Challenging Misconceptions about Race in Undergraduate Genetics

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ABSTRACT

Racial biases, which harm marginalized and excluded communities, may be combatted by clarifying misconceptions about race during biology lessons. We developed a human genetics laboratory activity that challenges the misconception that race is biological (biological essentialism). We assessed the relationship between this activity and student outcomes using a survey of students' attitudes about biological essentialism and color-evasive ideology and a concept inventory about phylogeny and human diversity. Students in the human genetics laboratory activity showed a significant decrease in their acceptance of biological essentialism compared with a control group, but did not show changes in color-evasive ideology. Students in both groups exhibited increased knowledge in both areas of the concept inventory, but the gains were larger in the human genetics laboratory. In the second iteration of this activity, we found that only white students' decreases in biological essentialist beliefs were significant and the activity failed to decrease color-evasive ideologies for all students. Concept inventory gains were similar and significant for both white and non-white students in this iteration. Our findings underscore the effectiveness of addressing misconceptions about the biological origins of race and encourage more research on ways to effectively change damaging student attitudes about race in undergraduate genetics education.

INTRODUCTION

The belief that racial groups[1] are genetically determined persists among the general public, including health and STEM (science, technology, engineering and mathematics) professionals (Jayaratne, 2006, 2009; Roth, 2023). This mindset continues even though it is contrary to scientific understanding of human genetic diversity and the clear sociological and historical context of race categorization (Norton *et al.*, 2019; Visintainer, 2022). This belief, that social, cultural, and other aspects of a person's identity are attributes of their biological makeup, is known as *biological essentialism* (Bailey and Knobe, 2023). Scientific understanding of human genetic diversity, however, does not provide support for biologically constructed races (Smedley and Smedley, 2005; McChesney, 2015). Furthermore, this misconception is contradictory to the consensus held by most social scientists that race is "a social construct that artificially divides people into distinct groups" (Wijeysinghe *et al.*, 1997). Those holding fast to the false ideas underlying biological essentialism tend to be more accepting of racial prejudices, believing differences across racial groups arise from individual biological make-ups and not from social constructs (Bastian and Haslam, 2006;

[1]In the context of this paper, when we mention racial categories, we are referring to the racial classifications defined by the U.S. Census Data at the time of publication. We acknowledge that the concept of race is a social construct historically used to assert the superiority of one group over another. As white authors, we recognize that we possess certain privileges not earned through our own actions. It is important to note that while race is a factor we consider, the ethnicity of the participants was not included in the data collection process. Consequently, our analysis relies solely on the self-reported racial information provided by the participants.

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William and Eberhardt, 2008). Essentialist beliefs about race contribute to the reinforcement of social hierarchies as natural, perpetuating existing hierarchies through bias against marginalized social groups (Smedley and Smedley, 2005; Mandalaywala *et al.*, 2018).

Historically, racial prejudices associated with biological essentialist thinking have been explicit. For example, Charles Davenport tried to prove that personality characteristics and unfavorable traits such as alcoholism and criminality were inherited in Mendelian manner in an attempt to prove a genetic basis for white supremacy (Allen, 1983). However, while explicit prejudices have been declining in the United States over the past few decades (Dovidio *et al.*, 2000; Charlesworth and Banaji, 2022), implicit biases, like color-evasive ideologies (Bonilla-Silva 2018; King *et al.*, 2023), have been growing throughout the socioeconomic and governmental infrastructure of the United States (Vela *et al.*, 2022) and are even perpetuated by biology instructors (King *et al.*, 2023). Someone who exhibits color-evasive racist ideologies may claim to not "see" skin color and believe that all outcomes from any given group are based on individual merit, neglecting the systematic inequalities that were previously constructed based on racist ideologies (Jones, 2016). Engaging in color-evasive thinking, which denies the existence of racism, legitimizes the current system and undermines any corrective efforts to address inequities (Gushue and Constantine, 2007).

Both biological essentialist and color-evasive ideologies perpetuate the systemic disadvantage of people of certain races. However, the relationship between biological essentialism and color-evasive racism is currently unknown, as previous studies have only measured the link between biological essentialism and explicit racial biases. Notably, this relationship is hypothesized to be causal (Mandalaywala *et al.*, 2018). We hypothesize that individuals who understand that race is socially constructed may likewise understand the social ramifications of race, and thus there may be a link between color-evasive racism and biological essentialism. Here, we designed a genetics laboratory activity to address erroneous biological essentialist beliefs about race. We ask how this activity changes student biological essentialist beliefs and whether their color-evasive ideologies likewise shift.

Biological Essentialism in Science

With the persistent misuse of genetics research to justify racism, scientists have actively and outwardly rejected the use of "race" categories in genetic and medical research (Yudell *et al.*, 2016; Cho *et al.*, 2023). Several prominent organizations have held workshops and launched investigations into the problematic use of race in genomics and medical research (e.g., the National Academies of Sciences and Medicine, NASM, 2023; American Society of Human Genetics, Jackson *et al.*, 2023; the National Human Genome Research Institute & National Institute of Minority Health and Health Disparities, 2016). In undergraduate genetics courses, clarifying race as a social construct is rarely emphasized, partially due to instructors being hesitant to talk about race (King *et al.*, 2023), leaving students to make uninformed inferences about the role of genetics in race categories. Rather, instructors prefer to adhere to a "value-free" curriculum that portrays science as objective and enlightened (Beatty *et al.*, 2023). We argue that more work needs to be done to address biological essentialism when designing genetics learning activities. Without explicitly addressing this misconception, students may make assumptions about genetic origins of racial groups.

While few studies have directly measured student conceptions of race, those that have found that students frequently conflate race with ethnicity or possess an incorrect and problematic understanding of the term (Morning, 2009). For example, one investigation found many instances in which students agreed with the statement, "There are biological races in the species *Homo sapiens*," (Morning, 2011, p. 154). When compared with anthropology students, Morning (2009) found biology students were more likely to define race using physical characteristics. Furthermore, biology students never defined race as socially constructed (Morning, 2011). Previous work also shows an association between race labels used in examples of genetic diseases and increased biological essentialism among students (Morning, 2011; Donovan, 2014, 2016, 2017; Willinsky, 2020). This underscores the need for explicit instruction in biology courses that emphasizes race as a social construct.

Current Approaches to Addressing Biological Essentialism in Biology

Previous research on classroom activities details ways to address student perceptions of race when teaching genetics topics. For example, studies have shown that standard genomics instruction on population genetics can decrease genetic determinism and essentialist misconceptions (Hubbard, 2017; Jamieson and Radick, 2017; Donovan *et al.*, 2021) and even racial biases (Donovan *et al.*, 2019). However, genomics and population genetics are rarely taught in introductory biology or genetics courses (Dougherty, 2009; Redfield, 2012; Boerwinkel *et al.*, 2017). Numerous articles underscore the necessity of biology courses addressing misconceptions related to genetics and race, as highlighted by Hales (2020), Hubbard (2017), and Beckwith *et al.* (2017). Nevertheless, our search yielded limited explicit instances of effective interventions. Donovan *et al.* (2021) implemented an experimental activity to explain and decrease essentialist thinking among 7th to 12th grade students. In comparison to students engaged in a control activity about climate, students in the treatment group displayed increased genetics knowledge and decreased essentialist perceptions, attributions, and beliefs. While these basic genetics principles such as the DNA "blueprint" metaphor (Parrott and Smith, 2014) or "gene for this disease" language (Lynch *et al.*, 2008), are important ideas for genetics students to learn, instructors often omit the nuances and limitations of these models for more complex phenomena, such as the failure of Mendelian genetics to describe the inheritance of eye and skin color because the mechanisms of inheritance are much more complex. Donovan found that failure to discuss these nuances can increase essentialism in students (Morning, 2011; Donovan, 2014, 2016, 2017; Willinsky, 2020). Additionally, genetics topics that emphasize differences in humans can potentially set the stage for microaggressions and feelings of alienation (Hales, 2020). There is a clear need to incorporate and test the effects of new activities designed for students in introductory genetics that simultaneously decrease essentialist views while teaching foundational concepts in genetics. Thus, following Donovan's work, the activity studied here focuses on teaching both fundamental genetics concepts

(e.g., phylogeny) while also discussing the limitations and nuances of applying such models to more complex genetic mechanisms (i.e., skin color).

