and discussing the historical context of bias and exclusion in biology and more broadly in STEM, before applying that context toward proactive strategies to combat bias in and outside of educational environments. Throughout the course, we encouraged participants to engage in course curricula and discussions with a rigorous understanding of their own bias in order to facilitate safe and constructive class engagement.

Course structure

In this course our learning outcomes for participants included reviewing the history of racism, exclusion, and bias in Science, Technology, Engineering, and Mathematics (STEM) and how it continues to persist today. Participants discussed primary scientific literature and learned how to identify and critique work that has contributed to biases in STEM. As a group, we identified actions we could each implement as individuals, and steps institutions could take to decrease bias and promote equity and inclusion.

Learning about implicit bias in STEM requires historical context of the stereotypes, and continued reinforcement of these stereotypes, that have impacted STEM fields across identities and time. Our course structure is designed to facilitate a learning community and educate participants on how pervasive and constant implicit bias has and continues to be in STEM (Fig. 1). Therefore, it is important for participants to learn and digest the impact of implicit bias in STEM through space, time, and their own backgrounds by critically analyzing the intersection of STEM, as well as the foundational events that gave rise to multiple stereotypes toward marginalized identities. Then, we use this grounding knowledge to critically analyze how implicit bias underpins contemporary scientific literature and knowledge. Below we outline the primary sections of our course (refer to Table 1 and Supplementary File 1 for a more detailed example of how this outline translates into a timeline, instructional process, and course materials used).

We begin the course with a historical background of examples of bias in STEM. The background spans the timeline of STEM including, but not limited to, understanding the development and implementation of eugenics, cataloguing scientific societies' involvement in the Trans-Atlantic slave trade, the use of female slaves for the foundations of gynocology, scientific explorations to 'prove' nonheterosexual orientations, as well as why some people are rich and some are poor. Chronicling the prevalence and instances of bias in notable events in STEM sets the groundwork for understanding that bias in STEM is part of a watershed system of systemic and ingrained discrimination within professional and personal environments and cultures. We use historical context with the goal to train participants to view the rest of the course curricula through the lens of systemic discrimination, rather than through a lens that isolates instances of bias on a case-by-case basis. If we were to do the latter, then that would create an assumption that discriminatory behavior is isolated to one person's experiences, minimizing the underlying biases that provoke such discrimination in the first place. Furthermore, it creates an arbitrary judgment from the audience, instructor, and participant alike, on the magnitude of effect that this bias has had, or if it counts as bias in the first place, subsequently promoting destructive rather than constructive engagement.

We then transition to discipline-specific data on STEM bias, providing contemporary primary literature papers to discuss evidence of bias and its impact against particular identities and a broader audience outside of those identities. This section forms the major focus of the course, critically assessing the impact of studies that demonstrate implicit bias against under-represented identities in gender, sexual orientation, disabilities, socioeconomic status, race, and ethnicities. It is important to showcase multiple examples of different forms of bias to underpin the fact that bias has and continues to target identities that were excluded from STEM or are subject to cultural oppression from majority identities across the history of humanity. Furthermore, it illustrates the diversity of stereotypes and stigmas that primary literature enforces about minority identities that carry over across space and time.

The final weeks of the course involve progress and actionable items to decrease bias in STEM. This section concludes the course by utilizing the information gathered on the prevalence of bias and racism in STEM to empower practical applications toward mitigating said harm in participants' lives, roles, and institutions. The sheer diversity in which implicit bias can manifest in STEM also provides an equal breadth of opportunity to bring antidiscriminatory approaches to a variety of professional stages, roles, and situations. We wanted students to not only be aware of the
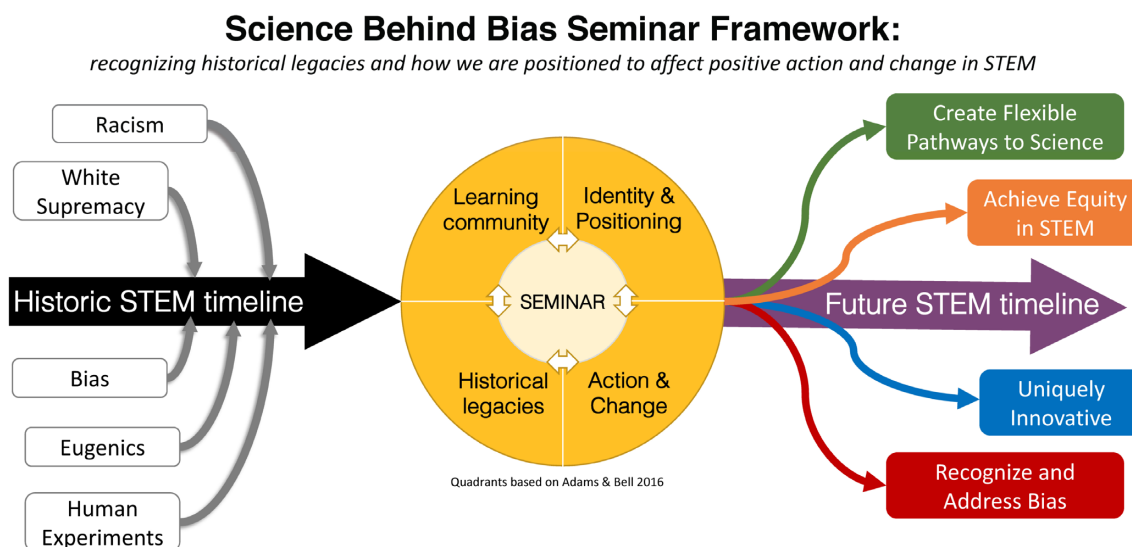
Science Behind Bias Seminar Framework:

