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| Research Article

Students' perceptions of social issues in biology courses

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ABSTRACT Students' scientific literacy may be improved by the integration of social issues into biology courses, enabling them to make informed decisions on social issues in the context of their scientific knowledge. Additionally, this may allow students to recognize the connection between science and society. Although there are a number of benefits with having students learn about social issues in biology courses, most undergraduate courses may follow a traditional curriculum, which emphasizes the scientific content without framing it in a social context. Here, we investigated whether undergraduate students have been exposed to social issues in previous biology courses and examined how their perceptions changed before and after taking a biology course that incorporated social issues. In surveys, most students reported having no exposure to social issues in biology courses. Most students, especially females and persons excluded because of their ethnicity or race (PEERs), agreed with the integration of social issues in biology courses before taking the course. Students found reflection essays to be a useful tool in allowing them to think and share their thoughts on social issues as well as relate the course content to their personal lives. These results highlight students' interest in learning about social issues from a scientific perspective and how reflection essays may be used to practice applying their knowledge to real-world issues.

KEYWORDS socioscientific issues, scientific literacy, reflection essays

A major goal of scientific literacy is for individuals to access and interpret scientific information and make informed decisions with respect to individuals, local communities, and broader society (1). In addition to scientific knowledge, individuals make informed decisions by taking into consideration their personal experiences, family perspectives, emotions, and societal concerns (2–4). Given the complex network of information and decision-making, biology education needs to ensure that students understand the relationship between science and society (5). Moving beyond understanding, educators may center equity at the core of scientific literacy and empower students to use their scientific knowledge to recognize and disrupt societal inequities, becoming societal change agents (6).

Although there is a need to integrate science and society in the classroom, traditional biology curricula have emphasized teaching students a wide range of content, potentially at a superficial level (7). Time constraints are one of the biggest barriers for faculty to teach science process skills, such as scientific reading and writing, in their courses (8). Many of these skills are addressed in laboratory courses where students have opportunities to engage in science practices (9). With an emphasis primarily on scientific content and methodology, many introductory biology students fail to recognize the impact of science on society (10).

Without practice, students struggle to transfer and apply their knowledge to real-world scenarios (11–13). For example, they do not include their knowledge of molecular and cellular processes when explaining genetically modified organisms (12). Similarly, students may have knowledge about mRNA vaccines, but they do not apply their vaccine knowledge in their arguments to counter vaccine hesitancy (11). Without

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learning to apply science to cultural and social contexts, students have difficulty making scientific arguments and applying their knowledge to social issues (14, 15).

One way to explicitly link science and society for students is through the integration of socioscientific issues into biology courses, where students are asked to analyze and discuss social issues from a science perspective (16). Similarly, teaching an ideological awareness curriculum challenges students to evaluate how biases and assumptions impact scientific knowledge (10). Discussions on social issues require students to draw on their own personal backgrounds and share their diverse moral, political, social, and economic perspectives. Furthermore, students are more likely to consider the moral and ethical implications of science on society, identify potential solutions to societal problems, and connect topics of science and society (10, 17, 18). By integrating social issues into biology courses, instructors have the opportunity to model social responsibility and students may practice addressing social issues by combining their scientific knowledge with their different perspectives (15, 19).

Teaching science in a social context is critical for all students, including both science majors and non-science majors, to become scientifically literate citizens (5, 20). Student benefits include increased motivation, content knowledge, application, and critical thinking skills (18, 21–23). When introductory biology students are taught to connect science and society, they relate more to the content and have increased motivation in a laboratory course (21). Students exposed to an ideological awareness curriculum demonstrate a better understanding of the biological content of a course and are less likely to mention pseudoscience compared with those in a traditional curriculum (18). Applying scientific knowledge to social issues is challenging without practice (11, 22, 23). Students develop and share their own opinions, including scientific concepts in their explanations, when taught to consider both legal and ethical perspectives (22). By practicing the application of science on social issues, students exhibit improved critical thinking skills compared with those who did not (23).