Why Don't Biology Instructors Talk about Race?

Biology instructors report that teaching about topics such as race can be intimidating due to lack of experience resulting from their own undergraduate exposure to the traditional, "value-free" STEM curricula (Beatty *et al.*, 2023). However, integrating biological and societal concepts provides students with several benefits, such as opportunities to apply scientific and moral reasoning to real-world contexts (Hales, 2020; Beatty *et al.*, 2021; Costello *et al.*, 2023). Biology educators are uniquely suited to teach about race (O'Connell *et al.*, 2022) and have been called to do more to address race and racial bias in the classroom (Donovan, 2022). More broadly, creating sustainable change beyond the timeline of an intervention in instructional practices can be challenging, as this requires convincing other instructors of the need for change (Stark and Smith, 2016), providing adjustment time for instructors to feel confident in a new curriculum (Lewis, 2006), and offering vetted curricular materials (e.g., from the journal CourseSource).

Motivating the Current Study

Several prior studies have informed the design and analysis of the activity which is the focus of this study. Culturally relevant pedagogy, defined by Ladson-Billings (1995), emphasizes student success, cultural competence, and sociopolitical consciousness in teaching behaviors. According to Young (2010), the role of culturally relevant pedagogy and sociopolitical consciousness is to encourage students to "question, challenge, and critique structural inequalities that exist in society" (Young, 2010). Both Young (2010) and Costello *et al.* (2023) argue that sociopolitical consciousness is a component of culturally relevant pedagogy that is implemented and reported on less than the other two pillars of culturally relevant pedagogy, student success and cultural competence. Our work aims to increase student sociopolitical consciousness through education on essentialism using a human genetics laboratory. For example, after engaging in discussions that contradict biological essentialism, we ask students to consider the real-world consequences of making assumptions about someone's race based on physical characteristics (see Supplemental Information).

In developing the laboratory activity and this study, we also used the idea of preparation for future learning (Bransford and Schwartz, 1999; Sears, 2017). In preparation for future learning, students attempt an activity or make a prediction (an "invention" activity) before receiving instruction on the scientific consensus. Often, instructors might use contrasting cases to help students identify salient features of mathematical or scientific models to assist them in coming up with models or rules for how systems might behave. This stands in contrast to many student-centered pedagogical activities in which students are first given instruction on the scientific consensus before being asked to apply those ideas to solving problems. Preparation for future learning has been shown to be more effective than an invention activity without a follow-up lecture or a lecture alone (Schwartz and Martin, 2004), as it both draws on students' prior knowledge and provides timely feedback to cement the understanding of the ideas.

We designed our activity to ask students to make predictions based on their current understanding of human diversity and then use scientific data to determine whether their predictions match the data. Once students finish the activity, the instructor discusses the results with the students to support student learning and explicitly articulate the baselessness of race as a biological concept. This postactivity discussion is an essential part of the activity as the "invention" part of the activity could unintentionally *reinforce* biases that students might have by asking them to engage in using physical features to identify race or ancestry. The discussion had students reflect on their own misconceptions about race (from the beginning of the activity) and discuss the implications of these misconceptions in their interactions with people of different races.

Scholars of critical race theory suggest that we should acknowledge our positions, biases, and privileges as researchers (see positionality statement below; Pearson *et al.*, 2022). Moreover, we must work to understand and mitigate previous harms done to historically marginalized groups in the name of scientific inquiry and discovery (Graves, 2003; Cech and Waidzunas, 2021; Reinholz and Ridgway, 2021). Indeed, this study was motivated as a way to counter the harmful ways that genetics and evolutionary biology have been used against marginalized populations. For example, many eugenicists suggested that traits such as criminality were hereditary and linked with race (Allen, 1983). More salient to this context is eugenicists' focus on the relationship between intelligence and race (Levine, 2017). The belief that white Americans are more intelligent than Black Americans and that intelligence is hereditary persists to this day through stereotype threat (Brown, 2019). We acknowledge this racist past and aim to counter those false ideas through this activity and this research project. Specifically, we hope that, by engaging students with the idea that race is not biological in origin, we can counter harmful stereotypes in the classroom that someone's race thus determines their intelligence.

Current Study: Measures of Proficiency and Prejudice

Here, we incorporated a self-contained lesson into a single genetics laboratory class and evaluated its relationship with students' perceptions of race. Human genetics is a suitable context in which to address erroneous beliefs about race, and we used the genetic code to demonstrate how closely related all humans are. In doing so, this laboratory activity targeted the common misconception among biology students that race is biological in origin. However, students may learn to reject the idea that race is biologically derived while still holding racist views and prejudice. In this case, students exhibit "implicit ambivalence," a change in explicit attitudes after exposure to evidence but without a simultaneous change at the unconscious level (Bohner and Dickel, 2011). In other words, students may be proficient in data-based conclusions that undermine race as a biological concept, while still adhering to prejudice and color-evasive ideologies. We addressed this by distributing a survey consisting of multiple subscales: the subscale targeted the content of the genetics lab exercise by measuring the extent to which students believe that race is biologically derived (i.e., biological essentialism); the second and third subscales measured student prejudice through their beliefs in color-evasive racial ideologies. We also used a concept inventory consisting

of two subscales to measure student understanding of the course materials focused on phylogenetics and human diversity.

Stage *et al.* (2007) suggest that racial differences in student outcomes are not measures of student deficiencies, but rather a reflection of bias in the measurement itself or the system in which the students are embedded. While typically applied to performance metrics, scholars have recently extended this to look at changes in affective outcomes such as science identity (Potvin *et al.*, 2023). In this study, we investigate differences in color-evasive beliefs and biological essentialist beliefs between white students and non-white students. Prior work (Mandalaywala *et al.*, 2018) has shown differences between white and non-white students' ideas about biological essentialism. Those authors theorize that race/ethnicity may be more central to the identities of non-white students, and thus a different approach might be needed for different groups of students. In the current study, we were motivated to investigate these differences primarily to determine whether we were inadvertently harming students from non-white racial groups. Furthermore, any observed differences would motivate future studies concerning potential biases in the measurements themselves—such as social desirability bias for white students—as well as whether it is realistic to affect the attitudes of non-white students on race given how pervasive racism is in their daily lives.

The Primary Research Questions Include

1. To what extent does completing a laboratory about human genetics relate to students' attitudes about biological essentialism and color-evasive ideology?
2. How do these results differ between white and non-white students?

We hypothesized that the students who participated in the human genetics laboratory activity would have greater changes in their attitudes about race (both biological essentialism and color-evasive ideologies) than a control group who completed a different activity related to phylogeny. Additionally, we expected less change in color-evasive ideology among non-white students relative to white students because of their lived experiences as members of racialized groups in the United States. We did not have a strong hypothesis about whether white and non-white students would see different changes in beliefs about biological essentialism, though Williams and Eberhardt (2008) found that white and non-white students scored similarly on the original version of their assessment. This is mirrored in our data below. The possible effect of initial racial attitudes on impact of the activity is addressed in our methodology to determine whether students with stronger biological essentialist views initially see more or less change in their beliefs.

MATERIALS AND METHODS

This research was determined exempt from review by the Auburn University Institutional Review Board (Protocol #21-544 EX 2111).

Positionality Statement

As faculty and staff in the fields of biology and physics education, we (the authors) engage in STEM education and research regularly. We believe it is important to understand one's own position and how that might affect interpretation of the data (Secules *et al.*, 2021). We identify as white *cis*-men and women, one author identifies as Jewish, and one author identifies as part of the LGBTQIA+ community. Although we cannot personally relate to the experiences of non-white students, we believe that our positions of privilege and teaching roles in science departments at a relatively conservative institution in the Southeast should be used to advance antiracist ideas. We are aware of the shortcomings in teaching about race in STEM higher education but aim to continue to improve by incorporating inclusive approaches in our teaching and mentoring, studying outcomes, and carefully listening to feedback.