recognizing historical legacies and how we are positioned to affect positive action and change in STEM

Figure 1. Through science history, white supremacy and other systems of privilege have played an important role in shaping and whitewashing what we now call STEM and academia. Contributions to science from individuals of marginalized identities were and are still overlooked, underappreciated, and in several cases unacknowledged or stolen. The Science Behind Bias seminar recognizes the impact of these historic legacies and our current barriers to achieving inclusion and equity in STEM. Positive actions and behavioral changes are necessary to achieve equity and inclusion in STEM. In the seminar, participants integrate these historic legacies with their identity and positioning in the community to inform what actions they can take to create a more diverse and inclusive STEM. Quadrants in figure follow Adams and Bell (2016).

various ways in which bias can manifest, but also envision avenues for designing policies and behaviors to limit, reduce, or remove bias and racism that they could implement in their own lives and that of their broader societies. We suggest using the last 2–3 weeks of the term to delve into the discussion and development of actionable items.

We approached this section of the course by first including readings that highlighted a need for intention and proactive measures taken with empathy and forethought across all career and administrative levels. Participants were then asked to brainstorm an action they could commit toward increasing diversity, equity, and inclusion, and decreasing bias in STEM. We used group sharing tools such as Google Jamboard (https://jamboard.google.com/) or Padlet (https://padlet.com/) to share individual actions. Anecdotally, we observed participants with shared identities (e.g. professional, such as career stage, or personal) apply takeaways from the course readings and discussions, and begin collaborations geared toward actions within their parts of academia. It is very important to finish the course curricula with a call to action for participants to identify where they can make change after studying the myriad of ways in which they encounter bias in their STEM worlds.

Building a safe community in the classroom

This course applies to multiple disciplines and career stages in STEM, reflecting the diversity of STEM and how implicit bias manifests in and between said diversity. However, bias can also manifest within the classroom, driving participants to follow a normative culture of pedagogy that risks alienating students of different cultures from the instructor or facilitator (Staats et al. 2017). Some pedagogical frameworks (e.g. a lecture-only format with rote memorization as assessment) can encourage a classroom culture that may not work for all students, dissuading open and engaging discussion of course material (Sidky 2017). As such, it is imperative to intentionally design the pedagogical framework with the diversity of those who participate in STEM in mind. Ad-

ditionally, we must address pre-existing perceptions of privilege and power dynamics that could deter or inhibit full engagement of the classroom when critically discussing sensitive course material (Reinsvold and Cochran 2011). Here, we discuss the strategies we used to develop a framework that encourages students from diverse backgrounds to engage with each other and the coursework.

Integration of intergroup dialogue training

For the first iteration of the course, we limited course enrollment to 50 participants. This size allowed us to ensure that we could hold small-group (∼10 participants per group) discussions throughout the course, with each group led by one course facilitator. The participants in our course came from different levels of education including, but not limited to, undergraduate and graduate students as well as faculty. Participants also came from varying levels of experiences around the topics discussed. Given that undergraduates and faculty were taking the course at the same time, we assigned the small discussion groups with those who were in similar career stages. This was to limit undergraduates being in a small discussion with a faculty member who at some point may have been or will be their instructor. Additionally, the discussion of sensitive topics and history of trauma is stressful and at times can make individuals feel uncomfortable or relive harmful episodes during the course. Thus, it was important for us to utilize techniques and methods commonly used in intergroup dialogue (IGD) training to manage these types of discussions. IGD is a process where people from diverse social identity groups work together to understand and relate with one another (Zúñiga 2003). We used practices from IGD to establish a precedent of mutual respect and interaction amongst participants and facilitators, so when situations arise, we have a known compact of how we treat each other.