While there are a number of benefits, few studies have evaluated how students perceive the integration of social issues in biology courses in higher education. After learning about social issues in an introductory biology course, most students report enjoying and approving the inclusion of these topics, especially persons excluded because of their ethnicity or race (PEERs) (10). However, it is unclear how students viewed this integration prior to exposure in their introductory biology course. When students are unfamiliar with a teaching strategy, instructors are concerned about how students respond and instructors may adapt their teaching to minimize any potential resistance from students (24, 25). It is important for instructors to understand how students view these topics in biology courses to identify how best to introduce and integrate social issues into courses. In this study, we address the following research questions:

1. What exposure do students have to social issues in biology courses?
2. What are the students' opinions about social issues in biology courses? Are there differences in opinions based on students' backgrounds (gender, ethnicity/race, first-generation status, or socioeconomic status)?
3. How do their opinions change after taking a course where social issues are discussed?

METHODS

Study participants

The study was conducted starting in the winter quarter of 2021 through the fall quarter of 2022 at a large public university with a Carnegie basic classification of Doctoral University: Highest Research Activity. It is a Hispanic-serving institution with at least 25% of the undergraduate student population identifying as Hispanic or Latinx. The study was conducted under the guidelines of the Institutional Review Board (protocol number 2817).

All participants were enrolled in an upper-division biology laboratory course. While the course was an elective, students majoring in biological sciences were required to complete at least two upper-division biology laboratory courses for their degree. Most students (98.8%) were science, technology, engineering, and mathematics (STEM) majors. Prerequisites for the course included six biology courses on cell biology and organismal biology, ecology and evolutionary biology, genetics, biochemistry, molecular biology, and scientific writing. Upper-division cell biology or developmental biology courses were possible corequisites. Most students enrolled in the upper division laboratory course in their fourth year or later (76.9%, n = 459). 23.1% of students (n = 138) were enrolled in their third year. Demographic information for students enrolled in the course is provided in Table 1.

Upper division biology laboratory course

The 10-week course was a developmental and cell biology laboratory course that was designed for students to learn about the biological basis of skin pigmentation. The course met weekly for a 1-h lecture and 3-h laboratory section. Students learned about the development of pigment cells (melanocytes), melanin synthesis, and the development and incidence of melanoma. Using zebrafish embryos as a model organism, students conducted experiments to answer research questions about the development and pigmentation. In addition to the scientific topics, social issues including animal models in research, data reproducibility in research, racism, and healthcare inequities, were integrated into the course through readings, videos, reflections, and class discussions. Reflection essays were assigned throughout the quarter to provide students an opportunity to express their opinions on specific social issues, and these were graded for completion. Reflection essay prompts are provided in Appendix 1.

Survey

The pre-survey was administered at the beginning of the course (Appendix 2). Students were informed that there were no correct or incorrect answers. Students received participation points for completing the surveys. To determine the students' perception of social issues in their biology courses, they were provided with five-item survey regarding social issues in biology courses and asked to rate them on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). They were provided with examples of social issues such as socioeconomic class, racism, and access to health care. Items included statements like "It is important to discuss social issues in a biology course" and "I am interested in learning more about social issues in a biology course." To determine their

TABLE 1 Demographic characteristics of students[a]

	% (*n*)
Gender	
Female	60.0% (358)
Male	40.0% (239)
Race/ethnicity	
American Indian or Alaskan Native	0.2% (1)
Asian	48.9% (292)
Black or African American	4.0% (24)
Native Hawaiian or other Pacific Islander	9.4% (56)
Latinx	21.1% (126)
White	14.7% (88)
Decline to state	1.7% (10)
Low-income	33.5% (200)
First-generation	47.4% (283)
Transfer	17.6% (105)
STEM major	98.8% (590)

[a]Source: Institutional Research Office.

prior experiences with social issues in their courses, students responded to a yes or no question that stated "I have taken a biology course where they discussed social issues."

To determine if their views about social issues had changed due to the course, students were provided with the same five-item survey regarding social issues in the post-survey, which was administered at the end of the course. To further explore how students viewed social issues, an open-response question included in the post-survey asked students "What did you think about the reflection essays? Explain." The reflection essays were used only for the discussion of social issues.

