

Scientific Life

Teaching between
the Lines:
Representation in
Science TextbooksDasia Y. Simpson,^{1,2}
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Science textbooks communicate fundamental discoveries and serve as platforms showcasing role models for students. However, the scientists represented across undergraduate textbooks do not reflect the demographic makeup of the student population reading those materials. We recommend a series of changes within curricula to challenge the stereotypical identity of science.

Solo Status in Science

Students with marginalized identities continue to face solo status in science, where they are one of few students who share that social identity in their classes or majors [1]. Examples of social identities can include, but are not limited to, race/ethnicity, gender, disability status, nationality, sexual orientation, and socioeconomic background. A number of environmental factors and structural inequalities contribute to a lack of diversity in higher education, resulting in isolation and solo status mindsets [2]. The impacts of these results, along with other hurdles, can create insurmountable barriers for students. For example, a longitudinal study that followed over 44 000 science, technology, engineering, and mathematics (STEM) students from over 160 institutions showed that students of color were more likely to withdraw from STEM majors than their white peers [1].

A lack of relatable role models is one factor that contributes to the feelings of isolation

that marginalized students experience. Perceptions of who has done and can do science develop early; for example, one classic study aimed to identify at what age children first develop stereotypes of scientists by asking them to participate in a 'draw a scientist test'. They found that by the second grade, most drew what they believed a stereotypical scientist looked like: a nerdy, benevolent white man draped in a white lab coat [3]. A generation later, after years of exposure to science classes and science in the media, one might expect more complex, counterstereotypical representations of scientists from undergraduate students. However, these drawings exhibited similar stereotypical characteristics to those by children in grade school [4].

Undergraduate science textbooks reinforce a dominant language of science that is often white and masculine. They do so by defining exceptionalism in narrow terms, emphasizing historical figures, and exhibiting scientists from mostly selective institutions. To challenge the notion that all scientists fit the same stereotype, we advocate for inclusive representation of scientists in classroom resources. This format requires an emphasis on humanizing, contemporary science, and the adoption of active learning practices that challenge students to confront the exploitative nature of science history (an example of exploitative knowledge production can be seen in [5]).

Why Are Role Models in Science Important?

Role models are inspiring and critical to personal and professional growth, but students who identify with groups that are marginalized in science are less likely to have mentors or role models that share their marginalized identities. The lack of mentors and inclusive content in classrooms discourages marginalized students from developing their interests in science [6]. Role models give under-

represented students a sense of opportunity and confidence to enter STEM professions [7] by highlighting the feasibility of careers in STEM, providing the necessary perspective and guidance students may not receive from traditional teaching curricula.

Previous work with ninth grade students suggests that positive perceptions of scientists is associated with higher performance outcomes in science [8] and stronger commitment to pursue STEM careers. Similarly, student perceptions of 'chilly' classroom climates negatively impacted their short- and long-term learning gains and academic preparation for their future career [9]. In undergraduate biology, providing students with counterstereotypical examples of scientists in class shifted their perceptions of scientists, and improved their science identity and performance [10]. Textbooks can serve as a medium to present counterstereotypical scientists as historical and modern figures.

How Are Diverse Role Models Represented in Textbooks?

Subtle prejudices are actively communicated through the lack of contributions by marginalized scientists in teaching materials. Previous work has focused on the unconscious of science, or the subtextual messaging that promotes an unwritten but definitive worldview [6]. Through the content, layout, diagrams, photographs, and examples presented to students, materials communicate who can and cannot participate in science. Whether intentionally or not, the unconscious of science is infused into course materials, and these are in turn a part of the student learning experience that shapes perceptions of what a scientist looks like.

Analyses of commonly used ecology [11], geology [6], and introductory biology [12] textbooks revealed significant under-

representation of women and/or scientists of color. In ecology and geology textbooks, approximately 5% of founders and innovators were women [6,11]. Women and people of color were rarely featured in photos, diagrams, and drawings, and their roles in textbooks were generally unrelated to scientific contributions. For example, geology textbooks used images of women's bodies that appeal to heterosexual men's desires to illustrate or describe scientific principles. In one geology textbook, 10 of the 12 Black individuals included in the text were in a single photograph depicting the concept of overpopulation [6].

Another study that examined common introductory biology textbooks found that despite progress in representing women among contemporary biological discoveries, textbooks highlighted only one woman scientist for every seven men, even though 60% of students awarded undergraduate biology degrees are women [12]. Similarly, while 35% of students in biology bachelor's programs were people of color, only 6.67% of total scientists in biology textbooks were people of color. While some demographic groups (e.g., white women and Asian men) have become increasingly represented, other groups (e.g., Asian and Hispanic women) remained under-represented, and still others (Black women) completely lacked representation across all textbooks [12]. The authors developed forecasts based on current rates of change to predict when biology textbooks would achieve inclusive representation. They reported that under the status quo, it will be hundreds of years until textbooks reflect the demographic composition of the general population and the biology student population in the USA [12].

