**Research Statement**

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**Overview.** For over a century, biology has been used to rationalize racial and gender prejudice. Prejudiced beliefs based in genetic thinking share a set of assumptions that are scientifically flawed. First is the premise that people of the same social group (e.g. race or gender) are genetically uniform. Second is the premise that people of disparate groups are categorically different. When these assumptions are combined with the belief that biologically influenced abilities are immutable, people will argue that it is pointless to intervene to reduce social inequality because race or gender biologically determines ability. My research program explores how these beliefs and arguments are learned by examining the interplay between biology education and social cognition.

To understand these phenomena, my research uses randomized control trials (RCTs), quasi-experiments, cognitive think-alouds, clinical interviews, focus groups, and video-analyses of teaching along with a variety of different statistical and qualitative data analysis methods. Insights from my research have begun to elucidate how biology education affects the development of sexism and racism. Below, I describe the concepts that drive my research as well as findings from my research program. Along the way, I explain the big questions these explorations have raised and how I intend to investigate those questions over the next five to seven years.

**Dissertation Studies.** Race has been a recurring topic in biology textbooks over the last century. At the start of the 20th century biology texts directly communicated the idea of a racial hierarchy. Today racialist thinking is no longer communicated by biology texts. Yet, racial differences in genetic disease prevalence are still a topic of the biology curriculum. For example, you may recall learning during high school that African-Americans have a high prevalence of sickle cell-anemia or that Northern Europeans have a high prevalence of cystic fibrosis. My dissertation investigated if text-based instruction on racial differences in genetic disease prevalence affects a social-cognitive bias associated with prejudice and stereotyping that is called genetic essentialism.

Genetic essentialism is a belief system which assumes that the genes inherent in people make individuals of the same social group physically and behaviorally uniform and people of different groups physically and behaviorally discrete (Andreychik & Gill, 2014). People who believe in the genetic uniformity of social category members have been found to believe that stereotypes apply to all members of a group (Yzerbyt et al., 2001). When people believe that social groups are biologically discrete categories they also tend to endorse stereotypes (Bastian & Haslam, 2006) because discreteness beliefs facilitate category-based inductions about group members (Gelman, 2004). Finally, when people believe there are inherent differences in the genes of groups, they attribute cognitive and behavioral differences between groups to genetics because believing that groups cohere around inherent characteristics accentuates uniformity and discreteness beliefs (Yzerbyt et al., 2001). Therefore, if learning affects the belief that social groups are genetically discrete and/or the belief that individuals of the same group are genetically uniform, it could affect stereotype endorsement by impacting belief in genetic essentialism. My dissertation explored the plausibility of this mechanism.

The first chapter of my dissertation, published in *Science Education* (Donovan, 2015b), argued that racial terminology in the biology curriculum can increase belief in genetic essentialism of race during adolescence for reasons described in the previous two paragraphs. In my time at Stanford, I designed and conducted three double-blinded field experiments to test that claim. The first study, published in the *Journal of Research in Science Teaching*, was carried out in eighth grade classrooms in a private school in San Francisco (Donovan, 2014). Students ($N$ = 43) were assigned at random to read about the prevalence of human genetic diseases with or without racial terminology and they responded to items in two validated measures of genetic essentialism of race. Endpoint analyses using ordinary least squares (OLS) regression indicated that students in the racial condition agreed significantly more with items in both measures of genetic essentialism than students in the nonracial condition.

Next, I sought to replicate these findings in a new population drawn from a sample of public high school students in the San Francisco Bay Area ($N$ = 86). Published in *Science Education* (Donovan, 2016), the results of this field experiment replicated the findings from the previous study. Not only did students agree significantly more that races differ in intelligence because of genetics after reading about racial differences in genetic disease prevalence, a qualitative analysis of their responses revealed that they were also more likely to explain the existence of the racial achievement gap by appealing to a genetic cause for it. Furthermore, in this study I showed that students' pre-existing genetic essentialist biases interacted with biology learning materials to negatively affect students' intentions to redress racial disparities in education.