One of the goals of IGD is consciousness raising, where all participants of both privileged and oppressed groups work to understand the history of oppression of marginalized groups and the

Table 1. Course themes, learning outcomes, and suggested readings.

Theme	Learning outcomes	Suggested readings
Historical racism in STEM—origins of the concept of race	To understand the origin of the term 'race', how the term manifested, and under what cultural contexts.	Hudson (1996)
Historical racism in STEM—experimentation on groups	To learn and synthesize the multiple ways in which human experimentation occurred through a lens of implicit bias.	Sartin (2004), Prather et al. (2018)
Historical racism in STEM—eugenics	To understand the history and origins of eugenics and its contemporary manifestations in primary literature.	Online video assignment (10 minute expert of 'The Gene—an intimate history' by Ken Burns on PBS). Friedmann (2019)
Historical racism in STEM—the transatlantic slave trade and naturalists	To understand the historical context of racism and colonialism in STEM, and how it still benefits some fields and scientific societies.	Govier (1999)
Data and bias against women in STEM	To understand the manifestation of bias against women in STEM using primary literature.	Holman et al. (2018)
Data and bias against LGBTQIA + in STEM	To understand the manifestation of bias against LGBTQIA + in STEM using primary literature.	Broockman and Kalla (2016)
Data and bias against people with disabilities in STEM	To understand the manifestation of bias against people with disabilities in STEM using primary literature.	Lee (2011)
Data and bias against people of colour in STEM	To understand the manifestation of bias against people of colour in STEM using primary literature.	Hofstra et al. (2020), Hoppe et al. (2019) Why Asian Americans are not the Model Minority—Alice Li—TEDx Talks (10:35 minutes).
Data and bias against first generation and low-income people in STEM	To understand the manifestation of bias against first generation and low-income people in STEM using primary literature.	Douglass and Thomson (2008)
Gender and racial bias in artificial intelligence	To understand how technology can be used to create and perpetuate bias.	Leavy (2018)
Myths born from bad, biased research	To understand how ongoing research continues to reinforce bias through the misuse of science.	Hill et al. (2019), Jabbour et al. (2020)
Systemic racism, bias, and exclusion in STEM: from the homework to the classroom, to the administration	To identify and design practices to promote diversity, equity, and inclusion in STEM.	Miller and Roksa (2020), Ma et al. (2019)
Progress on reducing racism, bias, and exclusion in STEM	To understand the progress in promoting diversity and inclusion in words vs. practice.	Bentley et al. (2017), Jimenez et al. (2019)
Identifying actionable steps to achieve equity and inclusion in STEM	To identify and design practices to promote diversity, equity, and inclusion in STEM.	Cooper et al. (2020), Schell et al. (2020), Smith et al. (2015), Chapman (2019)

lasting impacts of that oppression (Zúñiga et al. 2007). We define privilege as the advantages one has had in life that shape one's opinions and actions as well as the lack of awareness of disadvantages and struggles others face (Fig. 1; Adams and Bell 2016). In order to develop an understanding of current societal privileges, it is important to understand the history that has created the context for enduring privileges.

Setting the tone on day 1 of instruction is crucial to instill a sense of self-awareness within our students about their own intersectional identities, especially when those identities are tied to positions of privilege, so they recognize the lens through which they interpret course material and interact with each other. On the first day of class, we conducted an exercise for students to reflect individually on aspects of their identity that give them privilege in society; e.g. understanding how a cis-gendered White man holds more societal privilege than a transgendered Black woman.

Course participants were united under the foundational knowledge that bias has originated and continues to exist in society. By starting from a place of working to understand one's privilege and its impact on one's life and that of one's peers, the course design fostered more genuine and open conversation. Addition-

ally, following consciousness raising principles reduces any perceptions that one is an 'outsider' to bias, because everyone from the marginalized to the privileged is impacted by bias, and so everyone can and should play an active role in addressing bias and forming solutions to reduce bias in their society (Zúñiga et al. 2007). For example, White Americans, the majority identity within The United States and Canada, have experienced a myriad of privileged roles/amenities over non-White Americans for generations that span pedagogy, policy, and popular media, to the point that bias is deep-rooted and implicit in many peoples' psyches. Similar degrees of privilege—and subsequent implicit biases—exist within/between different identities from the same axes of our society, emphasizing the need to address it head-on in the classroom if one is to facilitate healthy discussion of bias in STEM and how to proactively mitigate it.

