Teaching the Tough Topics: Fostering Ideological Awareness through the Inclusion of Societally Impactful Topics in Introductory Biology

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ABSTRACT

While science has profound social impacts, we often teach biology as removed from societally debated issues. Here, we address this gap in biology education through the implementation of novel materials that promote ideological awareness (IA). Using mixed-method analyses, we explore students' perceptions of the relationship between science and society, as well as their attitudes toward and knowledge of IA in biology. We found students that received the IA curriculum reported relationships between science and society that aligned with the IA activities, such as providing solutions to societal problems and combating misinformation. Additionally, we discovered a preference for IA materials over a traditional curriculum, with persons excluded because of their ethnicity and race (PEERs) reporting greater approval than non-PEERs. Although we found that the IA curriculum did not result in significant gains in science identity, engagement in biology, or science community values, we did find that students gained awareness of IA topics through a task in which they named as many scientists as possible. Specifically, IA students displayed a 300% increase in the frequency of named scientists from minoritized backgrounds compared with the traditionally taught students. We encourage instructors to incorporate IA materials into their curricula as we move toward more diverse, equitable, and inclusive teaching practices.

INTRODUCTION

Science has profound impacts on society, yet instructors often teach science as though it is divorced from societal issues. Traditional scientific training exclusively prepares students for *scientific practice* without helping students navigate social concepts. This is particularly true for potentially controversial issues at the intersection of biology and politics, religion, race, or LGBTQIA+ identity. Instructors may be hesitant to discuss these issues, preferring instead to stick to the traditional "value-free" biology curriculum, which suggests that social and ethical values should have no influence on the conduct of science and that scientists should have little concern for such values (Cross and Price, 1996; Douglas, 2009). However, choosing not to address these topics in the classroom perpetuates the falsity that biology as a field is removed from these social issues.

Despite the prevalence of the value-free biology curriculum, critical pedagogy theory supports the idea that science and society are not separate entities. Instead, critical pedagogy views education as a process of problem-posing and self-discovery, developing one's power and capacities with an open mind and in cooperation with others, rather than only memorization and recitation (Freire and Macedo, 2018). Through this process, students draw connections with the world around them and understand the impacts of their field on the functionality of society. Making the connections

between science and society is also one of six core competencies in undergraduate biology promoted by the American Association for the Advancement of Science (AAAS, 2011) in a formative document, *Vision and Change in Undergraduate Biology Education: A Call to Action*.

Instructors are the "link" between the world of science and society. They have an important role in guiding their students to function as critical citizens (Lazarowitz and Bloch, 2005). Linking societal issues to biological concepts allows students to formulate their own positions while also advancing their critical-thinking, decision-making, argumentative, reflective judgment, and scientific literacy skills (Aikenhead, 1985, 2002; Solomon, 1992; Zeidler *et al.*, 1992, 2005; Zeidler, 1997; Sadler and Zeidler, 2004; Sadler *et al.*, 2006; Zohar and Nemet, 2002; Driver *et al.*, 2000; Dawson and Venville, 2010; Eastwood *et al.*, 2012). If a goal in science education is to develop a scientifically literate population capable of making informed decisions in a democracy, then issues that sit at the intersection of biology and society should be a defining component of any biology curriculum.

One way to meet this goal is through teaching *ideological awareness* (IA), an understanding of biases, stereotypes, and assumptions that shape contemporary and historical science. Contemporary philosophers of science have described the importance of acknowledging the role of values in science and incorporating them thoughtfully and with scrutiny, rather than not at all, highlighting the critical role of IA in disciplinary study (Elliott, 2017; Potochnik, 2020). An IA curriculum opposes a *value-free ideal* for science, accepts the pervasive role that values have in all aspects of science and enables students to challenge prevailing worldviews and the status quo. IA activities occur in the classroom when the topic is thematized—for example, an activity in which students discuss the consequences when a majority of studies in medical sciences disproportionately focus on white cis-men (Perez, 2019). As a result, we know far less about how various ailments manifest in cis-gender women, transgender people, nonbinary people, and people of color. This has consequences for the next generation of doctors and policy makers, who must be able to characterize best practices for a global population, evaluate medical responses, and prioritize the recipients of available treatments.

Teaching IA may include discussions of biases and stereotypes that shape our perception of what a scientist looks like. For many students, perceptions of scientists are shaped by those who are highlighted in textbooks. One demographic analysis that extracted over 1000 human names from common biology textbooks and assessed the binary gender and race of featured scientists showed that the most commonly scientists were white men (Wood *et al.*, 2020). Assuming the current rate of change continues, their projections suggested that it could take multiple centuries before textbooks reach inclusive representation (Wood *et al.*, 2020). By exclusively highlighting stereotypical scientists, we not only communicate to students who scientists *have been*, but who they *can be*. These perceptions begin forming early in development; in one classic longitudinal study (Chambers, 1983), researchers asked children to participate in a "Draw a Scientist Test." Most children drew what they believed a stereotypical scientist looked like: an intellectual, white cis-gender man draped in a white lab coat (Chambers, 1983).

However, after being provided the opportunity to engage with scientists of different identities, perceptions of what a scientist looked like changed to include diverse identities (Phillips and Hausbeck, 2000). Following years of exposure to scientific media and course work, drawings produced by undergraduate students still exhibited stereotypic characteristics similar to those drawn by children in grade school (Thomas *et al.*, 2006). But research shows highlighting counter-stereotypical examples of scientists can increase undergraduate students' interest in science, performance outcomes, and ability to relate to scientists (Schinske *et al.*, 2016).