While the research we describe above focuses on US textbooks and student populations, global calls for change aim to increase the diversity of our international science workforce [13]. Scientists who

identify with under-represented groups, and even how we define under-represented in science, differs across geographic regions, underscoring the importance of additional research and teaching that addresses localized issues of representation. However, the patterns described here are not unique to the USA (e.g., Lebanon; [14]). We challenge educators worldwide to assess their teaching materials and use different resources to help increase the inclusivity of their curriculum. We provide supportive materials as a guide to aid that process (Table 1).

What Can Be Done to Diversify Scientist Role Models?

As educators, we want to do our best to serve our diverse student populations. This means we must actively challenge pre-existing notions through inclusive teaching practices. To diversify scientist role models, we must first recognize that qualified scientists are everywhere. Many people have the perception that there are not many scientists from marginalized groups. This is not because they do not exist, but because their work and voices are not celebrated like those of scientists from nonmarginalized groups. For example, nearly every student in introductory biology learns that the Petri dish is named after Julius Petri, who came up with the idea. Meanwhile, a woman named Fanny Hesse, who recommended the use of agar to grow bacterial cultures, is rarely heralded for her contributions.

Promoting diversity and inclusion in STEM is critical to our international interests, and proactively challenging societal biases begins in our own classrooms. We recommend instructor-focused short-term and long-term actions to accomplish these goals.

Short-Term Action: Modify Class Materials

Previous research has shown that small changes to teaching materials have the potential to increase student awareness of diversity in STEM and enhance science

identity [11]. Instructors can enrich existing course materials with supplemental readings such as nonfiction books, as well as websites highlighting diversity, and analyses of real-world data highlighting racial disparities inside and outside of education (Table 1). When discussing research, we recommend humanizing scientists when possible, and avoiding the presentation of science primarily conducted by white male scientists at selective institutions.

Long-Term Action: Integrate into Curricula

Sustained action that integrates and diversifies curricula will advance equitable representation in the field. What can graduate students, postdocs, and faculty do to support these efforts, given their latitude of influence? At our home institution, we developed a class that integrates implicit bias training, encourages respectful and productive conversation, and addresses important areas that are generally not emphasized in the biology curriculum. These include: (i) the historical contributions of scientists from under-represented backgrounds; (ii) unethical experimentation and its relation to human rights evolution; (iii) environmental racism of the past and present; (iv) how biological science shapes societal views on identities related to gender, sexuality, and disabilities; and (v) how historical beliefs shaped by societal biases persist in science today. We provide the syllabus that illustrates how we are integrating these materials into our university curriculum (see Appendix 1 in the supplemental information online).

Implementation can occur in three potential formats, each building upon the last and leading to long-term and sustainable reform: (i) a shortened modular approach taught by a secondary guest speaker in existing courses; (ii) faculty integration and adaptation of examples for semester long integration; and (iii) development of a multicredit, in-depth independent course. While the modular approach will reach many students across multiple courses,

Table 1. Resources for Students: Increasing Diversity and Fostering Discussions on Inequity in Science