After building self-awareness of identities and their privileges, we move forward to use commonly used IGD training to facilitate open discussion with each other. One of the methods we used is the LARA method (Listen, Affirm, Respond, and Add), a method of communication developed by Bonnie Tinker (Tinker 2004) that allows dialogue across different social identities and lived experi-

ences. This tool aims to establish trust and community connection and establish mutual respect and understanding between those who come from diverse backgrounds. This method was extremely relevant for us to use due to participants coming from a range of career stages (undergrads, graduates, postdocs, and faculty), racial, and cultural backgrounds that have varying levels of privilege and disadvantages.

Another method we used to achieve this in the classroom was to develop and uphold community guidelines prior to engaging in course content. Community guidelines are a way for us to set expectations for engaging in group discussion (Supplementary Table 1). We adapted most of our class's community guidelines from Cornell's Intergroup Dialogue Project (Intergroup Dialogue Project 2021, Fig. 2). Participants in our course also contributed to our community guidelines in addition to those we adapted. It was important that participants in our course knew that their contributions to community guidelines were valued so that it really felt like something that everyone could agree on. We used our community guidelines as the foundation for creating and upholding a safe space for this specific community in which all participants could feel like they could express themselves freely and without judgment. Part of free expression is instilling participants with self-awareness about the ways in which privilege manifests in their lives, whether by virtue of their own identities or through interaction of others with different magnitudes and types of privilege.

Nonnegotiable community guidelines that any group can adopt include the use of 'I' statements when offering critical feedback in dialogue. In this way, participants speak on their own personal experience and actions, critiquing ideas/behaviors and not individuals. Another nonnegotiable community guideline is the practice of 'stories stay and lessons leave.' It is extremely vulnerable for an individual to share experiences with the group that are personal to the topic of discussion or to share one's ignorance on an issue. Thus, it is important to establish that whatever personal identifying story a student shares in class does not leave that group setting; in doing so we encourage people to share openly and freely when they come to the classroom. We acknowledge that lessons from specific stories can be crucial for us to share with our community outside of the classroom, which is why we encourage the 'lessons leave' point of the phrase.

Ultimately, our integration of IGD training was an important approach we established on day 1 of the class and throughout the entirety of the semester. In this way, we could facilitate a safe environment where students and facilitators can engage with difficult content addressed in class as well as reach mutual understanding and build connections amongst those who are coming from different backgrounds. It is crucial for scientists aspiring to facilitate a course of this nature to have prior training in IGD before facilitating. The University of Michigan's Intergroup Relations Program is the longest running IGD university program and has been a model for other university-run IGD programs (The Program on Intergroup Relations at the University Michigan 2008). We highly recommend people leverage IGD programs at their institution or utilize the University of Michigan's training if such programs are not offered. Additionally, see Table S1 (Supporting Information) for recommended and publicly available resources regarding IGD tools and methods.

Addressing power dynamics in the classroom

We recommend that course instructors consider potential power dynamics within the classroom and take proactive steps to mitigate chances for those dynamics to affect participation. For example, our classroom demographic included early- and late-stage professionals, presenting the possibility that younger participants would not speak as candidly in a space with someone in a position of much higher power. We observed that some participants were more likely to engage in deep discussion when they were in a group with other participants in their career stage (undergraduate, graduate, or faculty). For example, undergraduate students shared more often when in a group with only other undergraduates. If there is a subset of professionals who will exist in a power imbalance in the classroom (e.g. professors and undergraduate students), provide a space for them to engage in the material without discomfort. Furthermore, when in these subgroups, be aware of the power dynamics that can exist between seminar instructor and participants. For example, power dynamics between an early professional course instructor and others will vary if the participants are undergraduate students vs. faculty participants (Sidky 2017). In these diverse groups, instructors must ensure that the individual voices of participants can be heard, and i.e. accomplished by employing different strategies for engaging different demographics within the classroom. One way to do this is to remind participants that we need to make space for everyone to have the opportunity to share their thoughts or reactions to the materials. Instructors can also explicitly ask those that have engaged or participated more to make space for those that have participated less. Also leading discussions with open-ended, higher-level questions relevant to specific papers or themes discussed have proven effective in promoting exploration of STEM topics for younger audiences (Reinsvold and Cochran 2011). Through these practices, students can explore the concept of bias in STEM more easily, rather than focusing on rote memorization, a method of learning that relies on repetition until one recalls from memory. In regard to later-stage professionals like faculty participants, we found honing discussion questions to focus on the unique perspectives of their background has proven useful in stimulating discussion of the course material.

