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GUEST EDITORIAL

Genetics and Identity

Introduction to the Special Issue

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Many countries throughout the world are struggling to address longstanding inequalities stemming from deeply ingrained societal prejudices about race, ethnicity, sex, gender, disability, and sexual orientation.[1] Prejudice can manifest itself in many different and often cryptic forms. A cognitive form of prejudice that influences how humans—particularly those living in Westernized cultures—make sense of societal inequalities is genetic essentialism (Henrich et al. 2010). Genetic essentialism is the belief that people of the same socially-defined group (e.g., race or gender) share genes that make them physically, cognitively, and behaviorally uniform, and distinct from other groups (Dar-Nimrod and Heine 2011). Several studies demonstrate that genetic essentialism mediates and moderates prejudiced attitudes toward racial minorities (Dar-Nimrod and Heine 2011), women (Brescoll et al. 2013; Morton et al. 2009b), and transgender individuals (Ching and Xu 2018). It also factors into ethnic violence, segregation, and discrimination (Halperin et al. 2011; Kimel et al. 2016; Morton et al. 2009a; Williams and Eberhardt 2008).

As genetic science advanced through the twentieth century, this new knowledge was often used to reinforce existing sexist and racist social policies (Jackson and Depew 2017). Throughout this history, essentialist assumptions about social identities were embedded into United States (US) laws (Fox 2019; Jackson and Depew 2017; Kitcher 2001; Omi and Winant 1994), and cultural artifacts (Nelkin and Lindee 1995), such as educational materials (Donovan 2015b; Donovan et al. 2019; Morning 2008; Nehm and Young 2008; Willinsky 1998). As a consequence, US society—like many others—is imbued with implicit and explicit messages

[1]We do not have the space in our introduction to unpack the definitions of these social concepts. Please refer to the papers in the Special Issue for a thicker description of their various conceptualizations. While we contend that these social categories are socially constructed through a complex interplay of culture and cognition, we also acknowledge that biological differences can be found within and between the groups that make up these social categories.

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reinforcing genetic essentialism (Nelkin and Lindee 1995) and very few messages suggesting otherwise (Nelkin and Lindee 2004). Genetics education in America serves as an example. Several experiments have found that when students learn about racial differences in genetic disease prevalence (e.g., sickle cell anemia), it can unintentionally increase their belief that races differ in their genetic potential for intelligence (Donovan 2014, 2016, 2017). Learning about the genetic basis of sex determination in humans or plants has also been found to exacerbate secondary school biology students' beliefs that men and women differ in their genetic potential for intelligence (Donovan et al. 2019).

Despite widespread recognition that genetic essentialism is a scientifically inaccurate and prejudiced view of human difference (Jackson and Depew 2017; Mayr 1982), essentialist thinking has not received sufficient attention from genetics educators (Donovan 2015b; Stern and Kampourakis 2017). Students are rarely taught how biologists and anthropologists discredited genetic essentialist beliefs about race in the mid-twentieth century by challenging the epistemology and ontology of race science (Donovan 2015b; Jackson and Depew 2017). Students are rarely taught how gender biases influence scientific discourse about biological sex, thereby exacerbating the public's belief in gender essentialism (Donovan et al. 2019; Martin 1991; Snyder and Broadway 2004). Finally, the US standards for genetics education rarely address human inheritance and variation in an anti-essentialist manner (e.g., addressing the complex ways in which genes, the social environment, and social identity interact to create continuous variation in human traits; Donovan et al. 2020; Dougherty et al. 2011; Jamieson and Radick 2013; Lewontin 1996). Altogether, the consequence of inaction by genetics education specialists (i.e., researchers, curriculum writers, teacher educators, and policy makers with professional expertise in genetics education) is that biology teachers continue to lack the educational materials and professional knowledge needed to address issues of social identity during formal genetics instruction, yet this is the context in which students appear to be developing genetic essentialist beliefs about various social groups (Donovan 2014, 2015a, b, 2016, 2017; Donovan et al. 2019; Stern and Kampourakis 2017).