Type	Resource	Brief description
Alternative texts and textbook supplements	<p>The Immortal Life of Henrietta Lacks Rebecca Skloot</p> <p>ISBN: 978-1400052189 Publisher: Broadway Books</p>	<p>This text highlights the impacts of bioethics in science while chronicling the impacts of HeLa cells.</p> <p>The cervical cells of Henrietta Lacks, an African American woman, were unknowingly harvested and used for medical advancements for the next 60 years. To this day, the use of her cells persists and have led to some of the most prolific cellular biology advancements known today.</p>
	<p>Madame Curie: A Biography Eve Curie</p> <p>ISBN: 978-0306810381 Publisher: Da Capo Press; Reissue edition</p>	<p>This biography narrates the life of noble peace prize awardee, Marie Curie, a world-renowned physicist and chemist who led pioneering research on radioactivity and the development of X-rays.</p>
	<p>Rosalind Franklin: The Dark Lady of DNA Brenda Maddox</p> <p>ISBN: 978-0060985080 Publisher: Harper Perennial</p>	<p>This text focuses on Rosalind Franklin, a woman scientist who discovered one of the most groundbreaking scientific discoveries of the 20th century: the structure of DNA.</p>
	<p>Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race Margot Lee Shetterly</p> <p>ISBN: 978-0062363596 Publisher: HarperCollins Publishers</p>	<p>This text reveals the inspiring stories of young women who overcame gender bias of maths and science and helped the USA engineer one of the biggest achievements in history: space exploration.</p>
	<p>Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy Cathy O'Neil</p> <p>ISBN: 978-0553418835 Publisher: Broadway Books; Reprint edition</p>	<p>This text investigates how algorithms control our everyday lives, including how we receive loans, insurance, and various policies. This book describes how data algorithms contribute to socioeconomic inequality.</p>
	<p>Nobody: Casualties of America's War on the Vulnerable, from Ferguson to Flint and Beyond Marc Lammont Hill</p> <p>ISBN: 978-1501124969 Publisher: Atria; Reprint edition</p>	<p>This text shines light on racial and social injustice in some of the USA's most controversial cases ranging from high-profile deaths of African Americans to the Flint Water Crisis, explaining how groups become vulnerable and what we can do to address it.</p>
	<p>Presumed Incompetent: The Intersections of Race and Class for Women in Academia Gabriella Gutiérrez y Muhs</p> <p>ISBN: 978-0874219227 Publisher: Utah State University Press</p>	<p>This text highlights challenges and struggles of women of color in academia. The entanglement of race, gender, and class are emphasized through the use of empirical studies and personal narratives of academic women of color.</p>
	<p>How to Be an Antiracist Ibram X. Kendi</p> <p>ISBN: 978-0525509288 Publisher: One World, First edition</p>	<p>This text builds on the idea of an antiracist society, highlighting the roles individuals can play in building it through an integrated view of ethics, history, science, and law.</p>
	<p>The Only Woman in the Room: Why Science Is Still a Boys' Club Eileen Pollack</p> <p>ISBN: 978-0807046579 Publisher: Beacon Press</p>	<p>This text explains why few of today's woman scientists achieve tenured positions. Through these means this book discusses societal, psychological, and collegiate barriers faced by women in the hard sciences.</p>
	<p>Superior: The Return of Race Science Angela Saini</p> <p>ISBN: 978-0807028421 Publisher: Beacon Press</p>	<p>This text uses expert interviews, author analyses, and personal experience to discuss how scientific racism through a historical looking glass persists in society today.</p>

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Table 1. (continued)

Type	Resource	Brief description
	<p>Inferior: How Science Got Women Wrong and the New Research That's Rewriting the Story Angela Saini</p> <p>ISBN: 978-0807071700 Publisher: Beacon Press</p>	This text discusses the effects of sexism in research and the resulting implications on social belief systems.
	<p>So You Want to Talk about Race Ijeoma Oluo</p> <p>ISBN: 978-1580058827 Publisher: Seal Press; Reprint edition</p>	This text provides details on how to have productive conversations about racism, and how racism is tied into the society of the USA.
Data application and problem sets	<p>DataClassroom https://about.dataclassroom.com/</p>	This data application website provides real-life data designed for analysis that can be used to integrate lessons on racial disparities into existing STEM curricula. For example, one available dataset is titled, 'Driving while Black or Brown: Exploring institutional racism through the lens of data.'
	<p>Harvard Dataverse https://dataverse.harvard.edu/</p>	This data application website is a free data repository that contains datasets available for download on a wide range of topics. Users can organize data sets and utilize them in curriculum in addition to highlighting data produced by marginalized groups.
Websites	<p>Teaching tolerance www.tolerance.org</p>	This website provides free resources for educators to promote and maintain inclusive teaching including lesson plans and additional student texts.
	<p>500 women scientists https://500womenscientists.org/</p>	This website is an online resource that provides opportunities to network with other women in academia while challenging societal and racial norms in science. This webpage provides potential role models and resources for women in science.
	<p>500 queer scientists https://500queerscientists.com/</p>	This website is an online resource to advocate LGBTQ+ representation in STEM professions. The webpage includes spotlights of scientists within the LGBTQ+ community, offering a resource for role model identification.
	<p>Scientist Spotlights Initiative https://scientistspotlights.org/</p>	This website encourages educators to promote diversity in the representation of scientists in today's curricula by promoting supplements that bring scientific role models to students of all background.
	<p>Project Biodiversify https://projectbiodiversify.org/</p>	This website is a repository of teaching materials that promote diversity and inclusion in biology courses by featuring scientists from diverse backgrounds.

faculty integration (i.e., tightly weaving the modules into existing coursework) or an independent course will immerse students into the issues, and build on their prior knowledge to gain a deep understanding of the history and practices that relate to equity in biology education. While our focus is biology education, our approaches are easily transferrable to other STEM disciplines. Through the study and development of inclusive learning materials we promote equitable representation in classrooms and reveal the textured history of science.

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