In light of these social discrepancies and in the wake of recent social reckoning and unrest in the United States, calls for teaching societally relevant topics in science, technology, engineering, and mathematics (STEM) classes have reached a crescendo (Dzirasa, 2020; Gewin, 2020; Schell *et al.*, 2020; Simpson *et al.*, 2021). Sustained action that diversifies and integrates IA into curricula will increase students' ability to apply scientific and moral reasoning to real-world situations. With this in mind, we developed an integrated curriculum that included three modules that encouraged respectful and productive conversation among students and addressed important areas that are generally not emphasized in introductory biology.

We then used this curriculum to explore the following research questions: 1) What are students' perceptions of the relationship between science and society? 2) How are science identity, engagement in biology, and science community values impacted by the inclusion of IA materials? 3) Do students prefer IA materials in the context of an introductory biology course? 4) How does student knowledge of societally impactful topics change after exposure to IA materials?

METHODS

To answer our research questions, the lead author (A.E.B.) developed a three-lesson IA curriculum and implemented it in one section of an introductory biology course in Fall 2020, collecting student data via pre- and post-course surveys. For comparison, we collected the same student survey data from another section of the course taught by a different instructor at the same institution. Both instructors followed the same main curricular content, containing congruent learning objectives. The students were assessed similarly and taught the materials in similar formats. Thus, the primary difference between the two sections was the implementation of the three-lesson IA curriculum and the instructor.

Curricular Development

The curriculum consisted of three modules: 1) "The Ugly Truth: Unethical Experimentation and Human Rights Evolution," 2) "Representation in STEM," and 3) "Intersection of Science and Identity." The modules will hereafter be referred to by abbreviated names: "The Ugly Truth", "Representation in STEM", and "Science and Identity". The modules take a "past, present, future" approach to discussing the progression of biology, highlighting the current trajectory of the field. For example, students were informed that "the father of gynecology" performed experiments on enslaved Black women without anesthesia because he believed they could not feel pain, and this was a legal act at that time. The instructor then acknowledged that practices such as these are presently illegal, discussing the

TABLE 1. IA Curriculum details

Module[a]	Learning objective	Lesson topics	Student activity
"The Ugly Truth: Unethical Experimentation and its Relation to Human Rights Evolution"[1,3,6,7]	Explore the exploitative nature of science history through the lens of human rights evolution, bringing student attention to the impacts of unethical scientific practices on vulnerable populations.	1. Eugenics 2. The exploitation of at-risk groups and unethical human experimentation: e.g., tuskegee syphilis study, malaria testing at Stateville Penitentiary, Willowbrook State School hepatitis study, J Marion Sims surgical experimentation, Japan's Unit 731, Germany twin experiments 3. Environmental racism 4. Disparities in healthcare access for minoritized groups	Student presentation: groups of students (three to four) gave a 10-minute presentation on one of the examples listed under lesson topics. Required information included: summary of event, ethical violations, groups involved and reasons for vulnerability, societal responses, current ethical advances preventing reoccurrence, biological concepts influenced.
"Intersection of Science and Identity"[2,3,7]	Address the ways in which science has been used as support for societal suppression of nonconforming identities and discuss the biological nature of individualistic identities.	1. Biological and social constructs: race versus ancestry 2. Biological and social constructs: sex versus gender 3. Biological support for gender identity and sexuality 4. Invalid and historical use of biology in support of reprogramming and sexual orientation change efforts 5. Addressing the false stereotype between gender identity and mental illness 6. The opportunities for coexistence of evolution and religion through the limitations of science	Henrietta Lacks reflective writing: students wrote a final reflection (four to five pages) on 1) a summary of the text and their feelings on the personal story of Henrietta Lacks and 2) the evolution of tissue research and legal ownership of body tissues.
"Representation in STEM"[3,4,5,6,7,8]	Expose students to the invaluable scientific contributions of scientists from diverse backgrounds, addressing the biological and psychological importance of representation within the field.	1. Lack of representation in STEM: from "Draw a Scientist Study" to representation in textbooks and faculty members 2. The unconscious of science 3. Prominent scientists from minoritized backgrounds: Charles Drew, Alice Augusta Ball, George Washington Carver, Gladys West; the wealth of diverse scientists available: Project BioDiversify, 500 Women Scientists, 500 Queer Scientists	Role model activity: each student identified a real-life biologist who they viewed as a role model and with whom they personally identify. They then wrote a summary of the scientist, their personal connection, their science, and how a combination of their science and identity have impacted the field.

[a]Introductory benchmark topics reinforced in module: [1]Genetics, [2]Evolution, [3]Anatomy and Physiology, [4]Bioinformatics, [5]Ecology, [6]Toxicology, [7]Ethics, [8]Scientific Engineering.

advancement of human medical rights. Additionally, New York removed the doctor's statue from Central Park and relocated it to his burial site, as people now recognize his wrongdoings. Finally, the instructor explained what a future with equal healthcare rights would look like, acknowledging current disparities among minoritized communities such as the Black and LGBTQ+ communities. For further detail on each module and how we integrated them into the biology curriculum, see Table 1. We discussed each IA module following traditional disciplinary materials, connecting the IA materials with core benchmarks of introductory biology. We explicitly made connections between the IA materials, the disciplinary concepts, and their societal importance, rather than assuming students would do so intuitively. The lead author (A.E.B.) delivered one module per class period for the last three class periods of the semester. In addition to these modules, she also replaced required read-

ings from the traditional textbook with *The Immortal Life of Henrietta Lacks*. Chapters from this book were assigned over the course of the semester and were easily integrated into multiple benchmark topics for the introductory course in addition to the IA modules. Additionally, the traditional textbook was required for students for the sake of comparison. While students were not assigned mandatory readings from the traditional textbook, for each lecture, we provided students with the corresponding textbook chapters and encouraged them to consult the text for additional information.

