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Using Culturally Relevant Pedagogy to Reconsider the Genetics Canon†

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In this article, we explore culturally relevant pedagogy (CRP) to work toward alleviating persistent underrepresentation in STEM fields of oppressed minorities. We argue that biology instructors can practice agency, or the capacity to act in ways that undermine opportunity gaps that lead to underrepresentation, by developing themselves into culturally relevant pedagogues who are committed to underrepresented minority (URM) students' learning and career success, who demonstrate cultural competence, and who develop a sociopolitical consciousness regarding the culturally laden nature of their discipline. We then explore Gregor Mendel's story to demonstrate the culturally laden nature of the history of science as well as the nature of our current curricular canon. The article concludes with a postulated alternative method to genetics education in a general biology course that reflects the culturally laden nature of our genetics knowledge, as well as our current understanding of inheritance.

INTRODUCTION

African Americans, Latinx, Native Americans, and Pacific Islanders together comprise 32.2% of the U.S. population, but these proportions are not reflected among the STEM workforce (1). Several institutionally racist practices have combined to perpetuate reduced participation by underrepresented minorities (URMs), including historical housing policies that promoted segregation and prevented homeownership among minorities (2, 3) and unfair public school funding policies, such as the use of local property taxes in the funding of public schools (4). The synthesis of these policies has been prevention of accumulation of wealth among minority families and limited access to effective education, the latter of which is a direct prerequisite to achievement in STEM fields.

Institutional racism is perpetuated in educational contexts through several additional means. First, there are differences in opportunity provided to White and Asian students versus African American and Hispanic students (5). These opportunity gaps arise as a result of several factors, including cultural conflicts between home and school cultures, teachers' attempts to adopt a context-neutral mindset (i.e., trying to be "color-blind") when teaching students with whom they do not identify, the myth of meritocracy, teachers' deficit mindset toward URM students, and teachers' higher expectations for majority students compared with URM students, which leads to URM students internalizing low expectations for themselves (5). In general, URM students are less likely to be afforded culturally relevant instruction (6), and teachers of URM students tend to be less committed to academic achievement (7) and less likely to recognize how students' cultural practices and beliefs may not be shared with school culture (8). Teachers of URM students are also likely to lack a sociopolitical consciousness that allows recognition of the roles that race, class, gender, sexual orientation, and other identities play in social and educational inequity (6). As such, opportunity gaps transform into achievement gaps, which become perpetuated throughout schooling and the STEM professions.

Instructors of science and mathematics disciplines are often under the impression that these disciplines are culture-free and therefore not subject to institutionally racist education practices. In this article, we argue that this assumption is foundational to the underrepresentation we observe across STEM disciplines. When college/university instructors fail to recognize the ways in which their discipline is culturally laden, they risk the creep of their implicit biases into both their instruction and their portrayal of the discipline itself. A striking example of this has been documented by Donovan (9), who showed that conventional genetics teaching perpetuated the misconception that race is a biological construct, rather than a social construct, and increased racist beliefs among students. Therefore, in this

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article we explore why culturally relevant pedagogy (CRP) is necessary in biology instruction, particularly when teaching genetics concepts that, if misunderstood, have damaging sociopolitical consequences.

THEORETICAL FRAMEWORK

The theoretical framing of our argument combines Milner's (5) depiction of opportunity gaps as sources of achievement gaps and Ladson-Billing's (6) CRP. By adopting Milner's (5) perspective, we acknowledge that achievement gaps are not an indication that some student groups are inherently less than others, but rather that achievement gaps are symptoms of the differential distribution of privilege across student groups in an educational system that suffers from institutionalized racism, classism, sexism, and heterosexism. Nonetheless, teachers, as actors in this system, have agency, or the potential capacity to act in ways that undermine opportunity gaps to some extent. To do so, we argue that science educators must become culturally relevant pedagogues, which has been demonstrated to improve both academic outcomes and students' identity development (10).

Culturally relevant pedagogues are educators who share three characteristics (7). First, they are committed to academic achievement, not in terms of standardized testing, but in terms of long-term skills that will enable lifelong learning and career success. In the context of science, we claim that this commitment is manifested as a commitment to wise implementation of instruction that supports active learning (11), engages students in authentic scientific practices (12), and enables students to develop the possibility lens (13) for entering a STEM field. Indeed, ample evidence has demonstrated the efficacy of instruction that promotes active learning (14, 15), engages students in scientific practices, such as those enacted during undergraduate research experiences (16, 17), and fosters a scientific identity (18).