Our study design was motivated by our consciousness to not perpetuate further harm against non-white students. For example, the postactivity discussion emphasized how making erroneous assumptions about race based on physical characteristics can be harmful. Our second research question was not motivated by an attempt to see whether the activity was equally "effective" for white and non-white students but was rather an attempt to ensure that we had not caused harm to non-white students with the implementation of this activity. We also followed-up the first implementation of the activity by interviewing non-white students to get their perspectives on whether this activity was helpful or may have caused harm, rather than relying on our own perspectives and observations. (We note that these interviews are not the focus of this study, but they did give us some confidence in moving forward with the activity.)

Human Genetics Laboratory Activity

We designed the human genetics laboratory activity using the principles of culturally relevant pedagogy and preparation for future learning to explicitly demonstrate that there is no genetic basis for race. Briefly, the activity used computer generated pictures ("Average Faces From Around The World," 2022) that depict average faces of populations from around the world and asked students to predict the population of origin for each picture, using the five major populations from the Human Genome Project (see Supplemental Material S2: Human Genetics Activity). Students were then assigned one of 11 distinct sets of single-nucleotide polymorphisms (SNPs), with each set comprising a total of seven alleles derived from genes linked to skin pigmentation.

From this sample of genetic variation, students used the 1000 Genomes Project database to match their set of SNPs to one of the five major populations in an effort to determine which population best matched their SNP set. Using skin pigmentation SNPs and population data from the 1000 genomes project via ensemble.org students estimated the probable population for each set of SNPs (the "invention" part of preparation for future learning). Following the activity, the students engaged in an instructor-led discussion, a crucial element of the activity, that addressed the results of the activity and the inaccuracies in the information they had obtained. The students used seven SNPs from skin pigmentation genes for this activity. In the discussion, they are confronted with information that ancestry tests typically use over 700,000 SNPs and this information remains probabilistic rather than firmly grounded in scientific certainty. We then discussed the complexity of skin pigmentation genes along with an explanation of their results, demonstrating why genes (in this case skin pigmentation

TABLE 1. Summary of research instruments

Instrument	Construct	Subscales	Questions	
			Original	Used
Survey	Color-evasive Ideology	Racial Privilege (CoBRAS Factor 1)	7	6
	Color-evasive Ideology	Institutional Discrimination (CoBRAS Factor 2)	7	4
	Biological Essentialism	Biological Essentialism (Racial Concepts Scale)	22	7
Concept Inventory	Phylogeny	Basic Tree Thinking Assessment	7	7
	Human Diversity	Human Diversity Quiz	13	13

Note that, in the Spring semester, all instruments were administered in a pre, post, follow-up format, whereas there was only a pretest and posttest in the Fall semester.

genes) cannot be used to determine race. Furthermore, the discussion delved into the misuse of race in medical diagnosis and highlighted the ever-changing nature of racial classifications, often influenced by current political climates. For example, racial classification in the United States has changed as recently 2020, when the U.S. Census allowed citizens to write-in their racial identity, and disaggregated questions about Latino ancestry (U.S. Census, 2020). Finally, we discussed definitions of and distinctions between race, ethnicity, ancestry, and identity, and how these terms are problematically conflated (the explanation part of the activity). Note that we used skin pigmentation as the physical characteristic used to address essentialism as it is the most notable physical feature that people use when guessing about a person's race (Cokley, 2007).

The control group in this experiment completed a lizard phylogeny activity from HHMI Biointeractive ("Using DNA to Explore Lizard Phylogeny," 2022). In this lab, students hypothesized how phenotypically similar lizards on different Caribbean islands evolved. Did the phenotypically similar lizards evolve over a single island and then disperse? Or did they evolve independently, yet similarly, on each island? The activity explained what traits allow each type of lizard to thrive in its niche, specifically by comparing five different types of lizards: trunk-ground, trunk, twig, trunk-crown, and crown-giant. The students re-evaluated their previous hypotheses (the "invention" part of preparation for future learning) based on the new information (the scientific consensus explanation). The students then used an online software program to create a phylogenetic tree using mitochondrial DNA that included the NADH dehydrogenase subunit 2 (ND2) gene and five tRNA genes. These genes are highly conserved, allowing one to compare distantly related species, but they are also variable enough to be unique to each individual species. From this tree activity, the students learned that the species of lizards on a single island are more closely related than phenotypically similar species on different islands (the explanation part of the activity). After the activity, the students were led in a discussion on adaptation, adaptive radiation, and convergent evolution. This activity serves as an appropriate control because both activities conclude that grouping by phenotype is inaccurate. In addition, lizards can be grouped, classified, and used in teaching about genetic variation, populations, and phylogenetic relationships without the social and historical contexts and biases that apply to humans.

The human genetics and lizard phylogeny activities were implemented in a genetics laboratory course in the spring and fall semesters of 2022 at Auburn University. This genetics course consisted of eight sections with up to 32 students per section and four graduate teaching assistants, each assigned two sections. In the spring of 2022, E.M.B. taught all eight sections during the week the Human Genetics activity and Lizard Phylogeny activity were completed. The four control sections completed the HHMI Lizard Phylogeny Lab, and the four experimental sections completed the human genetics laboratory. Each graduate teaching assistant oversaw one experimental and one control section to control for any effects of the instructor. Note that the implementation of the activity changed between spring and fall of 2022, which is discussed below under the Research Question 2 heading.

Students were given the option at the beginning of the semester to opt out of the study. Consent forms were signed at the beginning of the semester and stored in sealed envelopes until final grades were submitted. Students were given credit for completing activities, regardless of their choice to participate in the study. In the Spring semester, 149 of 173 students consented to participate and completed all portions of the study.

Students voluntarily completed a survey and concept inventory (Table 1) to assess attitudes and knowledge of phylogeny and human diversity during the first lab of the semester (pretest). The survey covered students' attitudes toward biological essentialism and color-evasive racism, while the accompanying concept inventory covered conceptual knowledge of phylogeny and human diversity. During the eighth laboratory week of the semester, students either completed the HHMI Lizard Phylogeny Lab ("Using DNA to Explore Lizard Phylogeny," 2022) or the human genetics laboratory (see Supplemental Material S4 – Lizard Phylogeny Activity). Both took a single 2-hour laboratory class period. Immediately following the laboratory activity, students voluntarily completed the same survey and concept inventory (posttest). After the last lab of the semester, students were asked again to voluntarily complete the same survey and concept inventory (follow-up test).

Racial Concepts Scale (Measure of Biological Essentialism)

Viewing race as biologically derived increases acceptance of racial inequities (William and Eberhardt, 2008). To measure biological conception of race, or the degree to which an individual accepts biological essentialism, William and Eberhardt (2008) developed the Racial Concepts Scale. We used confirmatory factor analysis (CFA) to determine the scale items included in the single Racial Concepts Scale factor and applied the following criteria: nonsignificant chi-squared, comparative fit index (CFI) > 0.9, Tucker-Lewis index (TLI) > 0.9, standardized root mean square residual (SRMR) < 0.08, root mean square error of approximation (RMSEA) < 0.08 (Taasoobshirazi and Wang, 2016; Knekta *et al.*, 2019; Shi *et al.*, 2019). We

TABLE 2. Fit indices from confirmatory factor analysis of survey. Not all indices fit the stated criteria, possibly due to sample sizes

Survey	Timepoint	Chi-squared	CFI	TLI	SRMR	RMSEA
Biological Essentialism	Pre	12.3	1.00	1.04	0.0495	0.00
Biological Essentialism	Post	29.0	0.911	0.867	0.0621	0.112
Biological Essentialism	Follow-up	25.2	0.942	0.913	0.0503	0.0970
Color-evasive Ideologies	Pre	28.7	1.00	1.02	0.0535	0.00
Color-evasive Ideologies	Post	45.2	0.969	0.959	0.0457	0.0624
Color-evasive Ideologies	Follow-up	38.9	0.990	0.986	0.0487	0.0413

Models were deemed acceptable based on overall criterion (Knekta *et al.*, 2019; Marsh *et al.*, 2004).

sequentially removed survey items with low correlation values until the remaining items best fit the parameters (Table 2). This reduced the Racial Concepts Scale to seven questions, all using a seven-point Likert scale where one signifies "strongly disagree" and seven signifies "strongly agree" (see Supplemental Material S1, page 6–7). The Racial Concepts Scale used statements such as, "A person's race is fixed at birth" and "It's easy to tell what race people are by looking at them." Many different instruments have been designed to measure genetic determinism and conceptualizations of race (Keller, 2005; Bowling *et al.*, 2008; Williams and Eberhardt, 2008; Carver *et al.*, 2017; Tawa, 2017; Yalaci *et al.*, 2021; Stern *et al.*, 2017). However, all these instruments have shortcomings when surveying undergraduate students in biology classrooms (Carver *et al.*, 2017; Yalaci *et al.*, 2021). For example, the scale developed by Carver *et al.* (2017) had lower levels of internal consistency when asking students about genetic determinism compared with other lines of questioning. They also only collected validity evidence from a sample of ~300 Brazilian college students, who may respond to these items differently than American students due to cultural and language differences. We selected the Racial Concepts Scale among these instruments, despite limited validity evidence, because the items most clearly aligned with the learning objectives of the activity set forth by the instructor.