Data analysis

There were more students who completed the pre-survey (n = 776) than the post-survey (n = 597). Students who completed both the pre- and post-surveys (n = 597) were included in the data analysis. The open-ended reflection essay question was used to determine how students viewed discussing social issues with reflection essays. For this open-ended question, researchers (H.M., J.T., S.T., and S.W.L) identified overarching themes and used inductive coding to generate a codebook (26). The researchers met repeatedly to compare and revise the codes until finalizing a codebook (Appendix 3). The final codebook consisted of two main categories: benefits inside the classroom and benefits outside the classroom. Within benefits inside the classroom, codes included (i) low stress, (ii) consolidate learning, (iii) self-expression, and (iv) novel experience. Within benefits outside the classroom, codes included (v) connect to social issues, (vi) apply to social issues, (vii) share information with others, and (viii) relevant to personal life. For responses that were outside the two main categories, additional codes included (ix) minimal positivity, (x) not beneficial, and (xi) no opinion. Once the codebook was established, two researchers (H.M and J.T) coded one-third of the data set independently to determine interrater reliability. There was an 82.1% agreement between the two researchers and Cohen's kappa was 0.79, indicating substantial agreement. Discussions occurred until a 100% agreement was met. Subsequently, the two researchers each coded one-third of the remaining data set independently.

The total for the five-item survey on social issues was determined for the pre- and post-surveys. The five-item survey total score had a possible score of 0–25. The five-item survey had an excellent internal consistency (pre-survey Cronbach's alpha = 0.92; post-survey Cronbach's alpha = 0.94). To further confirm the students' interpretation of the survey items, their responses to the open-ended reflection essay question were used to corroborate their survey responses. Students who wrote about the benefits of social issues in the course in the reflection essays (mean = 22.11, SD = 4.30, n = 177) had a significantly higher survey total score in the post-survey compared with those students who did not write about the benefits of social issues (mean = 20.75, SD = 4.92, n = 420) [$t(375.5)=-3.38$, $P < 0.001$]. This demonstrates that students who wrote about the benefits of social issues were more likely to agree with the integration of these topics in biology courses, and it suggests that students interpreted the survey items appropriately with respect to the idea of social issues.

All statistical analyses performed using R. Welch's t test were used to determine significant differences in pre- or post-surveys by gender, first-generation status, ethnicity/race, or socioeconomic status. PEERs included students who identified as Latinx, Black/African-American, Native Hawaiian/Pacific Islander, American Indian, and Alaskan Native.

RESULTS

Students' previous exposure to social issues in biology courses

In the pre-survey, students were asked about whether they had taken a biology class where social issues had been discussed. Most students (74.2%, n = 444) responded that they did not taken a biology course where social issues had been discussed (Fig. 1). For the 25.8% of students (n = 153) who did have prior experience, they provided examples

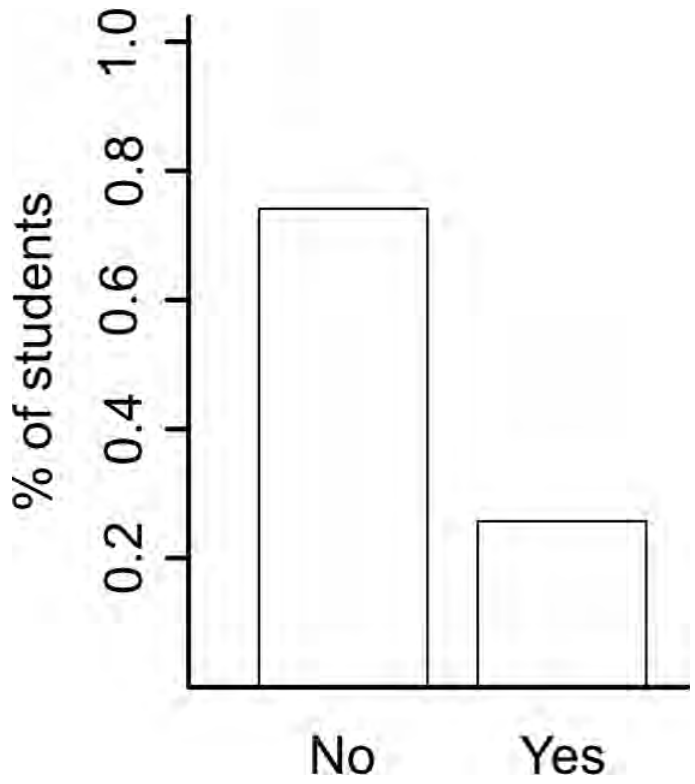

FIG 1 Students' prior experience with social issues in biology courses. Most students (74.2%, *n* = 444) did not have a previous experience with social issues being covered in biology courses. About a quarter of the students (25.8%, *n* = 153) took a biology course where they covered a social issue.