Student Population and Class Setting
We collected data from two sections of a nonmajors Introductory Biology course taught at a public university in the southeast region of the United States. The Introductory Biology course is a three-credit class that includes two 75-minute class sessions

each week. The instructors of both course sections taught lecture materials in an online format, in which materials (lectures, PowerPoints, etc.) and learning objectives were provided electronically through the class learning platform (i.e., BlackBoard). In the traditional section, students participated in active-learning activities individually online, while in the IA section students completed active learning activities individually in the classroom (in person, but socially distanced due to COVID-19 restrictions). The paper's lead author (A.E.B.) instructed the treatment section with the IA curriculum she created, and a coauthor (A.G.) taught the comparison section at the same university using the traditional curricular materials. To maintain consistency between the two sections and to avoid influencing student responses on the pre-course survey, instructors did not emphasize the presence or absence of IA topics in the semester's curriculum, beyond their inclusion in syllabus materials. The total enrollment for the course was 111 students across the two sections (55 in the IA section and 56 in the traditional section, with 51 and 38 students participating in either the pre-course survey, post-course survey, or both, respectively; Table 2).

Data Collection
We provided students with an electronic survey via Qualtrics at the end of the second week of the course and following the final class meeting of the semester. We offered a small amount of extra credit as an incentive to participate. As survey responses were anonymous, the entire class was offered bonus credit if 80% of the class submitted the survey by the deadline. Students provided a unique identifier consisting of the first three letters of their mother's name and first three numbers of their street address. Unique identifiers were used to pair pre- and post-course survey data.

Briefly, the survey consisted of previously validated constructs on a 7 point Likert scale, measuring Science Identity (Chemers *et al.*, 2011), Engagement in Biology (Wang *et al.*, 2016), and Scientific Community Values (Estrada *et al.*, 2011; Table 3). Additionally, we included short-answer responses to evaluate 1) course effectiveness, 2) student affect for each module and replacement texts, and 3) student learning gains (Supplementary Material).

We obtained IRB approval (20-376 EX 2008) from the appropriate institutional review boards, and we procured informed consent from participants before voluntary and anonymous participation in the study.

Data Coding and Analysis
We downloaded survey responses 1 week after the end of the semester. The response rate on the pre-course survey was an average of 75% between the two sections (traditional curriculum = 65%; IA curriculum = 87%) and the response rate for the post-course survey was 80% (traditional curriculum = 68%; IA curriculum = 93%). We parsed out survey responses into two data sets: 1) Likert-scale responses and 2) open responses.

Likert-Scale Responses
Because we used previously validated constructs (Science Identity, Engagement in Biology, and Science Community Values), and our sample sizes were insufficient for use in confirmatory factor analysis, we averaged individual responses for each construct on a per-student basis. We analyzed the data using linear

TABLE 2. Demographic breakdown of experimental sections

Demographics	IA modules (*N* = 51)	Traditional (*N* = 38)
Average age	21.38 years	22.23 years
Ethnicity		
Asian/Pacific Islander	1.9%	7.9%
Black/African American	39.2%	42.1%
Hispanic or Latino	9.8%	NA
Native American or American Indian	1.9%	NA
White	43.1%	47.4%
Other	3.9%	2.6%
Class standing		
Freshman	33.3%	5.2%
Sophomore	43.1%	50%
Junior	21.6%	39.5%
Senior	1.9%	5.3%
Major		
Biology	5.9%	2.6%
Non-biology science field	13.8%	21%
Non-science	70.6%	76.3%
Undecided	9.8%	NA
Gender		
Woman	62.7%	57.9%
Woman/gender neutral	3.9%	NA
Man	27.5%	42.1%
Man/gender neutral	3.9%	NA
Prefer not to disclose	1.9%	NA
First-generation status		
No	72.5%	57.9%
Yes	25.5%	31.6%
Unsure	1.9%	10.1%

mixed models (Pinheiro *et al.*, 2020), testing for reported gains in each of the three constructs between the two implementation types, including pre-course survey response as a random effect to control for incoming variation in student responses. We used anonymous identifiers in the model to account for repeated sampling.

Open Responses
We asked four open-response questions on the post-course survey (Table 4). For each of the open-response questions, two to three authors (depending on the question being assessed) created categories through first- and second-cycle analyses using open and thematic coding (Saldaña, 2013). Each question produced a number of coding themes (Table 4). Two to three independent researchers coded a subset of responses, at which point we adapted the coding themes to be increasingly inclusive and descriptive. We then coded responses into appropriate categories, where responses could be coded in more than one theme when necessary. We calculated percent agreement and percent exclusion on a per-question basis (Table 4). Of note, we excluded from the data set responses that were too vague for coding. After calculating percent agreement and exclusion, the same two or three researchers worked in collaboration to code all student responses to consensus. For cases in which two coders could