Course operations and recommendations
Teaching in-person or teaching online

The nature of this course requires that participants feel comfortable, and that they are in a safe space to share their thoughts and feelings on any particular topic. As instructors, it is necessary to promote engagement in a way that facilitates safe spaces, promotes dialogue, and does not bias the participation of one demographic over another (Adams and Bell 2016). There are different opportunities and challenges presented when trying to accomplish this in-person or in a virtual classroom.

Engaging in this material requires spaces where participants can speak openly and safely, as well as spaces in which the participants can also be exposed to differences of opinions and perspectives. In our experience, virtual formats can facilitate safe spaces through the physical separation of groups (i.e. breakout rooms). In Zoom, we provided multiple moderated breakout rooms to keep specific participants (e.g. undergraduates) in safe spaces to discuss the material and to limit power dynamics. We observed that breakout groups can facilitate safe spaces where groups cannot be overheard. However, it becomes challenging to create a familiar and comfortable space in the breakout groups when there are less opportunities to interact without verbal prompts from the course facilitators. Furthermore, in-person meetings make possible the use of nonverbal cues, which are critical for active participation and transparent communication (Puertas-Molero et al. 2018, Uzun

Community Guidelines

Know your privilege

Privilege is considering how the advantages you've had in life are contributing to your opinions and actions, and how the lack of disadvantages in certain areas are keeping you from fully understanding the struggles others are facing and how you may be contributing to those struggles.

Self-engagement

- Some of the topics covered may be triggering for you and others
- Embrace discomfort, but do not be afraid to take time/space for yourself if you need it
- Be proactive instead of reactive. Check in with yourself and ask "Why am I feeling this way in response to this conversation?"
- Impact over intention.
    - Take ownership of your words and actions
    - You will make mistakes. It is important to apologize if/when you do

Course-engagement

- All participants will be coming from different levels of understanding about the topics covered in this course
- Stories stay, but lessons leave
- Use "I" statements when discussing your thoughts/opinions on topics
- Take space, make space
- Be both teachers and learners
- Accept that conversations may not yield a resolution
- Listen to others

Figure 2. Community guidelines for Implicit Bias in STEM Seminar series. We give participants clear guidelines to engage in sensitive course material, grounding them in self-awareness through their identities and privilege. The overarching recommendation for participants is to be self-aware of the biases they bring into the classroom, and to use the guidelines for constructive engagement either with themselves or while interacting with other members of the course. Some of the guidelines were borrowed from the Cornell Intergroup Dialog Project—Engaging in Conversations on Racism faculty workshop, August 2020.

2020), especially on topics that can provoke tension or discomfort. Although we recognize that if face masks are required this can obscure nonverbal cues from an in-person classroom discussion and lead to some unexpected challenges with communication.

Different teaching and learning tools can take advantage of a classroom's space and teaching framework. While breakout rooms allowed for separation of groups, we had a few sessions where we shuffled different participants around with the intention of adding new perspectives to each group. We also used Google Jamboard (https://jamboard.google.com/) or Padlet (https://padlet.com/) to allow multiple groups to openly express their synthesis of the material, facilitating exposure to more diverse perspectives without the risk of biasing conversation toward power imbalances. Although most interactions were a response to prompted questions, we found that having at least a few minutes of open interaction through discussions of the readings or media throughout each class was essential to fomenting collegiality.

In-person teaching follows the structure of the remote format with breakout groups distributed across moveable tables and chairs in the classroom. This permits power dynamics to be limited by breaking up the larger group into smaller discussion groups according to career stage. In addition, interactive activities with the course material can be done in more traditional ways, such as using actual sticky notes and a whiteboard or chalkboard to connect content instead of using online tools.

Participation and evaluation of participants

All participants were expected to read/watch all materials and participate in our weekly class discussions. In addition, each participant was randomly assigned to help write discussion questions for a subset of reading materials covered in the course. Participants both in a virtual setting and in person were highly encouraged to engage with the active online discussion board on our course site and in-class activities with the interactive online tools or in person activities implemented within the course. During our

class discussions, participants took turns being the scribe, synthesizing, and sharing the main points/themes from their smaller groups to the whole class at the end of each meeting.