The problematic interplay between genetic essentialism and genetics education is not simply a product of teachers' own beliefs about social groups, nor is it a result of their unwillingness to change their teaching practices. Although it is true that a minority of biology teachers in several countries believe that some ethnic groups are genetically superior to others, many more biology teachers do not endorse genetic essentialism (Castéra and Clément 2012). There also appears to be a growing interest among biology teachers in challenging genetic essentialism (see, for example, *The American Biology Teacher*'s special issue on race). However, using genetics education to reduce belief in genetic essentialism among adolescent students requires much more than an educator's interest and commitment; it requires "educational know-how." Many scholars have advocated for the need to redress prejudice through biology education (for more on this see Beckwith et al. 2017; Dobzhansky 1973; Donovan 2015b; Goldsby 1973; Hubbard 2017a, b; Rudolph 2002). Few, however, have designed and executed empirical studies capable of establishing best practices for achieving this goal. A recent review of the last 20 years of genetics education research indicates that very little empirical work has addressed the interplay between genetics education and social identities (Stern and Kampourakis 2017). Biology teachers that want to educate their students about genetics in ways that reduce social prejudices lack evidence-based approaches for using curriculum and instruction to achieve this goal.

This special issue on Genetics and Identity seeks to strengthen the knowledge base for educators seeking to address the challenge of genetic essentialism. Articles in the collection include theoretical and empirical studies that address the psychological and sociocultural considerations involved in teaching genetics in order to foster changes in beliefs about genetic

essentialism. Across the seven papers, instructional and curricular issues related to race, gender, sexuality, and disability are discussed, and many different approaches for measuring essentialist beliefs about these social identities are described and evaluated.

The special issue begins with a hermeneutic analysis of twenty-first century biology textbooks by John Willinsky. Using eleven contemporary high school textbooks, Willinsky explores the ways in which race is directly and indirectly addressed when texts describe genetic disorders, human origins, skin color, eugenics, and race. He finds that race is referred to directly or indirectly in all but one textbook, and that in many texts, mixed messages about how to conceptualize race are communicated to students. The sample of textbooks contains messages that indirectly support genetic essentialism as well as those that indirectly refute it. Rather than criticizing the texts for their ambiguous, inconsistent, and indirect treatment of race, Willinsky proposes that such variability is a curricular affordance that may be used to help students understand the complicated history of the race concept in science. He concludes that genetics educators should provide students with learning opportunities that help them to interrogate the racial information contained in textbooks, examine the historical use of the 'race concept' in biology, and attend to contemporary racial issues that genetics researchers face.

The second paper by Brian Donovan, Monica Weindling, and Dennis Lee explores if and how formal instruction about genetics influences belief in genetic essentialism about race among adolescent students ($N = 254$, 7th–12th graders). Grounded in psychological and sociocultural theories of conceptual change, their quasi-experimental design contrasts the learning that occurs in classrooms oriented toward basic genomics literacy to the learning that occurs in classrooms oriented toward more humane forms of genomics literacy (i.e., genetics education organized with the epistemic aim of refuting genetic essentialism of race). Over a 3-month instructional intervention, they show that using a curriculum oriented toward humane forms of genomics literacy enhanced student knowledge of multifactorial genetics and decreased genetic essentialist perceptions, attributions, and beliefs. Donovan et al. argue that when genetics education is structured for humane aims, it can be an effective tool for challenging students' beliefs in the genetic essentialism of race.

The third paper in the special issue by John Tawa builds upon the work of the first two. The study employs a randomized control trial (RCT) with adult participants ($N = 116$) using a multidimensional instrument to assess essentialist beliefs about race. In particular, the study explores how exposure to social constructionist descriptions of race affects essentialist beliefs. Tawa finds that essentialist beliefs about race are not a unitary construct, and that different dimensions of these beliefs are impacted in different ways by his video-based educational interventions. Using learning theories about the situated nature of conceptual change, Tawa argues that genetics education will be more successful at reducing essentialist beliefs about race if it also provides students with opportunities for building a social constructionist conception of race. He argues that anti-essentialist learning goals and social-constructionist learning goals are two sides of the same coin, and that educators need to attend to both goals to reduce racial prejudice. This means that a science education paradigm that aims to reduce belief in genetic essentialism must not shy away from social science when instructing students about genetic science.