Color-Blind Racial Attitudes Scale (Measure of Color-evasive Ideologies)

We used the Color-Blind Racial Attitudes Scale (CoBRAS) developed by Neville *et al.* (2000) to evaluate students' color-evasive ideologies through their awareness of three different racial issues: racial privilege, institutional discrimination, and blatant racial issues. The CoBRAS scale consists of 20 total questions and uses a six-point Likert scale, ranging from strongly disagree (1) to strongly agree (6). We initially analyzed the CoBRAS factors by exploratory factor analysis (EFA; Knekta *et al.*, 2019). The EFA did not support the blatant racial issues subscale, which was subsequently removed from data analysis. We then used CFA to determine the internal reliability of the racial privilege and institutional discrimination factors (Table 2). The CFA reduced the racial privilege subscale from seven questions to six and the institutional discrimination subscale from seven questions to four. The racial privilege factor, which is reversed scored, measures the degree to which individuals acknowledge the inherent societal benefits of being viewed as "white" (Lawrence and Bunche, 1996). Statements in this subscale include, "Race plays an important role in who gets sent to prison" and "white people in the United States have certain advantages because of the color of their skin." The institutional discrimination factor measures the degree to which individuals believe that discrimination is embedded in policies that yield unequal access to resources, status, or power for specific groups (Smedley and Smedley, 2005). Statements such as "Social policies, such as affirmative action, discriminate unfairly against white people" and "Racial and ethnic minorities in the U.S. have certain advantages because of the color of their skin" are used to measure institutional discrimination. EFA and CFAs were conducted using Jamovi (The Jamovi Project, 2022).

Concept Inventory on Tree Thinking and Human Diversity Concepts

We used a concept inventory that included content from two previously published instruments—one covering basic phylogenetic tree thinking and one related to human diversity—to test whether students understood the core teaching objectives across the control group and the experimental group. We also wanted to determine whether students in the experimental group learned topics related to genetic diversity, which was only a focus in the experimental group. The first part of the concept inventory used the Basic Tree Thinking Assessment created by Baum *et al.* (2005), consisting of concepts covered in both groups. The second part of the concept inventory used the Human Diversity quiz ("RACE - The Power of an Illusion. Human Diversity | PBS," 2022) along with questions about the definitions of race, ethnicity, ancestry, and identity.

Research Question 1: Comparison between Laboratory Activities

Two different scales were combined to create the survey: the Racial Concepts Scale (biological essentialism; Williams and Eberhardt, 2008) and the CoBRAS (color-evasive ideology; Neville *et al.*, 2000) (Table 3).

We used regression analysis to explore how the laboratory activity was related to changes in students' biological essentialism and color-evasive ideology. Using the spring 2022 data, we conducted stepwise linear regression on each survey construct or factor: the Racial Concepts Scale (biological essentialism), the racial privilege factor and the institutional discrimination factor of the CoBRAS (color-evasive ideologies). The full regression models included the laboratory completed as the independent variable and the change in total score for the construct from the pretest to the posttest (i.e., total posttest score minus total pretest score). To control for potential ceiling effects, we also included the pretest score as a covariate. We transformed both the change in total scores and the pretest scores into z-scores, a measure of how many standard deviations (SDs) each students' total score or change in score was from the mean.

TABLE 3. Demographics for data used in the spring 2022 survey constructs

Survey	Laboratory	*N*	Gender identification			Race identification		Other/prefer not to say
			Man	Woman	Nonbinary	White	Non-White	
Color-evasive Ideology	Lizard	38	9	28	1	32	6	1
Color-evasive Ideology	Human	47	13	34	0	42	4	2
Biological Essentialism	Lizard	35	9	26	0	29	6	1
Biological Essentialism	Human	50	15	35	0	44	4	2

Any student selecting Black, Asian, Native American, or two or more races was considered non-white for the analysis. Students who selected Prefer not to say or other were not included in analysis of data but are included here for completeness.

We dichotomously coded laboratory completed, where zero was used for completion of the lizard phylogeny laboratory activity and one was used for completion of the human genetics laboratory activity. We also included an interaction term between laboratory activity completed and pretest score in our regression model. We interpret results from the most parsimonious model. We performed all statistical analyses using IBM SPSS Statistics version 28 (IBM Corp, Armonk, NY) and Jamovi (The Jamovi Project, 2022).

Research Question 2: Differences across Racial Groups

Between the spring 2022 semester and the fall 2022 semester, we made a few notable changes to the activity. First, in fall 2022, all eight sections of the Genetics Laboratory course completed the human genetics laboratory activity (i.e., there was no control section) and were taught by graduate teaching assistants. We made this change for two reasons. First, we wanted to explore whether the outcomes of the human genetics laboratory activity differed by race. As the overwhelming majority of students enrolled in this genetics course are white (Table 3), we decided to increase the sample size of non-white students in our student population by increasing the number of students exposed to the human genetics laboratory activity (Table 4). Second, we wanted to determine whether the efficacy of the activity persisted when taught by graduate teaching assistants, rather than the instructor who developed the activity. In the fall 2022 semester, we used the same survey and concept inventory, but we collected data only at the beginning of the semester (pretest) and immediately following the activity (posttest; i.e., no follow-up data were collected). We also lightly edited the activity in fall 2022 to clarify steps and shorten its length (Supplemental Material S2 – Human Genetics Activity).

Using the fall 2022 data, we used mixed model linear regression analysis to explore whether the relationship between the human genetics laboratory and students' ideas of biological essentialism and color-evasive ideologies varied across racial groups. For biological essentialism, we included the change in the total score for the Racial Concepts Scale from the pretest to the posttest as the dependent variable; race, the total pretest score for the Racial Concepts Scale, and the interaction between race and the pretest score as fixed effects; and graduate teaching assistant as a random effect. We transformed both the change in total scores and the pretest scores into z-scores in our model. Due to the small sample of non-white students, individual race could not be analyzed. Instead, we dichotomously coded student race, with zero for white students and one for non-white students. We used paired *t* tests comparing pre- and post- biological essentialism scores for students taught by each graduate teaching assistant to determine whether all instructors' students had an overall significant change in posttest score compared with pretest score. The choice not to further disaggregate racial data was made not just out of considerations of statistical power, but also considerations of anonymity of the data. Particular students could easily be identified if disaggregated by standard categorizations of race. Though this choice obscures the nuances of racism faced by particular groups (e.g., Asian students being a "model minority" [Walton and Truong, 2023]), we also thought it to be in line with our methodological choice to use skin color as our indicator of biological essentialism in the activity.

We performed a comparable examination for the color-evasive ideology scales, employing mixed model linear regression with the difference between pretest and posttest scores as the dependent variable. The model incorporated the total pretest score for either institutional discrimination or racial privilege, as well as the interaction between race and the pretest score, as fixed effects, using the same dichotomous coding for race. All survey scores were converted to z-scores before analysis and the graduate teaching assistant was considered as a random effect in the analysis.

