Research Statement

Brian M. Donovan

Overview. For over a century, people have argued that it is pointless to intervene socially to reduce social inequality because racial or gender difference is genetically determined. My research program explores how these beliefs are learned in school biology, and whether they can be unlearned when students construct complex understandings of genetics through curriculum and instruction emphasizing argumentation, model-based reasoning, and quantitative reasoning. To explore these questions, I use theories from social-psychology and cognitive science to design field studies that employ randomized control trials (RCTs), quasi-experiments, cognitive think-alouds, clinical interviews, focus groups, and video-analysis. Insights from my research have begun to show how biology education affects the development of prejudice, for better or worse.

Dissertation. Racial differences in genetic disease prevalence are a core component of any genetics curriculum (Morning, 2011). My dissertation investigated if text-based instruction on racial differences in genetic disease prevalence affected belief in genetic essentialism, which is a social-cognitive bias implicated in prejudice and stereotyping. Individuals who endorse genetic essentialism believe 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, Corneille, & Estrada, 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 stereotyping through genetic essentialism. My dissertation explored the plausibility of this mechanism.

Published in *Science Education* (Donovan, 2015b), the first chapter of my dissertation used genetic essentialism theory (GET) (Dar-Nimrod & Heine, 2011) to argue that racial terminology in the biology curriculum can increase belief in genetic essentialism of race during adolescence by affecting causal reasoning and social categorization. At Stanford, I designed and conducted three double-blinded field experiments (i.e. RCTs) to test this hypothesis. 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. 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 sample of public high school students in the San Francisco Bay Area (N = 86). Published in *Science Education* (Donovan, 2016), the results of this RCT replicated the findings of the first. Given these results, I hypothesized that repeated exposure to racial terminology in the biology curriculum would have a cumulative impact on belief in genetic essentialism of race by leading students to perceive more genetic variation between races and less genetic variation within races.

To test this hypothesis, I conducted a three-month long, double-blinded RCT, which was published in the *Journal of Research in Science Teaching* (Donovan, 2017). Individual students from Bay Area schools (N = 135, 7-9th grades) were randomly assigned within their classrooms to learn from a curriculum discussing racial differences in skeletal structure and the prevalence of genetic disease or from an identical curriculum that lacked racial terminology. Students in the racial condition grew significantly more in belief in genetic essentialism compared to students in the nonracial condition over the three-month course of study. Compared to the nonracial condition, students in the racial condition also grew significantly more in the *misperception* that there is more genetic variation between races than there is within them. These finding suggest that when students learn about the prevalence of specific genetic diseases in particular racial groups it could unintentionally lead students to make two incorrect inferences that strengthen belief in genetic essentialism. The first is that, if each group has its own special disease, then people of the same race must be highly uniform. The second is that, if disparate groups suffer from different diseases, then racial groups must be categorically different. For this paper, I received the 2017 *National Science Teacher Association Research Worth Reading Award.*

Current research. Findings from my early research program suggested that when biology education increases the perception that races are genetically different it can increase prejudice. But, is the converse also possible? That is, when people learn that there is, in fact, more genetic variation within races than there is between them, then 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 genetic science. My research team then studies how students learn with these materials to produce mechanistic knowledge about how genetics education affects social cognition of race. Using this knowledge, we then revise our learning materials. Thus, my current research employs a design-based research (DBR) approach.

The first study from this project was recently published in *Science Education* (Donovan, Semmens, et al., 2019). In this paper, my team randomized 8th and 9th 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. In a cross-over randomized trial with clustering, we demonstrated that the human genetic variation intervention significantly reduced perceptions of between group genetic variation and significantly increased perceptions of within group variation, which in turn caused a significant decrease in genetic essentialism and stereotyping. We then replicated these findings in two more RCTs, one with adults (N = 176) and another with biology students (N = 721, 9th-12th graders). Statistically, we have found that our genetics learning materials cause reductions in belief in genetic essentialism by increasing student understanding of genetic variation. Moreover, these reductions are statistically amplified for students who possess more multifactorial genetics knowledge.

To better understand the cognitive basis of these statistical findings, 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 our learning materials. This process allows these students to leverage more of the affordances in the materials to construct the understanding that there is more genetic variation within racial groups than between them. Our previous experiments found that when students develop this idea, it leads them to lower their belief in genetic essentialism (Donovan, Semmens, et al., 2019). Consequently, it appears that expertise (Chi, Glaser, & Rees, 1982) in genetics enabled the effects we observed in the RCTs. We currently have a paper under review at JRST describing these findings. Additionally, my lab has produced corroborating results for this expertise effect in middle and high school students through an analysis of data from a quasi-experiment and focus groups. Currently, my lab is using video analysis and a cluster randomized trial to explore how teacher expertise interacts with our intervention curriculum to affect student's belief in genetic essentialism through knowledge of multifactorial genetics. This work builds on my previous scholarship exploring the knowledge that teachers need to possess to teach about human genetic variation to reduce racial bias (see Donovan, 2015b, 2015a). I am also in the process of validating an assessment of multifactorial genetics knowledge for high schoolers.

Finally, my research program is also moving into the domain of gender essentialism. Recently, I published a field experiment in *Science Education* that explored how the content of the genetics curriculum on sex differences affects the development of beliefs about science ability through its impact on genetic essentialism of gender (Donovan, Stuhlsatz, Edelson, & Buck Bracey, 2019). Students (N = 460, 8th -10th 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. Relative to students in the refutational condition, students in the two sex conditions (plant and human) grew significantly more in their belief in genetic essentialism and also in their belief that science ability is innate. 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 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. I recently submitted a NSF CORE grant to extend this line of research.

Conclusion. My work contends that biology education affects how people make sense of social inequality by interacting with social cognitive biases about race and gender. Findings from my research could help us to understand how to design a more humane genetics education– one that improves scientific reasoning about complex biological phenomena in order to reduce social-cognitive biases that perpetuate social inequality.