This course was offered for one credit (equivalent to 1 h of classroom or direct faculty instruction and 2 h of out of class student work each week). Some participants took the course for letter grades and some took it for credit. We observed no difference in engagement between those participants that took the course for a grade vs. not. To evaluate students or participants for grades or pass/fail (both options were permitted), we evaluated the discussion questions posed by each participant, took attendance, noted who actively participated each week in the discussion sections and engaged with the online discussion board, and noted who has served as a scribe.

In all future versions of this class based on feedback from the past course participants, we will also include a final project where the participants will write a short reflection essay about a chosen topic related to the course content or outline their personal commitments to continue to create equitable and inclusive spaces in STEM. All the feedback we received was highly positive with the only critical feedback being that the participants wished we had more time for discussion of the assigned materials. Most of the comments we received mirrored these participant comments:

> "Make this course mandatory for every faculty, staff, student, grad, etc. Make it mandatory."

> "I would highly recommend this course to anyone in STEM at any academic level."

> "I think this is a great course! I truly feel that every student should take it, and I strongly encourage departments to consider adding a course like this as a major/field requirement."

> "This course was timely and effective. It created a space where I felt very comfortable learning with everyone, and having dialogue that

was honest. We read contemporary and important work. While we could get lost in the weeds with some conversations, it always felt useful to talk things through that we had disagreements about and it never felt hostile. I am very happy that I was able to be part of this and I really hope that this class in particular can continue but that it is the start of a much broader movement to normalize conversations around Diversity and Inclusion."

Into the future: conclusions and next steps

The course structure that we implemented in the *Diversity, Equity, and Inclusion in STEM: The Science Behind Bias seminar* can serve as a blueprint for similar courses at other institutions. Courses like this can harness the existing and currently expanding records of bias in primary literature and syntheses on diversity and inclusion within STEM. The increasing number of resources available for teaching about the historical contributions of science to race and racism within curricular courses (Bhagia et al. 2020, Donovan 2021, Fred Hutchinson Cancer Research Center Science Education Partnership 2021), combined with the literature from other disciplines (e.g. science, technology, and societies—STS) can build the curricula for critically analyzing the prevalence and effects of bias in STEM (Stephan 1982). We recommend that educators incorporate materials across a broad range of disciplines and provide spaces where there are opportunities to delve deeper into discussions. For instance, whole sessions or modules can be dedicated to exploring specific topics while also providing sessions to explore the intersectionality of the different topics. The resources we have detailed here for a seminar course support this complementary approach (Supplementary File 1). Additionally, we recommend that educators customize the topics and readings to fit the needs of their local communities and locations. Place-based education literature shows that students' understanding of their local cultural and political context creates powerful incentives for students' public engagement and accountability (McClennen et al. 2020, Anderson 2017, Gruenewald 2005, McInerney 2011, Woodhouse and Knapp 2000). Similarly, here, we expect that by adding to the curriculum topics of biases that are relevant at the local scale (e.g. forced experimentation on slaves and/or immigrants, land dispossession, among many others), students might be more likely to engage in actions that result in the inclusion and sense of belonging in STEM of marginalized individuals.

By explicitly teaching about the ways bias, racism, and exclusion in STEM have and continue to impact who is included, and actionable ways to limit or reduce these biases, we give participants in this course the knowledge to recognize bias and enact change in their personal, educational, and professional lives. Grounding the readings in the scientific literature permits discussions of not only what the data say about historical and ongoing biases, but also allows participants to critically evaluate papers that may be using scientific data or methods to continue to perpetuate bias, racism, and exclusion. We hope this structure is helpful to others that would like to engage in these topics with their students and colleagues, while remaining flexible enough to accommodate in-person or remote learning and customizable to address locally significant or field-specific literature and media. Until courses on racism, bias, and exclusion are required components of higher education, including courses focusing on these historical legacies in STEM, we provide this blueprint to help others integrate these topics into their own learning frameworks.

Supplementary data

Supplementary data are available at *FEMSPD* online.

Ethics statement

The authors declare no conflict of interest in the design and writing of this paper. Furthermore, the authors would like to acknowledge that while this paper is meant to provide a universal blueprint for discussing bias in STEM, it was made by authors with their own unique perspectives, lens, and own implicit biases. The five of us represent various career stages (faculty, postdoctoral researchers, and graduate students), and all teach within biology departments.

Acknowledgments

References

AAAS. *Vision and Change in Undergraduate Biology Education: A Call to Action.* Washington: AAAS, 2011. http://visionandchange.org/finalreport/. (5 December 2021, date last accessed).

Adams M, Bell LA. (eds). *Teaching for Diversity and Social Justice.* 3rd ed. New York: Routledge, 2016.