RESULTS

Research Question 1: Comparison between Laboratory Activities

We found a significant and medium-sized (Maher *et al.*, 2013) effect of laboratory activity on the change in students' biological

TABLE 4. Demographics for data used in the fall 2022 survey constructs

Survey	Laboratory	*N*	Gender identification			Race identification		Other/prefer not to say
			Man	Woman	Prefer not to say	White	Non-White	
Racial Privilege	Human	145	32	111	2	123	16	14
Institutional Discrimination	Human	147	32	113	2	124	17	14
Biological Essentialism	Human	142	32	108	2	120	16	9

Any student selecting Black, Asian, Native American, or two or more races was considered non-white for the analysis. Students who selected Prefer not to say or other were not included in analysis of data but are included here for completeness.

TABLE 5. Biological essentialism regression table for spring 2022

Post – Pre	b_0	b_{LC}	b_{Pre}	$b_{(LCxPre)}$	R^2
LC + Pre + (LC x Pre)	0.485 (0.160) **	–0.782 (0.208) ***	–0.323 (0.153) *	0.252 (0.207)	0.138

Note: Regression equations are determined by best-fit model (see Supplemental Table S1 for stepwise regression table); Dependent Variable = Posttest minus Pretest; LC = laboratory completed, where Lizard Lab = 0 and Human Genetics Lab = 1; Pre = standardized pretest score; LC x pre = Interaction term of laboratory completed and standardized pretest score; R^2 is adjusted R^2; Coefficient standard error in parentheses; ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$.

essentialism (β = –0.782 0.208; $p < 0.001$; Table 5). Students' scores on the biological essentialism scale on the posttest ($\bar{x}$ = 24.06; 0.976) for the human genetics laboratory activity were lower than the pretest scores ($\bar{x}$ = 29.68; 0.714; Figure 1). The students participating in the lizard activity also had lower posttest scores ($\bar{x}$ = 29.8; 1.051) on the biological essentialism scale compared with their pretest scores ($\bar{x}$ = 31.6; 0.929), but this difference was not statistically significant. Higher scores for biological essentialism indicate that students tend to believe that race is biological. We found a drop in biological essentialism scores overall, indicating a less biological understanding of race, but found a much larger drop for students who completed the human genetics laboratory activity (Figure 1). Our model controlled for pretest scores, meaning that differences in pretest scores did not account for the significant change in scores observed between the two types of laboratory activities (Table 5). The interaction term was not statistically significant, indicating that the correlation between pre-post change and pre-score did not differ between the two laboratory activities. We further found that the laboratory activity completed did not seem to be related to change in color-evasive ideology scores, for both the racial privilege and institutional discrimination subscales (Figure 2; Supplemental Tables S2 and S3).

Using the same regression model as above, except using follow-up test minus pretest as the dependent variable, we found that the effect of the lab lasts through the end of the course (3 weeks later; see regression tables in Supplemental Material S1, pages 2–5), though the effect is somewhat smaller at the follow-up time point (β = –0.470 instead of –0.782).

Students' scores on the concept inventory increased from pretest to posttest and from pretest to follow-up for both the phylogeny subscale and the Human Diversity subscale (Figure 3). Even though all students increased their knowledge in both subject areas, students who completed the human genetics laboratory activity had more than a 2-fold increase in their human diversity concept inventory score after completing the activity ($p < 0.001$). These students had a slight decrease in their scores for the follow-up assessment but maintained a significant increase ($p < 0.001$) in human diversity knowledge several weeks after the activity.

Research Question 2: Impact of Human Genetics Laboratory across Racial Groups

We found a significant effect of race on the change in students' biological essentialism (β = 0.648 ∓ 0.208; $p = 0.017$; Table 6) after controlling for student pretest scores. Biological essentialism measured by the Racial Concepts Scale decreased for white students but did not for non-white students (Figure 4). All paired t tests were significant for each instructor (Table 7). We further found that race did not affect the change in color-evasive ideology scores, for both the institutional discrimination and racial privilege subscales (Figure 5; Supplemental Table S4). There were also significant increases in both concept inventory scores (see Figure 6), and these increases were similar across both racial groups (increases in human diversity scores were d = 1.3 for non-white students and d = 1.4 for non-white students, $p < 0.001$ for both), though the increase in phylogeny scores was not statistically significant for non-white students (p = 0.079) due to the small sample size (effect size d = 0.38, size for white students d = 0.31). Finally, we found that for white students, biological essentialism had a moderate correlation with institutional discrimination (r = –0.36, $p < 0.001$) and racial privilege (r = 0.37, $p < 0.001$) at the pretest, while non-white students did not show this same correlation (r = 0.081, 0.074, respectively; $p > 0.05$). At the posttest, correlations were similar for white

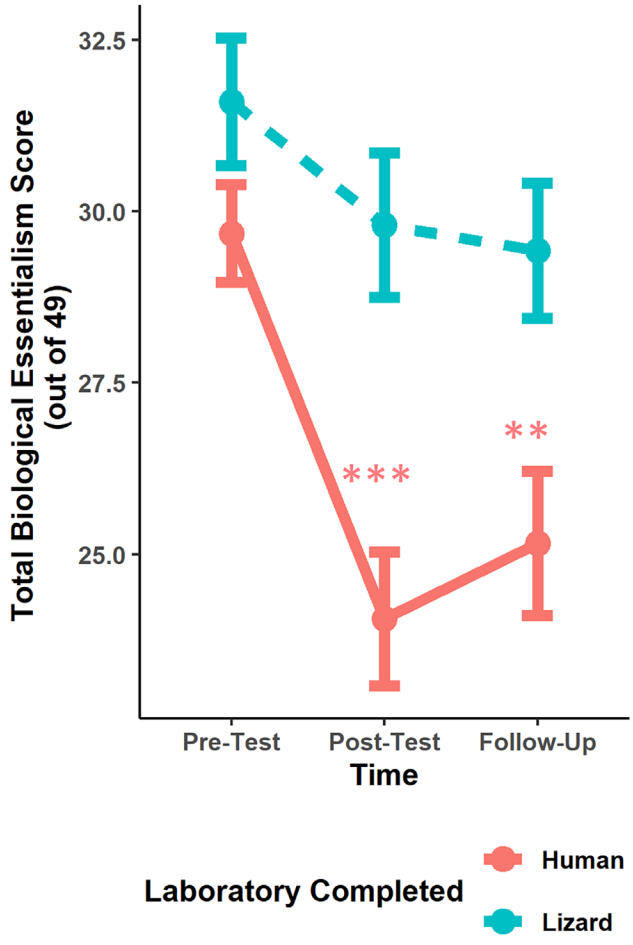

FIGURE 1. Spring 2022 total scores and standard error for biological essentialism parsed by which laboratory students completed. Significance is pre to post and pre to follow-up; ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$.