The fourth paper builds upon Tawa's argument about the need for a more interdisciplinary approach to genetics education. It also broadens the special issue's focus beyond race by exploring educational considerations about sex, gender, disability, and sexuality. Amelia Hubbard and Laurel Monnig propose a comprehensive framework for tackling essentialist

beliefs about all social identities that is rooted in four-field anthropology. They emphasize that anthropological concepts such as holism, biocultural causation, cultural relativism, and cross-cultural inquiry can help students understand human identity in a socially responsible and scientifically accurate manner. These concepts, they argue, can also help educators think about the tacit assumptions they make when teaching about social identity. Hubbard and Monnig also argue that their framework can help teachers address preconceptions and biases that students often bring into the classroom. Examples from their own undergraduate courses illustrate their approach to genetics education.

In the fifth paper, Molly Stuhlsatz, Zoë Buck Bracey, and Brian Donovan provide some empirical support for Hubbard and Monnig's suggestions for teaching about gender during school genetics. Stuhlsatz and colleagues explore how learning about the genetic basis of sex differences influences gender essentialist thinking. Using a RCT ($N = 460$ students in 8th–10th grade) and content analysis, they investigate if the cognitive conflation of sex (a biological concept) and gender (a social concept) in student writing samples differs after students engage with different text-based learning activities about sex and gender. In two of their study conditions, students read about the genetic basis of (i) plant sex or (ii) human sex in a traditional manner; in the third condition, they read about how gender disparities in complex traits are reproduced through unexamined societal beliefs about genes, rather than genes themselves. They find that students learning about plant and human sex tend to subconsciously conflate sex and gender more often than students who learn that gender disparities are not genetic. Using these results, the authors argue that educators need to help students disentangle the differences between sex and gender in order to facilitate changes in gender essentialism. In line with other contributors to this special issue, Stuhlsatz et al. contend that genetics teachers should integrate social-scientific understandings about gender concepts into genetics instruction about sex determination in order to reduce belief in genetic essentialism of gender.

Whereas the first five papers in the special issue consider formal classroom learning, the sixth paper by Alexandre Morin-Chassé asks readers to consider the informal ways in which people learn about social identity and genetics. Morin-Chassé uses data from a RCT to examine how journalistic reports about behavioral genetics research affect belief in genetic essentialism in a sample of US adults ($N = 965$). Morin-Chassé finds that belief in genetic essentialism is the highest after adults read journalistic reports about behavioral genetics research that report high heritability statistics. Belief in genetic essentialism is also high after adults read articles that include essentialist interpretations of genetic results, yet Morin-Chassé finds that journalistic reports including cautious interpretations of behavioral genetics research differentially affect beliefs in genetic essentialism among adults who vary in their educational attainment in biology. Consequently, Morin-Chassé argues that genetics education would benefit from teaching students about the limitations of behavioral genetics research, and the social controversies surrounding it, in order to reduce the risk that journalism about behavioral genetics might exacerbate public belief in genetic essentialism.

The final paper in the special issue addresses the unique challenges of defining and measuring belief in genetic determinism, which is a key subcomponent of belief of genetic essentialism. Through a Rasch analysis of data produced by a large North American undergraduate sample ($n > 800$), Robyn Tornabene, Gena Sbeglia, and Ross Nehm test validity inferences generated by the Public Understanding and attitudes toward Genetics and Genomics (PUGGs) instrument (Carver et al. 2017). The PUGGS was developed in order to measure the quantitative relationships among belief in genetic determinism (BGD), genetics knowledge, and demographic variables. Tornabene et al. explore (i) whether BGD and genetics knowledge

as measured by the PUGGs is multidimensional, and (ii) whether BGD is a domain-general belief system that persists across taxa (e.g., human vs. plant) and traits (e.g., height vs. political orientation). They find that BGD and genetics knowledge as measured by the PUGGs are multidimensional and that BGD differs in severity across traits but not across taxa. On the basis of these findings, the authors highlight the complexities of measuring BGD and the need for robust measurement tools that carefully operationalize target constructs. Empowered with such tools, researchers and educators can begin to meaningfully evaluate genetics education interventions designed to reduce belief in genetic determinism.