of which social issues had been covered in biology courses (Table 2). Some students provided multiple social issues and each issue was categorized based on the students' description. Given the interconnected nature of the categories, when applicable, a social issue was coded into multiple categories.

Of the students, 37.3% had been exposed to the topic of discrimination based on race, gender, LGBTQ+, and disability. More specifically, student responses in these subcategories included topics such as "redlining," "Black Lives Matter," and "women in science". A few students were non-specific and more general in their responses, such as "groups may be traditionally underrepresented" or "minorities in research."

The healthcare inequity category included topics that were about how groups of people receive different healthcare benefits based on factors like race/ethnicity, gender, and socioeconomic status. For example, students wrote about "unequal access to healthcare" or "minorities will have less medical benefits due to where they live and how they receive information." The socioeconomic category included topics related to socioeconomic status, and some student responses focused on learning about socioeconomic issues without providing more specific information. 11.1% of the students wrote "COVID-19," and most students did not provide detailed information about how it was discussed. 10.5% of student responses included food inequality experienced by people from different backgrounds. 9.2% of students wrote about ethical issues related to genetics, including "designer babies," "cloning," or "genetic modification." 7.8% of students focused on climate change as a topic covered in another biology course. 10.5% of students provided only a course number or did not provide a specific topic.

TABLE 2 Social issues discussed in other biology courses

Social issue topic	% of students (*n*)
Discrimination	37.3% (57)
Race	24.8% (38)
Gender	7.8% (12)
LGBTQ+	1.3% (2)
Disability	0.1% (1)
Non-specific	2.6% (4)
Healthcare inequities	32.0% (49)
Socioeconomic	13.7% (21)
COVID-19	11.1% (17)
Food inequality	10.5% (16)
Ethics related to genetics	9.2% (14)
Climate change	7.8% (12)
Undefined	10.5% (16)

Students' opinions on social issues in biology courses

To determine the students' perspective on the integration of social issues in biology courses, the total score on the five-item pre-survey was analyzed. The mean total score for the pre-survey was 20.08 (SD = 4.49, $n = 597$) for all students, indicating an agreement for the integration of social issues in biology courses. Further analysis (Fig. 2) revealed that female students were more likely to agree (mean 20.73, SD 4.11, $n = 358$) compared with male students (mean 19.10, SD 4.86, $n = 239$) [$t(451.1)=-4.29$, $P < 0.001$]. PEERs were more likely to agree (mean 21.01, SD 4.25, $n = 207$) compared with non-PEERs (mean 19.58, SD 4.54, $n = 390$) [$t(444.66)=-3.82$, $P < 0.001$]. There was no difference in the pre-survey total score based on first generation status [$t(566.28)=0.77$, $P = 0.44$] or socioeconomic status [$t(413.17)=-0.20$, $P = 0.84$].

To determine the students' perspectives on social issues after completing a course that integrated them, the total score on the five-item post-survey was analyzed. The mean total score for the post-survey was 21.15 (SD = 4.78, $n = 597$) for all students. Further analysis (Fig. 3) revealed that female students (mean 21.93, SD 4.09, $n = 358$) were