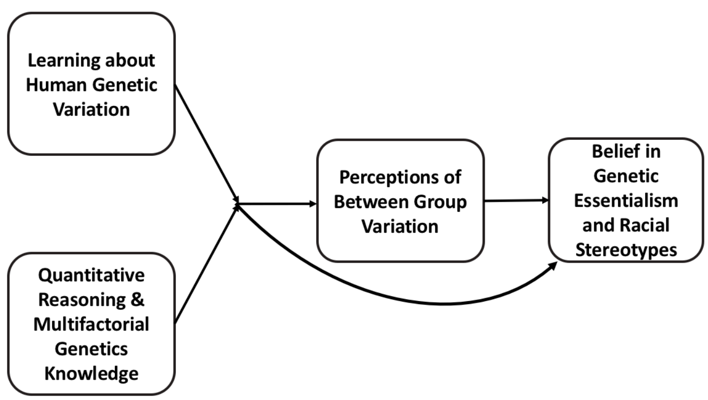
**Post-Dissertation Research at Stanford.** Given my dissertation results, I hypothesized that repeated exposure to racial terminology in the biology curriculum has a cumulative impact on belief in genetic essentialism of race because of a cognitive bias called an availability heuristic. To test that hypothesis, I conducted a three-month double-blinded field experiment randomized at the student level, which was recently published in the *Journal of Research in Science Teaching* (Donovan, 2017). Individual students from Bay Area schools (N = 135, 7-9$^{th}$ grades) were randomly assigned within their classrooms to learn from a curriculum discussing racial differences in skeletal structure and the prevalence of genetic diseases or from an identical curriculum that lacked racial terminology. The four lessons of instruction in each condition used identical readings from the same state approved California textbook. A series of linear mixed models, marginal models, and generalized estimating equations demonstrated that students in the racial condition grew significantly more in their racial prejudices compared to students in the nonracial condition over the three-month course of study. Compared to the nonracial condition, the racial condition grew significantly more in their perception of genetic variation between racial groups and in their belief in genetic essentialism. At the end of the study, the racial condition was significantly more likely to believe that races differ in academic ability for genetic reasons. And, on average, they were significantly less interested in socializing across racial lines and significantly more opposed to educational policies that reduce racial inequality. For this paper, I received the 2017 *National Science Teacher Association Research Worth Reading Award*.

**Current Research.** Findings from my early research program suggest that when biology education increases the perception that races are genetically different it can increase racial bias. But, is the converse also possible? That is, when people learn scientifically accurate information about genetic variation between and within human racial groups can such learning reduce racial bias? I am now exploring this question as the PI of a NSF funded grant "**Towards a More Human(e) Genetics Education: Exploring how Knowledge of Genetic Variation and Causation Affects Racial Bias among Adolescents" (NSF CORE award #** 1660985, USD $1.29 million). This project uses intervention learning materials that engage students in quantitative reasoning, model-based reasoning, and scientific argumentation to help them make sense of variability in the domain of human genetics. My research team then studies how students learn with these materials in formal classroom settings to produce mechanistic knowledge about how genetics education affects racial cognition. We also explore how teachers implement these materials in order to understand the professional knowledge, teaching practices, and student-teacher interactions associated with teaching in this domain. Using this knowledge, we then revise our learning materials through a design-based research (DBR) approach.

The first study from this project is now under review at *Cognition and Instruction*. In this paper, my team randomized 8$^{th}$ and 9$^{th}$ grade students (N = 166) into separate classrooms to learn for an entire week either about the topics of: (i) human genetic variation; or (ii) climate variation. We used a unit on climate variation for a control condition because it ensures that both student groups learn about controversial topics in the media associated with scientific estimates of variation, thereby controlling for cognitive and political confounding. In a cross-over randomized trial with clustering, we demonstrate that the human genetic variation intervention significantly reduces perceptions of between group genetic variation and significantly increases perceptions of within group variation thereby causing a significant decrease in racial biases such as genetic essentialism and stereotyping. We then replicate these findings in two more RCTs, one with adults (N = 176) and another with biology students (N = 721, $9^{th}$-$12^{th}$ graders). These results suggest that teaching about variation in the domain of human genetics has potentially powerful impacts on social cognition during adolescence.

We are now beginning to uncover how these effects occurred by combining Bayesian analyses of RCT data with analyses of cognitive think-aloud data. In the RCT analyses, we have found that our genetics learning materials cause significantly greater reductions in perceptions of between group genetic variation and racial bias among students who score higher on assessments of multifactorial genetics knowledge and quantitative reasoning. To understand how this moderation effect occurred, my research team recently finished a comparative case analysis of transcript data for N = 21 cognitive think-alouds with our intervention materials. We found that students scoring higher on assessments of quantitative reasoning and multifactorial genetics knowledge activate and apply more prior knowledge over time while they are interacting with learning materials than do students who score low on these assessments. These findings suggest that quantitative reasoning and genetics knowledge moderate the effects of the human genetic variation intervention because students with the relevant prior knowledge are able to construct more meaning from intervention materials as they read them. Altogether, the phase one findings from my NSF grant suggest the model of learning in Figure 1.