TABLE 3. Likert-scale survey constructs

Construct	Individual survey questions
Science Identity (Chemers *et al.*, 2011)	I have a strong sense of belonging to the scientific community of scientists. I derive great personal satisfaction from working on a team that is doing important work. I have come to think of myself as a scientist. I feel like I belong in the field of science. The daily work of a scientist is greatly appealing to me.
Engagement in Biology (Wang *et al.*, 2016)	How hard were you working in class? How well were you concentrating? How important was what you were doing in class to you? How important was this lesson to your future? How interesting were the activities? To what degree did you enjoy what you were doing?
Science Community Values (Estrada *et al.*, 2011)	The material covered in class aligns with your views on the following concept: It is valuable to conduct research that builds the world's scientific knowledge. The material covered in class aligns with your views of the following concept: Discovering something new in the sciences is thrilling. The material covered in class aligns with your views of the following concept: Discussing new theories and ideas between scientists is important. Scientific research can solve many of today's world challenges.

not reach consensus, we consulted with an additional author until consensus could be reached.

RESULTS

Student Perceptions of Science and Society

In the first week of the semester of Introductory Biology, we asked students: "How does science impact social perspectives and problems?" Across treatments, students' open-ended responses indicated that science helps us to understand the world (25%), answer societal problems (20.1%), and combat misinformation (22.6%; Figure 1). Despite this recognition, when students were asked whether or not they were aware of the topics presented in the IA modules before the class (on a seven-point Likert scale), 43% of students indicated they were not aware of topics related to unethical experimentation on people in biology research, 48% of students reported being unaware of the issues surrounding representation in STEM and science research, and 50% of students had not considered how biological science shapes societal views on identities (Figure 2A).

Science Identity, Engagement, and Community Values

In response to a series of Likert-scale survey items, we found no significant gains in the IA curriculum in comparison to the traditional curriculum in terms of science identity (estimate = 0.12, SE = 0.35, $p = 0.07$), engagement in biology (estimate = 0.26, SE = 0.26, $p = 0.32$), or community values (estimate = 0.03, SE = 0.25, $p = 0.89$).

Student Perception of IA Materials

Following the IA curricular interventions, students indicated >68% approval and appreciation (agree to strongly agree) for the material in each of the modules (68% "The Ugly Truth" module; 68% "Representation in STEM" module; 69% "Science and Identity" module; Figure 2A). Students reported that they perceived the alternative text we read in class, *The Immortal Life of Henrietta Lacks*, to be more useful than corresponding textbook chapters (79% agree–strongly agree), more engaging than a textbook

(91% agree–strongly agree), and more relevant to teaching about societal issues (93% agree–strongly agree; Figure 2B).

We asked students what they liked and disliked about the curriculum using open-ended responses. Common themes emerged between the three modules (Figure 3). Students reported they learned something new in "The Ugly Truth", "Representation in STEM", and "Science and Identity" modules (i.e., 26%, 21%, and 26% of students, respectively) and that the materials were interesting and informative (23%, 14%, and 18% of students, respectively). As was to be expected, module-specific patterns also arose. For instance, students were likely to mention ethics or scientific practices (26% of students) in "The Ugly Truth" module, whereas they were likely to mention visible identities (18% of students) in the "Representation in STEM" module, but hidden (17% of students) and visible identities (17% of students) in the "Science and Identity" module. Unsurprisingly, students were likely to view the more modern modules as relevant (3% "Science and Identity" and 7% "Representation in STEM"). We found 18% of students made direct mention of the relatability of the materials in the "Representation in STEM" module, only 3% of students did so in the "Science and Identity" module, and no students reported relatability in "The Ugly Truth" module (Figure 3).

Interestingly, the majority of students reported that they did not dislike any portion of the modules (30% "The Ugly Truth", 59% "Representation in STEM", 50% "Science and Identity"). However, of the students who reported negative aspects of the modules, the most prominent was the bleakness of the material (28% "The Ugly Truth", 19% "Representation in STEM", 20% "Science and Identity"; Figure 3). For example, one student reported "Though I liked many things about this module, it was hard to learn about certain experiments. Some that stick out to me were the Nazi Twin experiments as well as the Iowa Stuttering Study," while another reported they did not like "The ugly truth that science, like any discipline, is one of biases against certain groups. It's not a nice thing to see in a pursuit of pureness of intent."

TABLE 4. Qualitative survey questions, coding categories, categorical descriptions, and methodological details