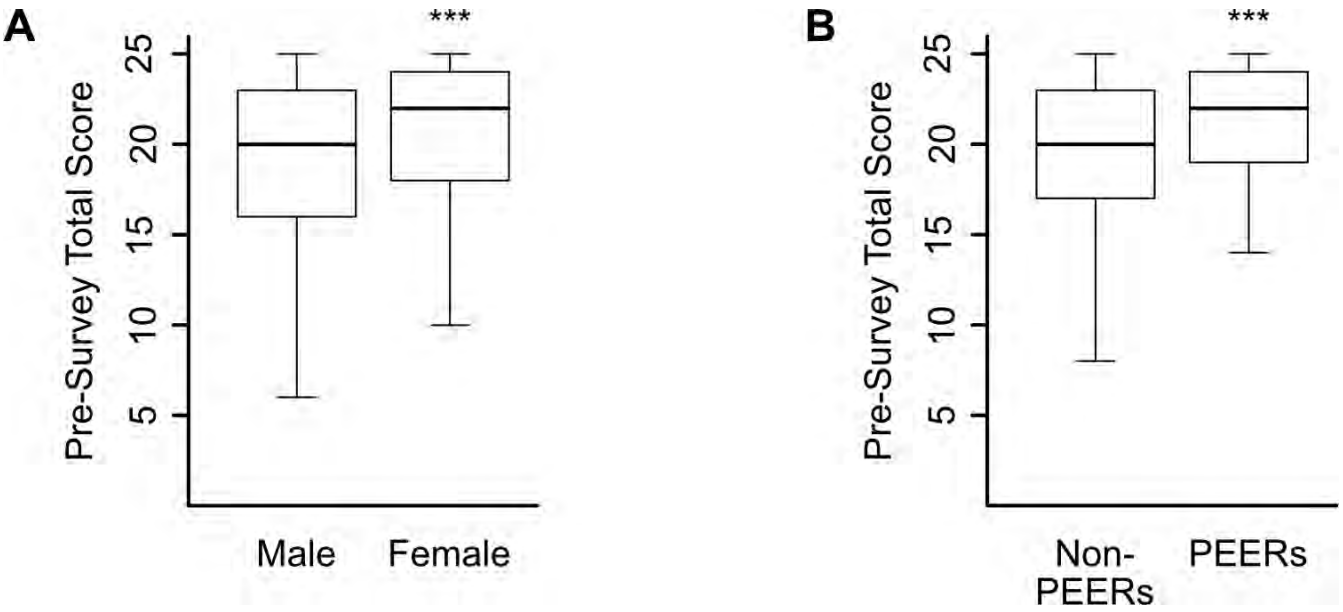

FIG 2 Students' opinions of social issues at the beginning of the course. Female students ($n = 358$) were significantly more likely to agree with the integration of social issues in biology courses compared to male students ($n = 239$) (A). Persons excluded because of their ethnicity or race (PEERs) ($n = 207$) were more likely to agree with the integration of social issues in biology courses compared to non-PEERs ($n = 390$) (B). Welch's t test, ***$P < 0.001$.

more likely to agree with the integration of social issues in biology courses compared with male students (mean 19.98, SD 5.46, n = 239) [t(411.35)=−4.69, P < 0.001]. There was no difference in PEERs (mean 21.48, SD 4.94, n = 207) compared with non-PEERS in the post-survey total score (mean 20.97, SD 4.69, n = 390) [t(401.8)=−1.22, P = 0.22]. There was no difference in the post-survey total score based on first-generation status [t(589.09)=−0.22, P = 0.83] or socioeconomic status [t(436.17)=−1.20, P = 0.23].

To determine how the students' perspectives on social issues shift after completing the course, the change in total score was determined (post-survey total score − pre-survey total score). The mean change in total score was 1.07 (SD = 4.79, n = 597) for all students. Further analysis revealed that there was no difference in female students (mean 1.19, SD 4.55, n = 358) compared with male students in the change in total score (mean 0.89, SD 5.13, n = 239) [t(467.48)=−0.75, P = 0.46]. There was a difference in mean change in PEERs (mean 0.47, SD 4.92, n = 207) compared with non-PEERs (mean 1.39, SD 4.69, n = 390) [t(402.76)=2.21, P < 0.05]. There was no difference in the mean change in total score based on first-generation status [t(569.14)=−0.94, P = 0.35] or socioeconomic status [t(416.61)=−0.99, P = 0.32].