Second, culturally relevant pedagogues have cultural competence, demonstrated by a recognition that some students' cultural practices and beliefs may not be shared with cultures present in academic institutions, within the scientific community, or within the larger society (8), and thus, students must learn to navigate between cultures if they are to attain success (19). In the context of science teaching, this involves creating safe space to explore cultural conflicts between science content and home cultures, such as acknowledging some students' conflict over evolutionary theory or geologic time. This also means contextualizing science instruction materials so that they hold cultural relevance to students who are marginalized by mainstream science instruction. Gonzalez-Espada and colleagues (20), who examined the impact of such contextualized and culturally relevant instructional materials, demonstrate that such an approach improved students' perceptions of the nature of science. Similarly, Favero and Van Hoomissen's attempt to infuse culturally relevant examples from human biology into their anatomy and physiology curriculum led to "a deeper and more complex understanding of how intersections of ancestry, culture, language, and socioeconomic status can impact health" (21).

Finally, culturally relevant pedagogues develop a sociopolitical consciousness in which they recognize the roles that race, class, gender, sexual orientation, and other identities play in social inequity (6). This requires teachers to acknowledge racial dimensions of the content we teach, instead of neutralizing the role of race in the subject (22). Furthermore, Utt and Tochluk identify six areas of self-work necessary for White educators to establish anti-racist White racial identities (23). This self-reflection means that White educators become aware of their own racial identity development and acknowledge the role that identity has played in their education and development as a scientist. This final aspect of CRP is the most challenging, as it requires us to consider unacknowledged aspects of the culturally laden nature of science and realize hegemonic forces in science's past and present.

In the absence of CRP that engages students in meaningful conversations about social inequities, student experiences can be minimized and become irrelevant to science learning goals (22). In this learning environment, inaccurate assumptions about the nature of science abound (24–27). A particularly troubling assumption is the idea that science as a field is acultural and acontextual; that is, science is an objective discipline unaffected by the culture and context in which scientific discoveries are made (22). We argue the opposite—that the way in which science is disseminated, publicized, and taught is culturally and contextually laden.

HISTORICAL CONTEXT

To demonstrate this point, we refer to the history of the rise of Mendelian genetics as discussed by Jamieson and Radick (28). First, it is important to acknowledge that Mendel did not set out to explain mechanisms of inheritance; rather, he endeavored to study hybridization and identify methods of producing novel true-breeding (i.e., homozygous) plants from hybrids (i.e., heterozygotes) in stable proportions (27–29). This goal led to his work with carefully selected true-breeding pea plants and the discovery of the ratios of monohybrid and dihybrid crosses that we are familiar with today (29). However, Mendel was not the only individual proposing theories of heredity at the time, and after his work was published in 1865, it went unknown until the 1900s (29). At that point, social and cultural interest in heredity was at a peak, following the dissemination of Darwin's work on natural selection and the discovery of chromosomal movement in cellular reproduction (29). The timing of these scientific discoveries coincided with a burgeoning interest in eugenics, leading to Mendel's work being publicized as a model to "improve the human race" through selective breeding of superior individuals (28, 29). Thus, the context in which Mendel's discoveries were made, as well as the prevailing cultural interest in eugenics, set the stage for Mendel's ideas now being considered the foundation of genetics.

Social interests were also at play at the time; as mentioned, others were proposing theories of heredity simultaneously, including W. F. R. Weldon (28, 29). Weldon's views dramatically contrasted with Mendel's dominant/recessive dichotomy, as Weldon demonstrated that peas, Mendel's own study system, expressed a wide distribution of phenotypes in nature (28). Since the natural variability of species did not match Mendel's tightly controlled experiments, Weldon proposed that the so-called "dominance" of traits was dependent upon the context in which the trait existed (28). For example, the shape of a seed could fall anywhere in between the extremes of wrinkled and smooth; we now understand that this depends upon the amount of DNA coding for enzymes that convert sugar to starch, which then impacts the amount of water absorbed by the seed (28). This example illustrates that variation exists even in the dominant/recessive dichotomy for which Mendel is so famous and that ideas about the complexity of inheritance were being presented while Mendel proposed his ideas.