Question	Coding categories	Description	Coders	% Agree	% Exclude
How does science impact social perspectives and problems?	Influences Understanding of the World	Mentions how things work, observations, how they work, or how people observe the natural world	C.J.B., S.E., T.G.	100%	8%
	Influences Morality	Mentions morality and ethical concerns Influences ethical perspectives			
	Negatively	Mentions science can have negative effects on society, negative agendas, etc.			
	Provide Answers to Societal Problems	Discusses how science provides answers to societal issues, social or practical, makes life easier, ir improves quality of life			
	Combat Misinformation	Emphasizes uncovering truths rather than falsehoods or prevent the consumption of misinformation			
	Provide More Perspectives	Provides multiple solutions or perspectives on issues from different geographic areas or sections of society			
	Concrete	Uses scientific terms such as "data," "findings," "studies"			
	Names Specifics	Names specific issues (references to specific societal issue like environment)			
What did you like about this module?	Everything	Explicitly mentions that they liked everything	A.E.B., E.P.D.	75%	24%
	Nothing	Indicates that there was nothing they liked about the material			
	Learned Something New/Informative	Mentions the gain of new knowledge or the informative nature of the materials.			
	Interesting/Engaging	Indicates that material was interesting or engaging			
	Relevant	Indicates that the materials are relevant or timely to current societal issues			
	Honesty	Indicates full disclosure and honesty of materials			
	Relatable/Helpful to Themselves or Others	Mentions they personally relate to the material or recognize how it may be personally helpful to them or others.			
	Mention of Visible Identities	Mentions the inclusion of visible identities.			
	Mention of Hidden Identities	Mention the inclusion of hidden identities.			
	Mention of Ethics and Scientific Practices	Relates the modules to the evolution of human rights and scientific and societal ethics			
What did you dislike about this module?	Everything	Explicitly mentions that they disliked everything	A.E.B., E.P.D.	92%	24%
	Nothing	Indicates that there was nothing they disliked about the material			
	Content Bleakness	Mentions the content itself was bleak, or sad, and it led to their dislike of the material			
	Mundane	Indicates that the material was not engaging			
	Material Complexity	States the complexity of the material and/or depth of the material was too difficult			
	Not Enough Information	Reports of modules being too vague or not containing enough information			
	Overabundance of Material	States the lessons took too long to cover or was too dense.			

There has always been a concern that addressing these societal issues could have disproportional negative effects on persons excluded because of their ethnicity or race (PEERs; Asai, 2020). However, our findings indicate that, in all three modules, students who self-identified as belonging to a PEER group were more likely to approve of the inclusion of the IA materials following their implementation than students from non-PEER groups (Figure 4). While 76% and 71% of students from PEER groups reported enjoyment and approval (agree–strongly agree) of the included materials in the "Representation in STEM" and "Science and Identity" modules respectively, only 65% of students in non-PEER groups felt the same about both of those modules. When surveyed on their view of "The Ugly Truth" module, 79% of students from PEER backgrounds responded positively (agree–strongly agree), while 56% of students in non-PEER groups reported enjoyment of and approval for the materials. Interestingly, a large proportion of students from non-PEER groups (i.e., 44%) reported neutrality to "The Ugly Truth" module, while none of the students reported negative feelings toward their inclusion (Figure 4).
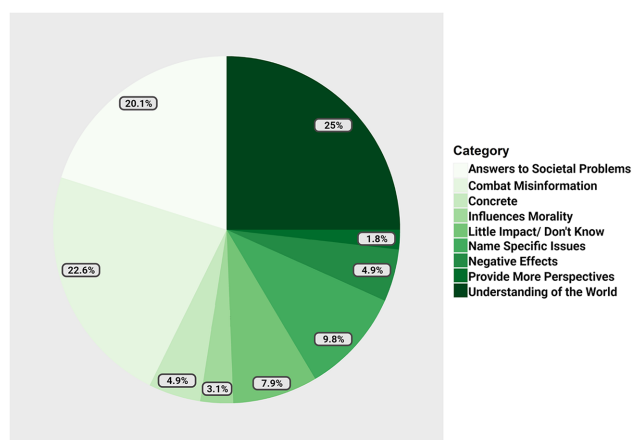
FIGURE 1. Student perceptions of science's impact on social perspectives and problems. Student responses were binned into nine categories, and the pie chart shows the proportion of responses within each category. Students were most likely to associate science with increasing our understanding of the world (25%), providing answers to societal problems (20.1%), and combating misinformation (22.6%).

Student Knowledge of Societally Impactful Topics

When prompted to agree or disagree on a 7-point Likert scale ranging from strongly agree to strongly disagree with the prompt "I am knowledgeable about the impact of biology on societal issues" on the pre-course survey, 20% of students in the traditional curriculum disagreed to some extent (disagree–strongly disagree) with the statement. In the IA curricular group, 20% of students also reported that they disagreed to some extent (disagree–strongly disagree). However, we observed an interesting trade-off in neutrality. While 50% of students in the traditional curriculum reported neutrality to the question, only 9% of students in the IA curriculum reported neutrality, leading to 72% of students reporting agreement with the statement (agree–strongly agree). This is noticeably more students reporting confidence in their knowledge of the relationship between biology and society following IA curriculum than in the traditional curriculum (72% and 30% agree–strongly agree, respectively). Additionally, no students in the IA curriculum responded with strongly disagree or disagree to the prompt; the lowest student report was "somewhat disagree" (Figure 5). We caution readers in their interpretations of these results, however, by emphasizing these are student perceptions of knowledge rather than meaningful reflections of actual knowledge gains.
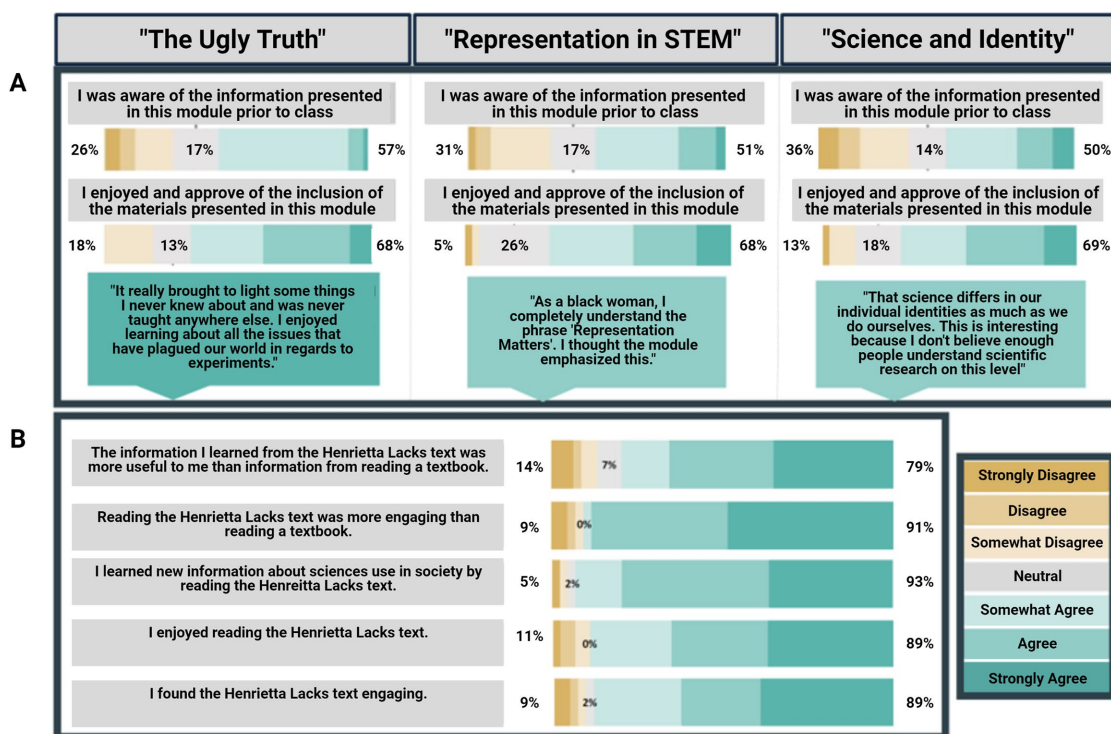