Students' opinions on reflection essays to discuss social issues

To determine how students viewed discussing social issues with reflection essays, the open-ended question was analyzed from the post-survey (Table 3). Most students (86.6%, n = 517) wrote about how they benefited from writing reflection essays. The reasons provided were categorized as benefits inside the classroom and benefits outside the classroom. Some students provided multiple benefits, and each benefit was categorized separately.

For the benefits inside the classroom, 21.1% of the students described the reflections as an opportunity to review and consolidate their learning of the material. 15.7% of students wrote about how it provided them with a space to share and express their opinions. 9.7% of students found the assignments to be minimal stress and easy to complete as part of their coursework. Lastly, 6.4% of the students commented on how writing a reflection is an unusual assignment in a biology course and a novel experience.

For the benefits outside the classroom, 29.1% of students wrote about how it allowed them to connect to social issues by providing time to think, discuss, and share their

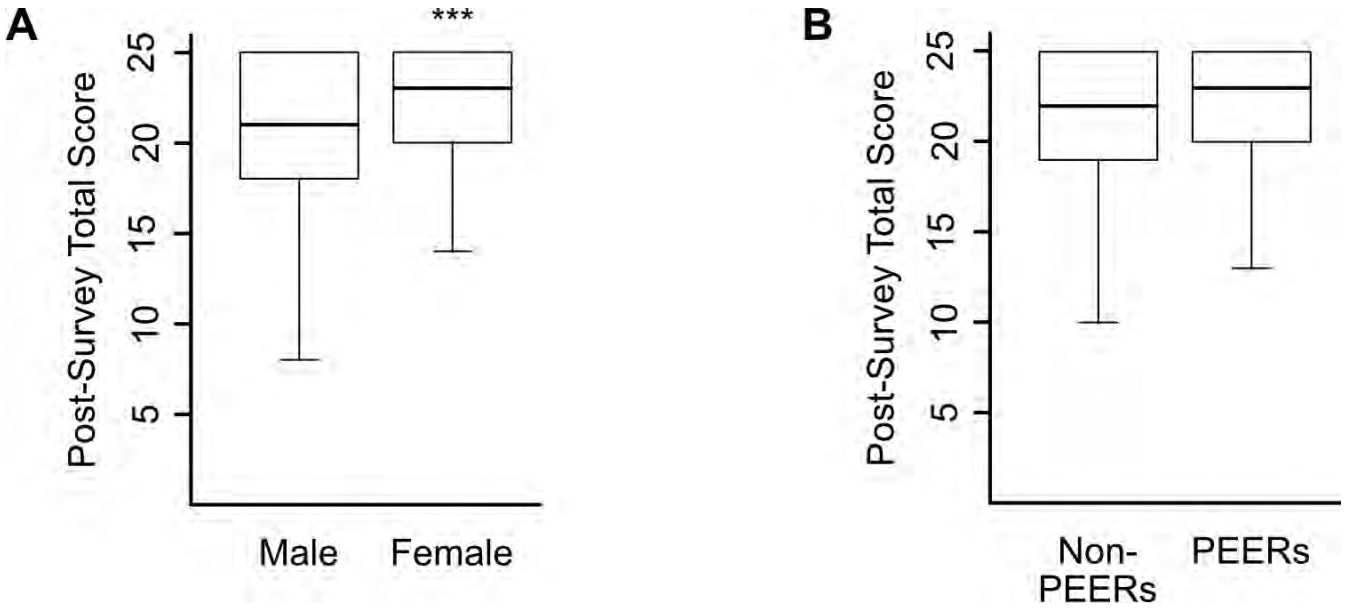

FIG 3 Students' opinions of social issues at the end of the course. Female students (n = 358) were significantly more likely to agree with the integration of social issues in biology courses compared to male students (n = 239) (A). There was no difference in persons excluded because of their ethnicity or race (PEERs) (n = 207) and non-PEERs (n = 390) in their opinion of the integration of social issues in biology courses (B). Welch's t test, ***P < 0.001.