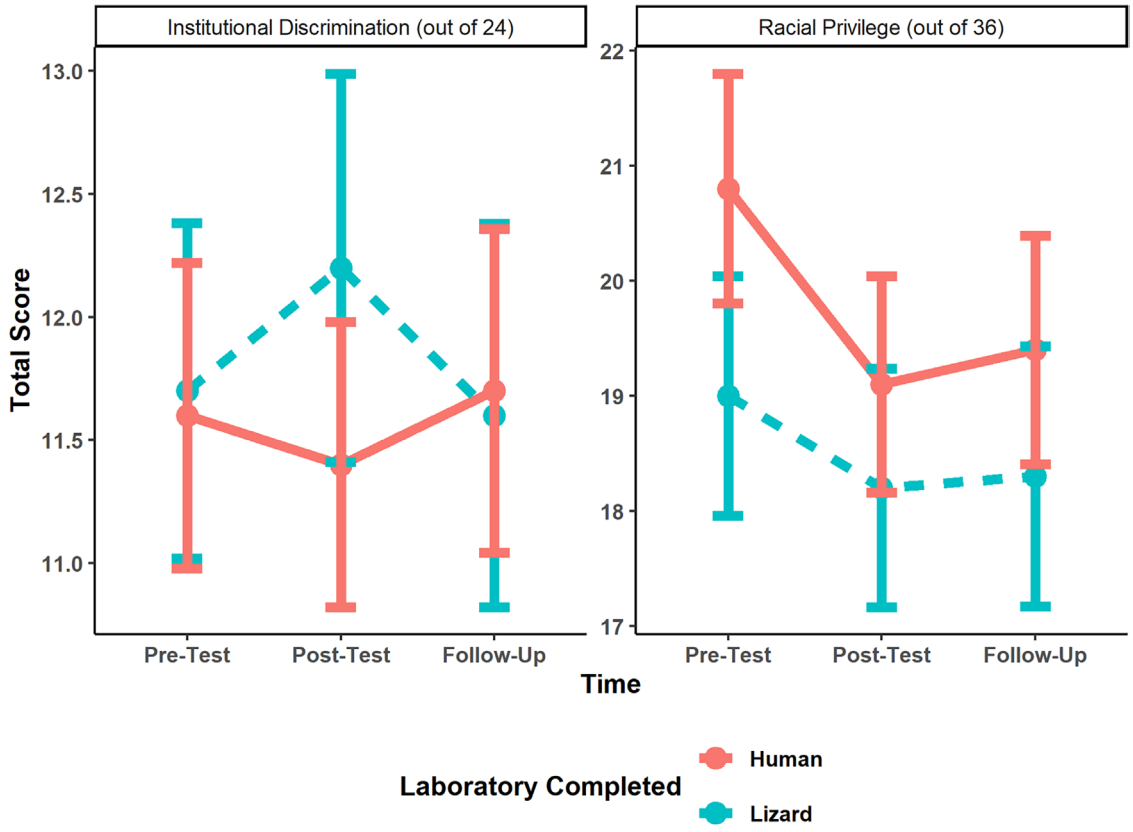

FIGURE 2. Total scores and standard errors for two measures of color-evasive racism parsed by which laboratory students completed. (A) Measures of Racial Privilege did not differ over time across laboratory activities. (B). Measures of institutional discrimination did not differ over time across laboratory activities.

students ($r = –0.36$, 0.46, respectively; $p < 0.001$), and larger but nonsignificant for non-white students ($r = 0.38$, $p = 0.25$; $r = 0.23$, $p = 0.46$).

DISCUSSION

Our genetics laboratory activity addressed misconceptions about the biological nature of race and our results underscore the importance of addressing such misconceptions in undergraduate biology education. Though the false belief that race is associated with distinct genetic markers or traits can be deeply ingrained and persistent (Richman, 2006), after the human genetics activity, students reported decreased agreement with biological essentialism. Despite these positive results, we did not observe any change in social attitudes about race after the human genetics activity. There are several potential explanations for this disconnect including limitations of the Racial Concepts Scale (Morning, 2009) to fully capture students' beliefs about essentialism or a failure of the activity to lead to more fundamental changes in thinking. This suggests that using quantitative data to support causal relationships between social attitudes about race and biological essentialism needs to be very carefully considered and supported with substantial validity evidence for the constructs being measured in the particular populations studied. These results show the promise of activities that can be used to address misconceptions in biology courses, but also highlight the complexities of challenging students' attitudes about race.

Biological Essentialism

The findings of our study provide compelling evidence that the human genetics laboratory successfully decreased students' belief that race has a biological basis. This suggests that the educational intervention effectively challenged and corrected misconceptions related to the biological aspects of race, helping students recognize the lack of scientific basis for such beliefs.

A crucial aspect of this human genetics laboratory activity was the postactivity discussion. Completing the activity without the discussion and clarification could be detrimental to the goals of this study, leaving students to draw their own conclusions, and possibly reinforcing the very misconceptions this activity seeks to dispel. In using preparation for future learning, the explanation (instructor-lead discussion), is vital to the overall learning of the students. Our study exposed potential biases during the activity, which likely prompted students to engage critically with the scientific evidence presented. The postactivity lecture (Supplemental Material S3 – Human Genetics Lecture) also ensured that the students received an accurate interpretation of the results. This design led to a more informed perspective, compared with other studies that did not directly address essentialist views (Kalinowski *et al.*, 2012;

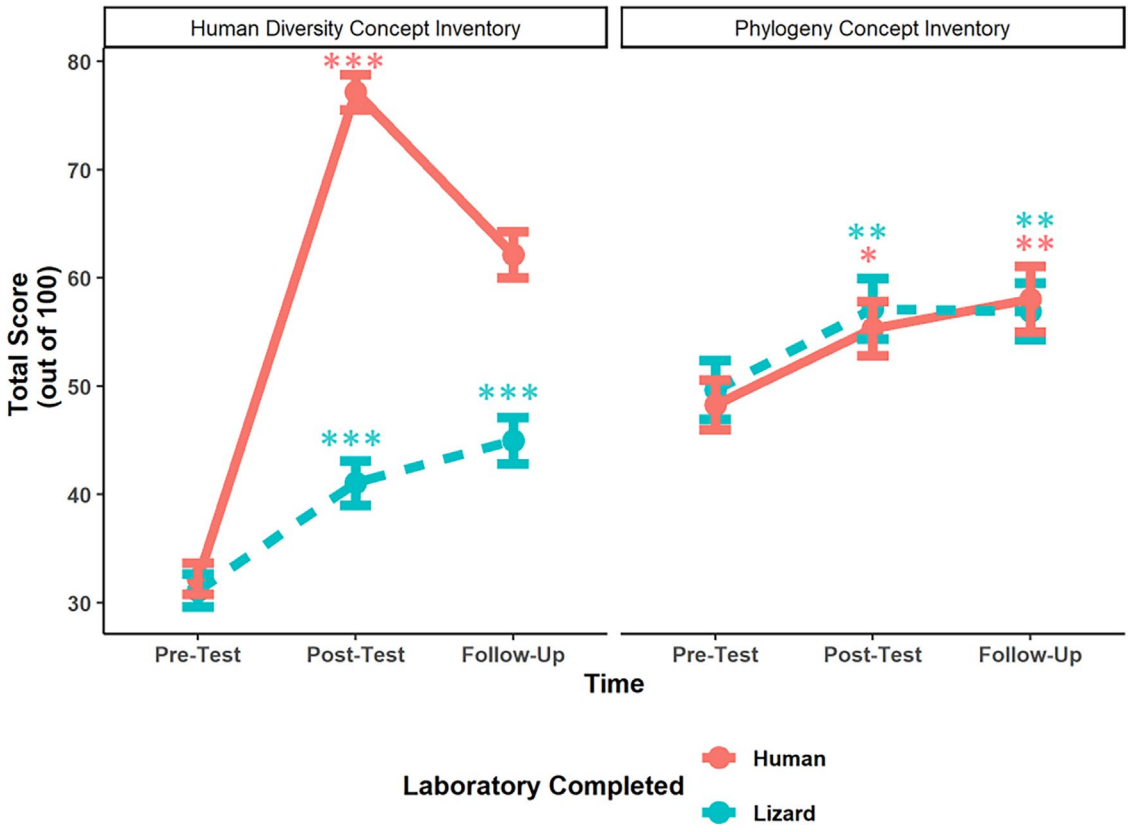

FIGURE 3. Mean scores and standard error for the concept inventory across both laboratory activities for spring 2022. Significance is from pre to post and pre to follow-up. ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$.

Yang *et al.*, 2017; Zimmerman *et al.*, 2022). Donovan *et al.* (2021) did address essentialism in their experimental group; however, they state the Standard Genomics Literacy knowledge is needed first. The Standard Genomics Literacy curriculum along with the treatment curriculum constituted a 4-week unit, whereas our activity achieved encouraging results with one 2-hour activity.

Biological essentialism is characterized by race often being incorrectly associated with distinct genetic markers or traits (Richman, 2006). This belief has contributed to the perpetuation of stereotypes, discrimination, and systemic inequalities (Smedley and Smedley, 2005; Mandalaywala *et al.*, 2018). Providing educational content in a genetics class that tackles racial misconceptions not only equips students with scientific knowledge pertaining to societal issues but also has the potential for broader influence as these students venture into the wider world. Students decreased their essentialist beliefs regardless of the instructor (E.M.B. or graduate teaching assistants), suggesting that the laboratory activity itself, rather than the specific teaching style or approach of any particular instructor, drove the change in students' perceptions. While curricular implementation is important, these consistent results suggest that this educational intervention can play a crucial role in challenging and reshaping deeply held beliefs and attitudes.