However, Weldon's views remain virtually unknown, largely due to the social influence of a man known as "Mendel's bulldog," William Bateson (29). When Mendel's 1866 paper surged in popularity in 1900, Bateson quickly became convinced that Mendel's discoveries would open an entirely new exploration of inheritance (28). As Weldon published critiques of Mendel's work, Bateson busily recruited other scientists, including Reginald Punnett, to help him publicize and expand upon Mendel's work, leading to his publication of a textbook on Mendelian heredity in 1902 (28). In fact, Bateson is credited with creating the term "genetics" during his pro-Mendel campaign (28). He resolutely promoted Mendelian genetics to groups for whom he thought it would be useful, including plant and animal breeders and advocates of eugenics (28). It is also worth noting that a rivalry between Bateson and Weldon may have contributed to Bateson's dogged determination to promote Mendelian genetics; Weldon and Bateson struck up a friendship when they were both students at Cambridge University, although Weldon is said to have enjoyed more success early in his career than Bateson, going so far as to publicly criticize Bateson's work (28). At the time that Bateson seized upon Mendel's work as the new foundation of biology, he held a low-level position at a Cambridge college, while Weldon was a high-ranking professor at Oxford University (28). It is entirely possible that Bateson chose to market Mendel's ideas rather than Weldon's in some part due to this rivalry, as Jamieson and Radick (28) suggest, and that genetics curricula could be very different if this feud and interest in eugenics had not existed.

Weldon is not the only scientist whose ideas have been either highlighted or gone relatively unnoticed as a result of cultural influences, as history clearly shows that science is far from culture-free. Famed taxonomist Carl Linnaeus did not simply create the modern classification system; he also classified humans into four racially derived categories with personality traits attributed to specific groups, such as Europeans, described as "active, very smart, inventive," Africans, described as "crafty, slow, foolish," Native Americans, described as "angry in disposition, obstinate, ill tempered," and Asians, described as "melancholy in disposition, severe, haughty" (30). Rosalind Franklin's contributions to the discovery of the double helix structure of DNA were unknown until questions were raised after Watson published *The Double Helix*, when it was discovered that Franklin's Photo 51 had been used without her knowledge or consent (31, 32). These examples, along with many others not listed here, demonstrate the culturally laden nature of science and, thus, of the collection of biological knowledge that makes up our educational canon.

As outlined above, by presenting science and science curricula as culture-free, we are not acting as culturally relevant pedagogues. We assume we do not need to acknowledge race, class, gender, and sexual orientation in the classroom, but blindness to the culturally laden nature of science can perpetuate racism within science classes. To demonstrate, we describe how common genetics teaching practice may build upon student prejudices, as discussed in Donovan (9).

Bio-somatic essentialism (belief that within-race and between-race variance is due to genetics) and bio-behavioral essentialism (belief that different races have different genetic predispositions for behaviors) can be reinforced within genetics curricula (9). Strong essentialist views are associated with prejudice (33, 34). In genetics, essentialism perpetuates inaccurate conceptions about the level of variation between individuals of the same race and the biological notion of race (9). For example, one common presentation of Mendelian genetics includes genetic disorder prevalence within specific racial groups (e.g., sickle cell anemia in Africa-descended populations). Small statements of racial differences in genetics classrooms can increase bio-somatic essentialism (9). Racialized genetics examples, when compared with neutral examples, lead to participant "othering" of racial groups, misconception development of biological heterogeneity within races, and declines in interest for cross-racial contact and support of culturally based educational policies (9). In addition, bio-somatic essentialism may lead students to infer bio-behavioral essentialism (9).

By oversimplifying genetics to easy case studies and presenting racial differences without emphasizing the greater variation within races, stereotypes and prejudice can be reinforced under the umbrella of science. As stated by Donovan (35), "when people are exposed to genetic explanations for group-based outcomes, it tends to strengthen a cognitive bias implicated in our reasoning about social categories," thus reinforcing the biological essentialism misconception. However, when students compare genetic variation within and between races, racial bias can be reduced (36). After critically analyzing the data around the "race is biological" misconception, students had an accurate understanding of the levels of between- and within-group genetic variation (35). By teaching genetics in ways that have been demonstrated to perpetuate racist beliefs, the genetics curriculum can enact CRP by allowing students to build long-term skills through data analysis, recognizing differences rather than claiming to be blind to them, and enhancing sociopolitical consciousness through acknowledgement that race is a social, not biological, construct.

ENVISIONING A CULTURALLY RELEVANT GENETICS UNIT

With CRP, students are encouraged to be in a community of learners focused on collaboration and knowledge building (37). The integration of CRP into curricula: 1) allows students to generate knowledge; 2) pulls in personal, cultural, and community knowledge; 3) uses and shares student language; 4) reframes student experiences as potential sources of evidence; and 5) encourages students to build a critical lens (37). Typically, the genetics unit in an introductory biology course does not accomplish such tasks.