*Figure 1. Model of Learning supported by phase one of grant*




In phase two of the grant, my research team will use a comparative interrupted time series, focus groups with students, and video-based analyses of the teaching of the intervention to identify social, cognitive, and teacher level variables that mediate and/or moderate the intervention effects on biology learning and social cognition. In phase three, we will use an individually randomized trial with clustering to test pre-registered mediating and/or moderating mechanisms that link the intervention to reductions in cognitive and affective forms of racial prejudice.

My research team is also using this knowledge to design professional developments, presentations, and curriculum for educators. For example, we are offering a professional development at the 2018 meeting of the National Association of Biology Teachers to help high school biology educators teach about human genetic variation more effectively. We are also presenting this work at the 2019 meeting of AAAS to help geneticists understand how to teach about human genetic variation in a more socially conscious manner. Thus, my current research has a strong research-to-practice link.

Over the next five years I intend to push this work into the realm of teacher education through a CAREER grant that explores how high school level biology educators conceptualize race and gender and navigate issues surrounding these categories when teaching about human genetic variation and the genetics of sex differences. In addition to building on the findings from this NSF grant, the CAREER grant will build on my previous scholarship exploring the subject matter knowledge that teachers need to possess to teach about human genetic variation to reduce racial bias (see Donovan, 2015b, 2015a) and also my most current research on genetics education and gender beliefs.

**Gender and Genetics Education**. In a study now under review at *Science Education,* I explore how the content of the genetics curriculum on human sex differences affects the development of beliefs about science ability through its impact on genetic essentialism of gender. Students (N = 460, $8^{th}$ -$10^{th}$ grade) were randomized to read a genetics text that: (i) explained plant sex differences; (ii) explained human sex differences; or (iii) refuted genetic essentialism of gender. After reading, students in the sex conditions (plant and human) had significantly greater belief in genetic essentialism and the innate basis of science ability compared to students who read the text that refuted genetic essentialism. Structural equation modeling of the data demonstrated that the effect of the readings on the belief that science ability is innate was mediated by genetic essentialism and this indirect effect was significant for girls, but not for boys. In turn, the belief that science ability is innate predicted lower future interest in STEM for girls, but not for boys. These findings tentatively suggest that gender disparities in STEM could, in part, be affected by the content of the human genetics curriculum. When the content of the human genetics curriculum challenges genetic essentialism, it could reduce the belief that science ability is innate– a belief that accounts for 29% gender inequality in STEM degree attainment. Currently, I am developing a new grant proposal with Andrei Cimpian (NYU) and Catherine Riegle-Crumb (UT Austin) that will extend this line of research.

**Conclusion.** Biological ideas about gender and racial difference are regularly used to justify social inequality. My work contends that biology education affects how people make sense of social inequality by interacting with social cognitive biases about race and gender. Over the next five years I intend to explore further the intersection between biology education and social cognition in five new ways. For example, one line of research, which I have already begun at BSCS, explores how to improve quantitative reasoning and multi-factorial genetics knowledge in order to reduce genetic essentialism of race and gender. Another line of research I intend to explore is how to improve learning about multifactorial genetics in order to influence the motivation to study science by impacting another form of essentialist thinking, called implicit person theories. I will submit an IUSE proposal with collaborators at Cornell University and the University of Leeds to explore this idea later this year.

Currently, I am also working on a pilot study that explores how genetic essentialism affects attitudes towards environmental justice issues. The rationale behind this idea is that environmental problems are caused by humans, such problems affect different groups of humans in disparate ways, and solutions to such problems depend on the cooperation of human groups. Since beliefs about human groups affect social behavior and policy attitudes, they could also influence how people understand and make sense of environmental problems. If this hypothesis bears fruit, then I intend to open up a new research program that explores how social cognition of human groups affects decision making and reasoning about environmental problems. Finally, the third line of research I intend to develop over my career is how biology education affects homophobia, transgender prejudice, and ableism. In closing, my research into the intersection of biology education and social cognition could help us understand how to design a better biology education– one that improves scientific reasoning about complex biological phenomena in order to reduce social-cognitive biases that perpetuate social inequality.