Implicit Ambivalence

Counter to the observed changes in students' biological perception of race, the human genetics laboratory did *not* substantively alter students' social attitudes toward race. Specifically, the laboratory activity did not change students' color-evasive beliefs, as measured by their understanding of racial privilege and institutional discrimination. This may be due to students' *implicit ambivalence*, in which people change their explicit attitudes after receiving convincing evidence, but uncertainty remains on the unconscious level (Bohner and Dickel, 2011). Implicit ambivalence often arises when individuals hold contradictory beliefs or emotions about someone or something, and

TABLE 6. Biological essentialism regression table for fall 2022

DV	b_0	b_{Pre}	b_{Race}	$b_{(PreXRace)}$	R^2
Pre-Post	–0.103 (0.142)	–0.373 (0.079) ***	0.592 (0.262) *	–0.185 (0.211)	0.216

Note: Regression equation determined by mixed model analysis. Dependent Variable = Posttest – Pretest; Race = Student Race, where white = 0 and non-white = 1; Pre = standardized pretest score; Pre X Race = Interaction term of standardized pretest score and student race; R^2 is psuedo-R^2; ***, $p < 0.001$; *, $p < 0.05$; *, $p < 0.05$.

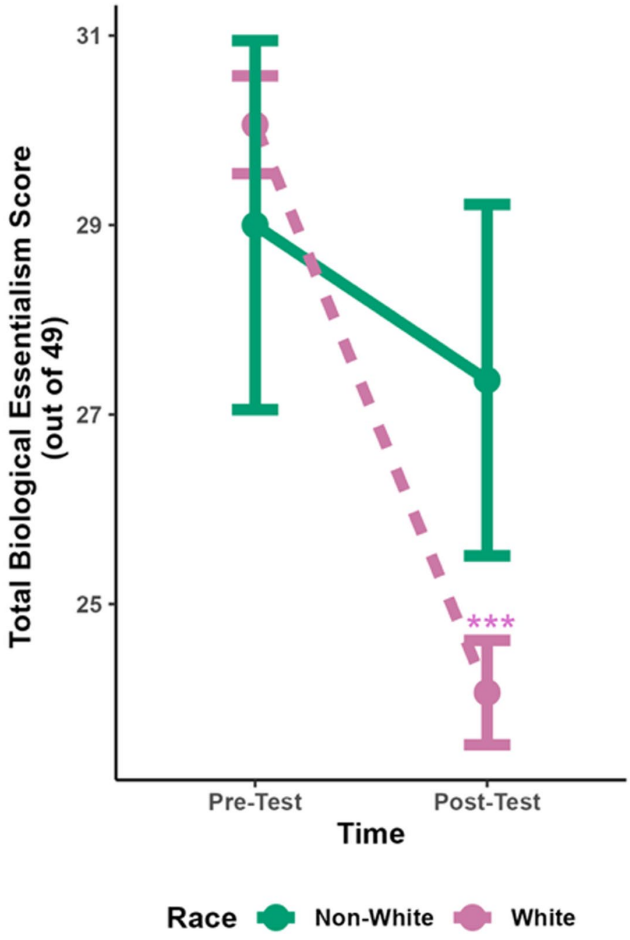

FIGURE 4. Fall 2022 total scores and standard error for biological essentialism parsed by race. ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$.

they have not fully processed or reconciled this conflict. Implicit ambivalence can be complex to navigate because it involves unconscious or subtle feelings that may not be readily apparent to the individual experiencing them as it requires a deeper level of self-reflection and exploration to uncover. Applied to our results, implicit ambivalence may explain why the activity, which targeted misconceptions about race as biological, affected students' understanding of race but not their social attitudes about race. Similarly, Morning (2009) highlights differences between *nonessentialist* thinking and *antiessentialist* thinking which provide further context to these results. Nonessentialist thinkers may reject biological assertions about race without connecting those to broader ideas about the socially constructed nature of race (antiessentialist).

Previous studies about the correlation between biological essentialism and racial prejudice have used older measurement scales, such as the Modern Racism Scale, which have explicitly racist statements. However, there have been arguments made that such scales do not reflect current attitudes, which tend toward color-evasive, or color-blind, racism (Neville *et al.*, 2000). Furthermore, these claims are predominantly correlational, and we could not find any intervention studies that sought to explore this relationship in a more causal manner. If the relationship were causal, one would expect our intervention that successfully changes beliefs in biological essentialism to also translate into changes in color-evasive ideology. Our data suggest that such a causal relationship could exist for white students (given the significant correlations between essentialist and color-evasive beliefs), but the evidence is insufficient as to whether this relationship exists for non-white students. Our results suggest that these may be distinct forms of racist thinking that may require separate or more comprehensive interventions to target. This finding is also supported by constructivist theories of learning, which posit that connections between important ideas need to be made explicit for students to develop more expert-like knowledge organization (Ambrose *et al.*, 2010).

Non-White Identity

We found that non-white students' perceptions of race as biological (i.e., the biological essentialism scale) were not impacted by the human genetics laboratory activity, unlike white students' beliefs. This result was notable because both groups held similar levels of essentialist beliefs before the activity began. QuantCrit suggests that we interpret potential differences between white and non-white students not as non-white students having greater misconceptions about the biological nature of race, but rather a failure of the measurements employed to adequately capture the nuanced views that non-white students might hold on race due to their lived experiences as people of color. Therefore, we use these comparisons to highlight where future research may be needed to address how biology students from different racial backgrounds think about race.

Mandalaywala *et al.* (2018) conducted a study that showed similar findings: manipulation of essentialist thinking led to changes in racial prejudices in white participants but did not produce similar changes in non-white participants. One theory they gave for the lack of change in non-white participants was that race/ethnicity is a more important part of non-white participants' identity, particularly at predominantly white institutions (Hunter *et al.*, 2019), but they also acknowledged that the design of that study may have limited their ability to detect links between essentialism and anti-Black attitudes among Black participants.

TABLE 7. Biological essentialism post/pre paired sample *t* test for instructor

Instructor	Mean	Std. error mean	*t*	Degrees of freedom	Significance one-sided
1	6.12000	1.08523	5.639	24	<0.001***
2	3.40625	1.08496	3.140	31	0.002**
3	4.22222	0.89097	4.739	35	<0.001***
4	6.82979	0.94351	7.239	46	<0.001***

NOTE: ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$.