We encourage our peers to consider a typical genetics curriculum at any college or university across the United States. First, students are introduced to Gregor Mendel, the monk, telling the story of his dedication to breeding and observing pea plants. His discovery of discretely inherited "alleles" (a term not coined at the time) is acknowledged, often noting how his contribution was not accepted within the scientific community until after his death. Students then are introduced to genes and alleles through Mendelian genetics, discussing different pea and plant traits, and determining probabilities using Punnett squares. Human genetic disorders and their prevalence within different racial groups are presented as case studies. After spending a lecture or two on Mendelian genetics, exceptions to discrete traits are discussed (e.g., co- and incomplete dominance, polygenic traits, pleiotropy, multifactorial inheritance). The Mendelian exceptions are presented as a list, each with a simple definition and an example. Environmental influences on traits are rarely deeply explored, and despite most human traits resulting from many genetic variants across the genome (38), the emphasis in a typical genetics unit implies polygenic and polyallelic traits are rare.

Introductory biology laboratory settings also share similar lesson characteristics. In biology major courses, students often breed fruit flies and track genetic traits. These experiments are tightly controlled, providing evidence for classic genetics and inheritance probabilities (27). In nonmajor courses, students may complete one or more of the following activities: compare Mendelian inherited, but rather uninteresting, traits within the class population (e.g., widow's peak, detached/attached earlobes), use random events, such as coin tosses, to evaluate probabilities of expected versus observed traits; or develop a pedigree based on a case study (e.g., hemophilia).

Within this typical genetic unit, there are few opportunities for students to generate accurate knowledge about inheritance patterns that do not operate in a Mendelian fashion, which constitute most of the inheritance relevant to our lives (27). Furthermore, only White male contributions are highlighted, terms are presented without consideration of student language, and, as laboratory activities are controlled for specific outcomes, few opportunities exist for building students' critical lens. By overemphasizing Mendelian genetics and quickly skimming over other forms of inheritance, which ironically describe most of the inheritance that is relevant to our lives, we lose the opportunity to foster key aspects of genetics literacy, such as gene expression, variation's role within evolution, and ethical discussions around genetic technology (39). We also fail to address the culturally laden nature of science by inaccurately portraying the historical development of our genetics knowledge.

To address these issues in genetics education, we echo a call to reframe the genetics curriculum, as proposed by several scholars (e.g., 26–28, 40). We envision this taking place in an active learning classroom in which clickers and discussion questions are used to facilitate small group analysis of case studies that contain regular connections with accompanying lab material. The unit begins with assessing students' prior knowledge of inheritance mechanisms, a discussion of Weldonian and molecular genetics to prime students, and the presentation of a case study that involves messy genomic data, such as *Living in a Genomic World* available from the National Center for Case Study Teaching in Science (41). We echo the suggestion made by Donovan *et al.* (36) that Rosenberg's (42) use of microsatellite polymorphisms from over 50 indigenous populations to refute essentialist conceptions of race would serve as an effective genetics laboratory exploration. In the following lecture session, the instructor guides students as they reflect on the conclusions gathered from the lab and what this indicates about the human genome. A detailed outline of this unit, which would be appropriate for introductory biology, can be found in Appendix 1; we refer colleagues to Redfield (26) for suggestions on how to reframe an entire genetics course.

At this point, it would be appropriate to present exceptions to these complex and context-dependent mechanisms of inheritance, such as Mendelian genetics, as well as reflect upon the history of the development of our genetics knowledge. This would require instructors to be aware of and teach about the culturally laden history of Mendel, Weldon, and Bateson as detailed above, which may create discomfort in some instructors. However, we argue that it is entirely appropriate to include this history, as we often teach about the history of scientific knowledge regarding the discovery of the double helix, atomic structure, evolution, and numerous other scientific concepts. Shying away from the impacts of culture on scientific knowledge only serves to reinforce deterministic, essentialist, and racist views of human genetics. It is far more appropriate to embrace the complexity and context-dependent nature of science education and of genetics itself to promote greater learning gains and begin to move toward culturally relevant genetics education.

CONCLUSION

We encourage our colleagues to embark on the lifelong process toward becoming a culturally relevant pedagogue. We acknowledge that recognizing the ways in which our disciplinary canon is culturally laden is challenging. However, when we pull the veil on this aspect of scientific knowledge, we help our students understand that despite its biases, scientific knowledge is nevertheless the most reliable body of knowledge yet developed. Furthermore, when students witness our genuine attempts to acknowledge the roles that bias and racism played in the development of our discipline, their sociopolitical consciousness is heightened, allowing them to see science as a means for combatting injustice and oppression, rather than yet another institution that attempts to hide its racist roots.

SUPPLEMENTAL MATERIALS

Appendix 1: Proposed genetics unit outline

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