AlShebli BK, Rahwan T, Woon WL. The preeminence of ethnic diversity in scientific collaboration. *Nat Commun* 2018;**9**:5163.

Anderson SK. Bringing School to Life: Place-Based Education Across the Curriculum. *United States: Rowman & Littlefield Publishers* 2017.

Bentley AR, Callier S, Rotimi CN. Diversity and inclusion in genomic research: why the uneven progress?. *J Community Genet* 2017;**8**:255–66.

Bhagia A, Chaudhry A, Porterfield J. Does race belong in undergraduate biology? Investigating the opinions of biology students and faculty at an undergraduate institution. 2020.

Booth JM, Garrett JM. Instructors' practices in and attitudes toward teaching ethics in the genetics classroom. *Genetics* 2004;**168**:1111–7.

Broockman D, Kalla J. Durably reducing transphobia: a field experiment on door-to-door canvassing. *Science* 2016;**352**:220–4.

Campbell LG, Mehtani S, Dozier ME *et al.* Gender-heterogeneous working groups produce higher quality science. *PLOS ONE* 2013;**8**:e79147.

Chapman R. Rendering the invisible visible: student success in exclusive excellence in STEM environments' Ch. 2 in Diversifying STEM: Multidisciplinary Perspectives on Race and Gender. 2019;36–52.

Cooper KM, Auerbach AJJ. Bader JD *et al.* Fourteen recommendations to create a more inclusive environment for LGBTQ + individuals in academic biology. *CBE Life Sci Educ* 2020;**19**:1–18.

Crenshaw K. Demarginalizing the intersection of race and sex: a black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *Univ Chic Legal Forum* 1989;**140**: 139–67.

Donovan BM. *Towards a More Humane Genetics Education*. Colorado Springs: BSCS Science Learning, 2021.

Douglass JA, Thomson G. The poor and the rich: a look at economic stratification and academic performance among undergraduate students in the United States. *CSHE Research and Occasional Paper Series* 2008;**15**:1–20.

Elliott R, Strenta AC, Adair R *et al.* The role of and leaving institutions ethnicity in choosing science in highly selective institutions. *Res High Educ* 1996;**37**:681–709.

Ford Foundation. *Diversity, Equity, and Inclusion Annual Report 2021*. 2021, 54.

Fred Hutchinson Cancer Research Center Science Education Partnership. *Race, Racism, and Genetics*. 2021.

Friedmann T. Genetic therapies human genetic enhancement and … eugenics?. *Gene Therapy* 2019;**26**:351–3.

Govier M. The Royal Society Slavery and the island of Jamaica: 1660–1700. *Notes Rec R Soc Lond* 1999;**53**:203–17.

Graves JL. African Americans in evolutionary science: where we have been, and what's next. *Evol Educ Outreach* 2019;**12**:18.

Gruenewald DA. Accountability and Collaboration: Institutional Barriers and Strategic Pathways for Place-based Education. *Ethics, Place & Environment* 2005;**8**:261–83. DOI: 10.1080/13668790500348208.

Hill WD, Davies NM, Ritchie SJ *et al.* Genome-wide analysis identifies molecular systems and 149 genetic loci associated with income. *Nat Commun* 2019;**10**:e5741.

Hofstra B, Kulkarni VV, Galvez SM-N *et al.* The diversity-innovation paradox in science. *PNAS* 2020;**117**:9284–91.

Holman L, Stuart-Fox D, Hauser CE. The gender gap in science: how long until women are equally represented?. *PLOS Biol* 2018;**16**:e2004956.

Hoppe TA, Litovitz A, Willis KA, *et al.* Topic choice contributes to the lower rate of NIH awards to African-American/black scientists. *Sci Adv* 2019;**5**:eaaw7238. DOI: 10.1126/sciadv.aaw7238.

Hubbard AR. Teaching race (bioculturally) matters: a visual approach for college biology courses. *Am Biol Teach* 2017;**79**:516–24.

Hudson N. From 'Nation' to 'Race': The origin of racial classification in eighteenth-century thought. *Eighteenth-Century Stud* 1996;**29**:247–64.

Intergroup Dialogue Project. *IDP Guide: Community Agreements. Intergroup Dialogue Project – Dialogue Across Difference*. 2021.

Jabbour J, Holmes L, Sylva D *et al.* Robust evidence for bisexual orientation among men. *PNAS* 2020;**117**:18369–77.

Jimenez MF, Laverty TM, Bombaci SP *et al.* Underrepresented faculty play a disproportionate role in advancing diversity and inclusion. *Nat Ecol Evol* 2019;**3**:1030–3.