FIGURE 2. Student perception of IA materials in the introductory classroom. Likert-scale responses (7-point scale ranging from strongly agree to strongly disagree) are presented as bar graphs depicting the proportion of students who respond positively (percentage on right), negatively (percentage on left), and neutrally (percentage in gray). (A) For each of the three modules, students were asked to respond to their awareness of the materials (top) and their approval and enjoyment of the materials (middle). Within each module, between 43% and 50% of students were unaware of the materials before entering the classroom, and greater than 68% of students expressed appreciation for the inclusion of IA materials. For each module, one student qualitative response is provided highlighting common benefits of the materials. Student quotes are color coded to their respective Likert-scale responses. (B) When traditional textbook readings were replaced with *The Immortal Life of Henrietta Lacks*, students reported high levels of engagement, societal connections, and utility.
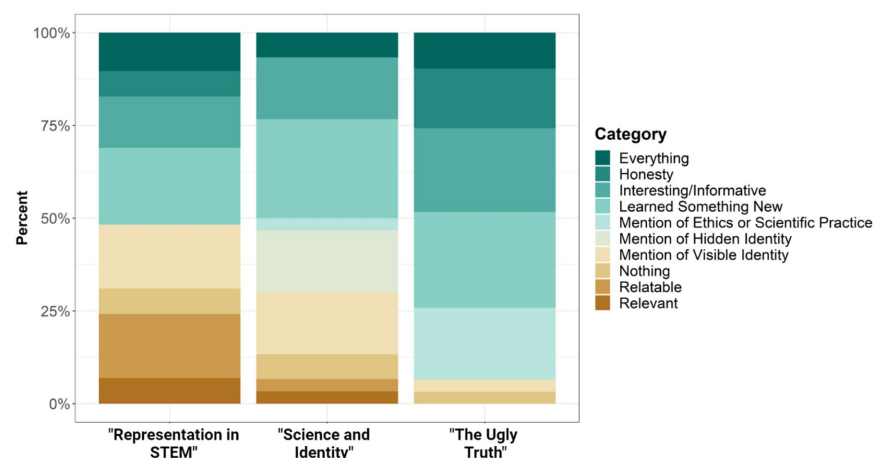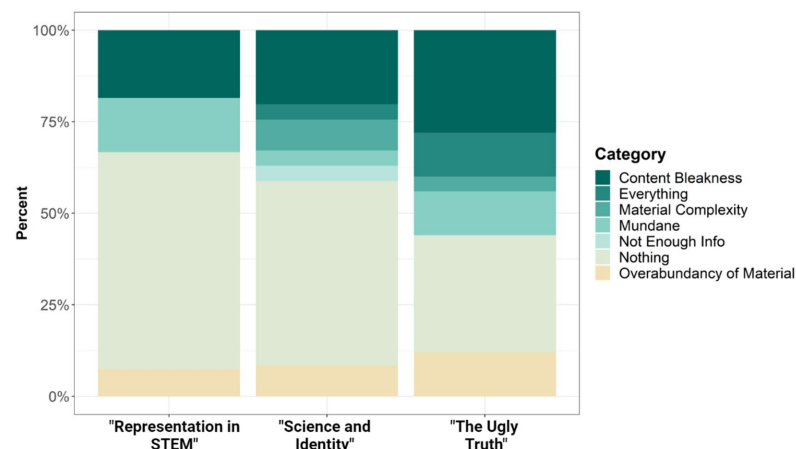
A What did you *like* about this module?

I What did you *dislike* about this module?