Collectively, the picture that emerges from the contributions to the special issue is that genetic essentialist beliefs are multidimensional, context-dependent, malleable, and responsive to carefully designed genetics education interventions. Several different research-based approaches exist for reducing belief in genetic essentialism through genetics education, but all of them require educators to help students construct knowledge about the social complexity of human inheritance and the social controversies and implications of genetics research. Genetics educators will gain insights into many theories and frameworks concerning how to teach genetics to prevent prejudice. Genetics education researchers will find several promising directions for future research concerning the interplay of genetics education and conceptualizations of social identity.

Nevertheless, a research-based consensus is lacking concerning: (a) what genetics content should be taught; (b) how such content should be taught; and (c) whether reducing prejudices about human social identities should be a goal of genetics education. Much more research is needed about: (1) how to measure genetic essentialism and knowledge about the complex relationships among society, biology, and human traits; (2) how to design effective instructional frameworks and curricula for teaching about genetic and social complexity suitable for refuting genetic essentialism; (3) how to strengthen teachers' professional knowledge and skills in relation to the topics noted above; and (4) how to empirically study the generalizability, durability, and downstream effects of refuting genetic essentialism using genetics instruction. Each of these issues is discussed in more detail below.

Issue 1 The first area in need of further research involves measuring genetic beliefs and knowledge. Researchers in the social and behavioral sciences often define and measure the same constructs in different ways (Longino 2013). A case in point can be found in the many different instruments that researchers in this special issue used to measure genetics knowledge and belief in genetic essentialism. Construct heterogeneity can make it difficult to reach a consensus about the effects of genetics education on genetic essentialist beliefs. When researchers define the same construct in different ways, any variation in outcome measures across studies could easily be due to measurement issues rather than sociocultural context or intervention effect differences. Hence, measurement concerns make it difficult to look across the literature to ascertain if the effects of genetics instruction on belief in genetic essentialism is situated in unique sociocultural contexts, or if it is constrained to reasoning about certain social identities, traits, or taxa. These measurement concerns also make it difficult to evaluate which approaches to genetics education are the most effective at reducing a student's belief in genetic essentialism. More attention must be devoted to the development and evaluation of instruments capable of robust measurement of core constructs (cf. Campbell and Nehm 2013).

Issue 2 Several different yet conceptually related approaches to teaching genetics have been proposed and evaluated in the special issue. Nevertheless, empirical evidence is lacking about

which approach is most effective, or whether different approaches may be combined to enhance outcomes. Filling this gap will hinge on resolving the measurement issues noted above. Research is also limited by the paucity of detailed qualitative work that uncovers how sensemaking unfolds during these interventions. Large-scale comparative studies using generalizable samples will also be needed to test the efficacy of new genetics education interventions. Only by integrating the findings of these studies will the field be able to build a robust evidence base suitable for convincing teachers, administrators, and policy makers that it is worth their effort to reform genetics education in order to reduce social prejudice.

Issue 3 Genetics education reform will not be successful without well-prepared teachers. The field lacks a robust research base on how to foster the professional knowledge, skills, and dispositions needed for effectively implementing curricula for reducing social prejudice. None of the papers in the Special Issue empirically explored this topic, yet it is difficult to imagine any significant change to genetics education without clear and evidence-based guidelines for teacher education. Specifically, additional research is needed to shed light on how teachers promote or inhibit sensemaking about genetics and social identity when they teach genetics. Studies are also needed that explore the subject matter knowledge, beliefs, and experiences required for teaching genetics in order to reduce social prejudice. Finally, when teachers themselves harbor social prejudices tied to genetics, empirical studies are needed to inform efforts to change teacher beliefs about social identities.

Issue 4 Finally, large-scale effectiveness trials are needed that explore how teacher level, student level, and curricular level factors moderate the relationship between genetics education, genetics knowledge, and beliefs about social identities. Put a different way, if genetics education as a field is serious about using genetics instruction as a tool for tackling prejudice, then it needs to approach this pursuit like a biomedical researcher approaches the prevention of any illness. Large-scale clinical trials that explore the generalizability, durability, and downstream effects of refuting genetic essentialism using genetics instruction are needed.

Taken together, these suggestions for future research motivated by the contributions to the special issue make it apparent that the science education, biology education, and History, Philosophy, and Science Teaching (HPST) communities have much more work to do in order to reform genetics education to realize its full humanitarian potential.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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