Leavy S. Gender bias in artificial intelligence: the need for diversity and gender theory in machine learning. *2018 ACM/IEEE 1st International Workshop on Gender Equality in Software Engineering* 2018;14–6.

Lee A. A comparison of postsecondary science, technology, engineering, and mathematics (STEM) enrollment for students with and without disabilities. *Career Dev Transit Except Individ* 2011;**34**: 72–82.

Ma Y, Oliveira DFM, Woodruff TK *et al.* Women who win prizes get less money and prestige. *Nature* 2019;**565**:287–8.

McClennen N. Liebtag E Vander Ark T The Power of Place: Authentic Learning Through Place-Based Education. *United States: ASCD* 2020.

McInerney P, Smyth J, Down B. 'Coming to a place near you?' The politics and possibilities of a critical pedagogy of place-based education. *Asia-Pac J Teach Edu* 2011;**39**:3–16. DOI: 10.1080/1359866X.2010.540894.

Miller C, Roksa J. Balancing research and service in academia: gender, race, and laboratory tasks. *Gend Soc* 2020;**34**:131–52.

O'Brien LT, Bart HL, Garcia DM. Why are there so few ethnic minorities in ecology and evolutionary biology? Challenges to inclusion and the role of sense of belonging. *Soc Psychol Educ* 2020;**23**: 449–77.

Perception Institute. *Implicit Bias Explained*. 2021.

Prather C, Fuller TR, Jeffries IV WL *et al.* Racism African American and their sexual and reproductive health: a review of historical and contemporary evidence and implications of health equity. *Health Equity* 2018;**2**:249–59.

Puertas-Molero P, Zurita-Ortega F, Chacón-Cuberos R *et al.* An explanatory model of emotional intelligence and its association with stress, burnout syndrome, and non-verbal communication in the university teachers. *J Clin Med* 2018;**7**:E524.

Reese AJ. An undergraduate elective course that introduces topics of diversity, equity, and inclusion into discussions of science. *J Microbiol Biol Educ* 2020;**21**:21.1.10.

Reinsvold L, Cochran K. Power dynamics and questioning in elementary science classrooms. *J Sci Teach Educ* 2011;**23**:1–24.

Sartin JS. J. Marion Sims, the father of gynecology: hero or villain?. *South Med J* 2004;**97**:500–5.

Schell CJ, Guy C, Shelton DS *et al.* Recreating Wakanda by promoting Black excellence in ecology and evolution. *Nat Ecol Evol* 2020; 1–3.

Sidky G. The power game: power dynamics between the teacher and the students in a graduate seminar. *Eng Lang Teach* 2017;**10**:179.

Smith KA, Arlotta P, Watt FM *et al.* Seven actionable strategies for advancing women in science, engineering, and medicine. *Cell Stem Cell* 2015;**16**:221–4.

Staats C, Capatosto K, Tenney L, *et al.* State of the Science: Implicit Bias Review. Kirwan Institute for the Study of Race and Ethnicity, 2017.

Stephan N. *Idea of Race in Science: Great Britain*. New York: The Macmillan Press LTD, 1982.

The Program on Intergroup Relations. *The Program on Intergroup Relations at the University Michigan*. Intergroup Dialogues, Intergroup Resources. Ann Arbor: University of Michigan, 2008.

Tinker B. *LARA: Engaging Controversy with a Non-violent, Transformative Response*. Stanford: Stanford SPARQ, 2004.

Uzun GÖ. A review of communication, body language and communication conflict. *Int J Psychosoc Rehabil* 2020;**24**:13.

Whittaker JA, Montgomery BL, Martinez Acosta VG. Retention of underrepresented minority faculty: strategic initiatives for institutional value proposition based on perspectives from a range of academic institutions. *J Undergrad Neurosci Educ* 2015;**13**:A136–45.

Whittaker JA, Montgomery BL. Cultivating diversity and competency in STEM: challenges and remedies for removing virtual barriers to constructing diverse higher education communities of success. *J Undergrad Neurosci Educ* 2012;**11**:A44–51.

Woodhouse JL, Knapp C. Place-based curriculum and instruction : outdoor and environmental education approaches. In: Charleston WV (ed.). *Clearinghouse on Rural Education and Small Schools, Appalachia Educational Laboratory*.2000.

Zúñiga X, Nagda B, Mark C *et al. Intergroup Dialogue in Higher Education: Definition, Origins, and Practices*. San Francisco: Wiley InterScience, 2007:1–128.

Zúñiga X. Bridging differences through dialogue. *About Campus* 2003;**7**:8–16.