FIGURE 3. Coded responses to the prompts (A) What did you like about this module? Students reported common likes across modules, including reports of learning something new and the interesting and informative nature of the materials. Student responses matched well to materials presented (e.g., ethics in "The Ugly Truth" and visible identities in the "Representation in STEM" module). (B) What did you dislike about this module? The majority of students reported that they did not dislike any portion of the modules (i.e., "nothing"). However, of the students who reported specific dislikes, the most prominent in all three modules was the bleakness of the materials.

Participation in IA modules also positively impacted student perceptions of diverse scientific identities. For instance, when given an opportunity to name as many scientists as possible over 2 minutes, students exposed to IA modules named more women scientists and scientists of color compared with students in the control section. Students in the traditional curriculum were 2.9% more likely to identify a scientist of color following the course, while students exposed to the IA curriculum displayed an 3-fold increase, or an increase of approximately 20.4% (Figure 6).

DISCUSSION
We tested the impacts of integrating an IA curriculum into a biology course for non-majors by including three modules at the end of the semester that focused on 1) unethical experimentation and human rights evolution, 2) representation in STEM, and 3) the intersection of science and identity. Our research questions centered on students' understandings of the relationship between science and society, their perceptions of the IA materials, and whether their knowledge of societally impactful topics changed after exposure to the curriculum. Previous work shows instructors believe science was not the appropriate subject to broach such topics (Sadler *et al.*, 2006), but our data suggest students responded positively to these modules, and the inclusion of IA materials impacted how students think about science and scientists.

Student Perception of Science and Society
Across the two treatments, students most frequently reported that science impacts social perspectives and problems by improving our understanding of how the world works, by providing solutions to societal problems, and by combating misinformation. We found these reflections aligned well with the conversations generated by the IA materials, which often sat at the intersection of biology and society. These responses suggest to us that students desire discussions about topics that strike at the core of the IA curriculum.

Impact of IA Inclusion on Science Identity and Science Community
The IA section and the traditional section of Introductory Biology did not differ with respect to their gains in measures of science identity, engagement in biology, and science community values over the semester. While we were surprised by these null results, they may hint at the possibility that IA materials do not impact these particular affective traits. Additionally, it is possible that the timing of IA integration, length of time dedicated to IA topics, and the nature of integration with nonmajors curriculum may impact these constructs.

Past research has demonstrated that teaching within the context of socioscientific issues, or those that directly apply biological or scientific principles to societal problems, can increase students' moral sensitivity and potentially their overall moral development (Fowler *et al.*, 2009). Lee *et al.* (2013) found that the implementation of 3–4 weeks of socioscientific issues material in a ninth-grade genetic curriculum promoted students' character and values as global citizens. As a result, students were more concerned for and more sensitive to the plight of those who are jeopardized because of technological advancements. Conversely, our focus related less to student capacity for
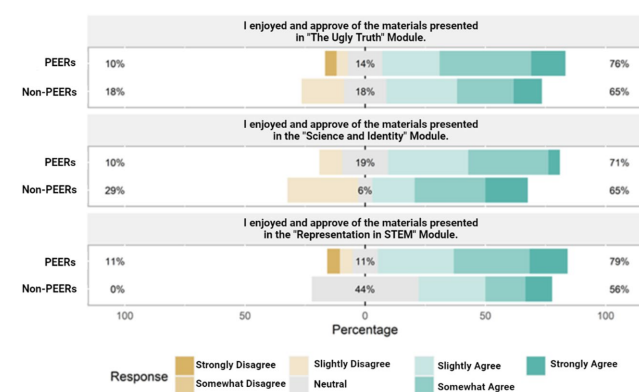
FIGURE 4. Student approval of material by representation status. Students who self-reported as PEERs reported higher levels of approval for each of the three IA modules than students who identify as non-PEERs.

FIGURE 6. Student recall of scientists from diverse backgrounds. When prompted to list scientists by name, students exposed to IA modules listed 20.4% more scientists from diverse backgrounds, while students in the control section listed 2.9% more (gains between pre- and post-course survey reports).

empathy and more to students identifying as scientists and agreeing with science community values.

Another possible explanation underlying these results may relate to students perceiving these topics as detached from their lived experiences, particularly those that occurred before they were born (Zeidler *et al.*, 2019), or experiences that they find personally relatable through empathetic or sympathetic responses. For example, much of "The Ugly Truth" model was centered on examples occurring before the 21st century. Additionally, students who personally related to the "Science and Identity" module were likely to be in the minority based on national demographics (i.e. students who identify as part of a minoritized demographic, such as the LGBTQIA+ community). As a result, students may have found the materials in "The Ugly Truth" module to be less relatable than that of the other modules, and therefore were less likely to impact their feelings of belonging within the field. This is supported by the absence of "relatability" reported by students in their short-answer responses to each of the aforementioned modules, while relatability was frequently mentioned in reference to the "Representation in STEM" module (Figure 3A).
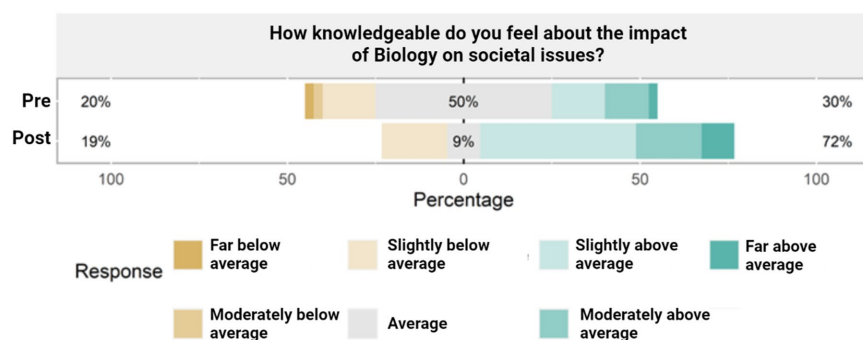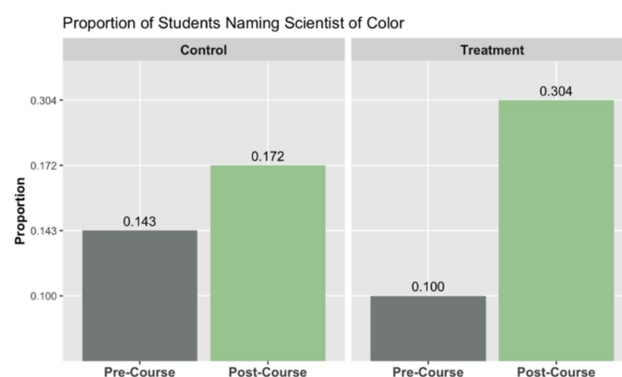