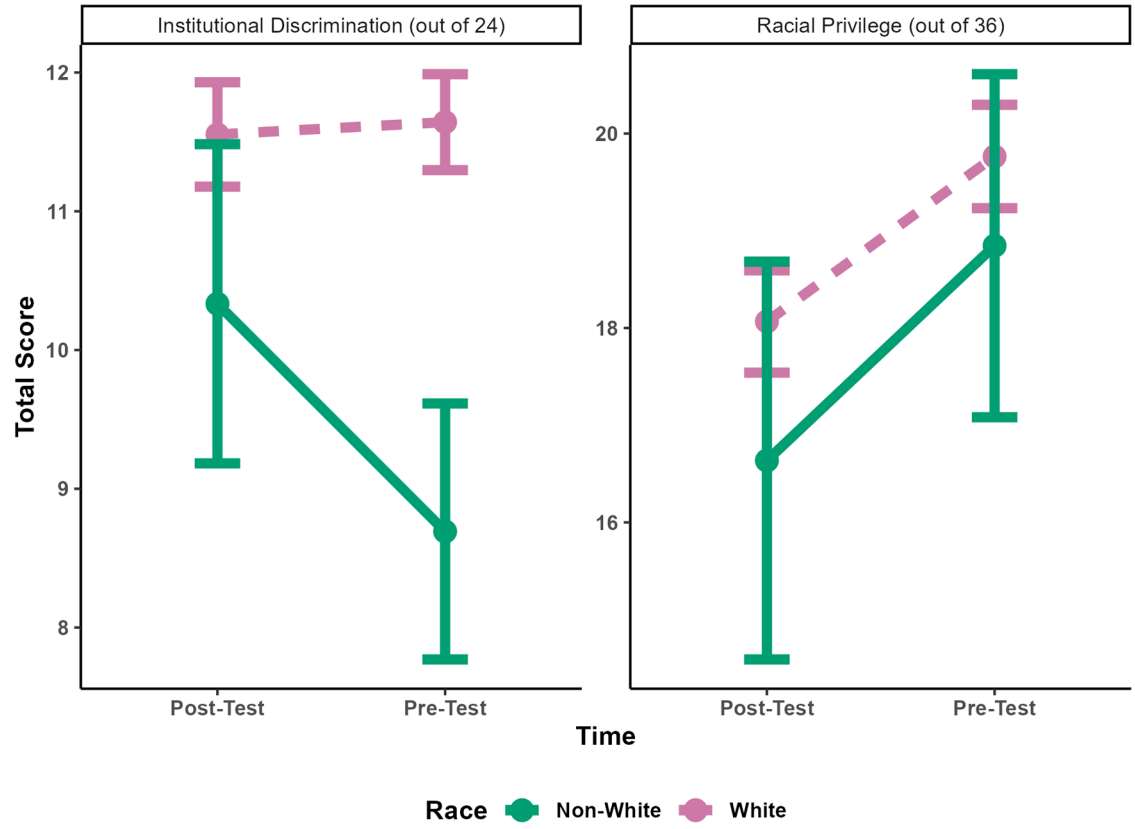

FIGURE 5. (A) Fall 2022 total scores and standard error for racial privilege parsed by race. (B) Fall 2022 total scores and standard error for institutional discrimination parsed by race. ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$.

Similarly, they did not find any studies to support associations between positive racial identity and essentialism. More detailed qualitative research that explores the links between racial identity, essentialism, and educational context would provide much needed clarity on how non-white students engage with nonessentialist or antiessentialist ideas.

Limitations

A central limitation of this research is the small sample size and lack of demographic diversity among students. Future work will benefit from further data collection and an expanded sample size to focus on how these activities might impact non-white students, as well as being able to further disaggregate non-white students. In depth, interviews with participants to gain specific insight into their thoughts and reactions to this laboratory would also enhance this research and will be a subject of a forthcoming study. Although this activity was designed to reach all students and avoid further marginalization of any group (Blackwell, 2010), we cannot determine whether this laboratory made non-white students feel tokenized, less engaged, or otherwise harmed.

Though our results are promising, we are not able to make strong claims about the relationship between activity outcomes and self-reported student racial identity. For non-white students, we did not observe major changes in either biological essentialism or color-evasive racism beliefs. Qualitative analyses and further validity studies may be necessary to explore these scales. The EFA and CFA completed for this research only evaluate internal validity. The scale used for racial privilege and institutional discrimination was extensively validated in 2000 (Neville *et al.*, 2000) for reliability and validity. However, the majority of the population for the validation study was white. It would be beneficial to update the validation study with a more diverse population. For the biological essentialism scale, three separate sample populations were used to develop the scale (William and Eberhardt, 2008). In the first population, white students made up about half (48%) of the population, the second population was only white and in the third white students were not in the numeric majority (30%). Given the more diverse population used to validate the original biological essentialism scale, we suggest that further qualitative research is needed to understand how non-white students respond to this activity.

Given this study was conducted at a single large R1 University, future research would profit from testing in other institutional contexts (e.g., community colleges, regional institutions, minority serving institutions). Indeed, the student population at this university is unusually racially homogenous and economically privileged compared the national population of postsecondary students. It is also located in a state with a long (and ongoing) history of oppression and segregation against Black people. This may be another reason that we did not find significant impacts on color-evasive ideologies among our students. Additionally, our aggregated non-white population may be very different from non-white populations elsewhere. For example, many of our non-white students were Asian, whereas non-white students at other universities in the state are majority Black.

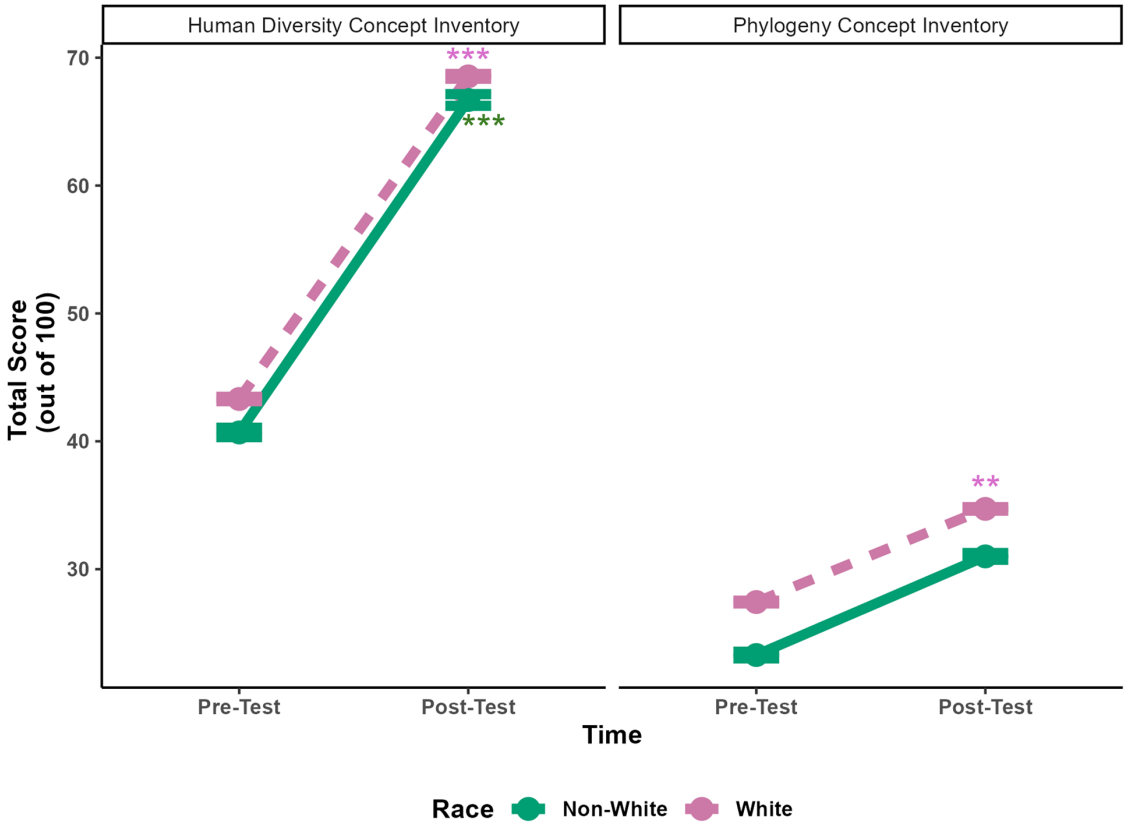

FIGURE 6. Mean scores and standard error for the concept inventory across race for fall 2022. Significance is from pre to post. All increases are statistically significant at the $p = 0.001$ level except for the increase in phylogeny scores for non-white students ($p = 0.079$).

CONCLUSION

This research evaluated a genetics laboratory activity that highlighted racial misconceptions prevalent in society. We found that this activity was effective at lowering students' essentialist beliefs but did not change students' broader social beliefs about race. We found that the activity was effective at reducing essentialist beliefs regardless of the instructor, suggesting that this activity could have success in other institutional contexts. Future work in more demographically diverse settings would be particularly illuminating, as we found that the activity did not decrease essentialist views of non-white students in our student sample.

We identified a laboratory activity for introductory genetics that significantly decreased essentialist views of students. Our discoveries highlight the efficacy of confronting misunderstandings about the biological foundations of race in genetics education at the undergraduate level. Subsequent research will delve into approaches aimed at diminishing racial prejudices among students.

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HIGHLIGHT:

We developed and evaluated a laboratory activity to combat a common misconception that race is biological in origin. Using concept inventories and surveys, we show that our laboratory activity was successful in reducing biological essentialism. This activity did not have any effect on color-evasive ideologies or non-white students.