FIGURE 5. Self-reported knowledge of societally impactful topics. Before IA materials, students reported 50% neutrality and 30% positive feelings toward their knowledge about the impact of biology on societal issues. Following exposure to IA materials, neutrality decreased to 9%, while positive reports increased to 72%, indicating that students felt more knowledgeable on the intersection of biology and society following participation in the IA curriculum.

Student Perception of IA Materials

Following the interventions, students overwhelmingly indicated approval of the materials in each module, and a vast majority perceived *The Immortal Life of Henrietta Lacks* to be more useful, engaging, and relevant than a traditional biology textbook (Figure 2B). It is important to note that students were not required to read the traditional textbook in the IA section at any point during the semester, although it was available to them as an optional text, and students' responses may be influenced by previous experiences with textbooks rather than a sole comparison with the textbook traditionally used in the course. We were particularly interested in the impacts these materials had on students who possess racial identities that have been historically marginalized in science (e.g., those who could personally identify with aspects of focal individuals described in the IA curriculum). Such students are at a greater risk of being tokenized (Muhs *et al.*, 2012) and receiving microaggressions in the classroom (Harrison and Tanner, 2018). We considered the possibility that these offenses would increase during class discussions.

However, our results showed that students who identify as a PEER reported equal or higher approval of IA materials than non-PEER students. Thus, while students may be affected differently by exposure to such materials, on average, we found that PEERs approved of their integration as much as, if not more, than their non-PEER peers in the classroom. Though these results are encouraging, we caution readers in their interpretation of these results, because we tested these materials in a single section at a single institution, and the courses were racially diverse. Thus, students who are racially underrepresented in STEM were well represented in these classes, reducing the possibility that such students are the only individuals in group discussions on these topics. Future work will benefit from investigations incorporating these curricula into other institutional contexts, class sizes, and course

levels (i.e., lower vs. upper division). Additionally, qualitative approaches to addressing the impact of these materials on students with marginalized identities would allow more in-depth and nuanced understanding. Finally, when any classroom topic relates to people's identities, inclusive approaches and language choices are critical (Hales, 2020). We acknowledge that one reason for the success of these modules may have been, in part, due to the impact of an instructor well versed in inclusive pedagogy.

Student Knowledge of Societally Impactful Topics

Across both class sections, 43% of students were not aware of topics related to unethical experimentation on people in biology research and 48% of students had not considered how biological science shapes societal views on identities. This shows a persistent deficiency in how students' prior education highlights IA in science.

After participation in IA modules, we found students were three times more likely to name women scientists and scientists of color during an exercise in which we asked students to name as many scientists as possible over 2 minutes. Thus, implementing IA materials may prove one effective strategy in combating the stereotype that only people with certain overrepresented and privileged backgrounds and identities can be scientists. These results also align with previous work showing recognition of scientists from diverse backgrounds can have positive impacts on student outcomes (e.g., increased empathy, student performance, interest in science; Schinske *et al.*, 2016). While we cannot pinpoint the IA modules as the underlying reason why so many more students named nontraditional scientists, we point to the possibility that students exposed to IA modules were more likely to confront their own unintentional biases when asked that survey question.

Moving Forward

Previous work has explored learning goals for nonscientists and suggested they may be distinct from those of developing scientists (Miller, 2004; Klymkowsky, 2005; Feinstein *et al.*, 2013; Ballen *et al.*, 2017). For example, scientific literacy skills, or the ability to access and make sense of science relevant to their daily lives (Feinstein *et al.*, 2013), may be more critical to promote among students for whom an introductory biology course is their only exposure to science throughout higher education. Similarly, the ability to apply evidence-based solutions to personally meaningful problems will be particularly important as nonmajors regularly engage with scientific issues relevant to their daily lives after they leave the biology classroom. However, we also argue that teaching IA is important for students majoring in biology and other science disciplines. Such students may be less likely to take classes that consider the social elements or real-world implications of biology and science.

Thus, integration of IA materials in lower-level biology may be students' only opportunity to discuss the prevalence of biases, stereotypes, and assumptions that shape science. Whether we are preparing nonscientists to evaluate science in the media or preparing biologists for a career that impacts society through scientific advancement, it is important for students to leave the classroom with a deeper understanding of how science impacts the world around them, as well as their role in this interaction.

Accessing Materials

All survey instruments used to complete this study are available in the Supplemental Materials.

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