TABLE 3 Students' opinions on reflection essays to discuss social issues

	Student opinion	% (*n*)	Example quotes
Benefits to inside the classroom	Consolidate learning	21.1% (126)	"I think they were very helpful as it allowed us to reflect on the content that was performed for the week and share thoughts in order to test our understandings." (Student 1746)
	Self-expression	15.7% (94)	"I think that the reflection essays fostered a space where I could express my personal sentiments. It is a very thought-provoking activity, and I appreciate them." (Student 3796)
	Low stress	9.7% (58)	"I liked that they were graded based on participation so I didn't have to worry about whether I addressed a certain thing and just write freely about what I thought." (Student 6354)
	Novel experience	6.4% (38)	"It was one of the first courses I have taken that distributed that much time to discussing biology's application to different social issues, and I thought it was very interesting." (Student 2227)
Benefits to outside the classroom	Connect to social issues	29.1% (174)	"I enjoyed writing the reflection essays in this course. They allowed me to think outside the scientific zone and explore really important social issues. The self-reflection has brought to light what I have experienced and also what I have not but know that others have. This perspective is really important to have when learning about science that affects everyone from all races, skin types, and backgrounds." (Student 4471)
	Relevance to personal life	21.8% (130)	"I think these essays are very great ways to reflect on new ideas and scientific methods that we may not learn outside of the class. Learning about specific parts of science is very interesting and can be very applicable to our daily lives such as applying sun screen and clothing." (Student 3380)
	Address social issues	1.2% (7)	"The reflection essays helped me see my own views on societal bias, and how I can change or reinforce my views with scientific evidence. Seeing how I've changed some of these views, I look forward to taking a more educated approach to my own views, rather than what I have received at face value from others." (Student 6449)
Other	Minimal positivity	9.7% (58)	"They were fun to complete." (Student 5204)
	Not beneficial	3.4% (20)	"They were okay. I feel like I didn't get much out of them." (Student 4329)

thoughts on social issues. A few students (1.2%, $n = 7$) wrote about how reflections made them consider how they might address social issues, including future actions they may take to educate themselves or to combat healthcare inequities. 21.8% of students found reflections as a way to write about how the material they are learning in the course is relevant and applicable to their personal lives.

Some students (9.7%, $n = 58$) described the assignment as positive without further elaboration such as "They're a great idea" or "I liked them." Few students (3.4%, $n = 20$) described the assignment as not beneficial to their learning.

DISCUSSION

In this study, we examined students' perceptions of social issues in biology courses. Most students reported that they had not taken a biology course that incorporated social issues. This is consistent with a previous study where introductory biology students did not understand how science impacts social issues (10). The limited exposure to social issues in biology courses may be due to a number of barriers including instructor confidence, curriculum priorities, and perceptions of students (27, 28). Instructors may feel they lack the necessary knowledge and training to effectively integrate these issues into their curriculum (27, 28). Instructors may also struggle with prioritizing social issues in a curriculum where scientific content is primarily emphasized and highly valued (27). Additionally, if instructors have been primarily lecture-based, then discussing social issues may require not only restructuring the curriculum but also teaching strategies (29). Even with these challenges, instructors recognize the importance and potential benefits of introducing students to social issues in biology courses (27). From the instructors' perspectives, the benefits for students include connections between science and social issues, learning different viewpoints on issues, and supporting PEERs in the classroom (27).

From the students' perspectives, students' interest in learning about social issues in biology courses depend largely on their background. At the start of the course, female

and PEER students were most likely to recognize the importance of discussing social issues in a biology course. This may be due to the life experiences of female students and PEERs in their STEM courses where they experience discrimination. Female and PEER students find the STEM environment to be less accepting compared with male and non-PEER students (30–33). Female and PEER students experience bias and feel unrecognized in STEM fields (31, 34–36). Based on their experiences in STEM courses, female and PEER students may be able to relate to social issues, including inequities, and benefit from the inclusion of these topics in biology courses.

For most students, their interest in social issues in biology courses remained similar before and after the course. There was a significant shift toward the agreement of inclusion of social issues for non-PEER compared with PEER students, which is likely due to the ceiling effect for PEER students. Collectively, these results suggest that students are receptive to learning and evaluating social issues from a science perspective. Furthermore, giving students the opportunities to discuss these issues may encourage them to become agents of societal change (6).

Students found the reflection essays to be beneficial because the reflection essays gave students the time to think, discuss, and share their opinions on social issues. To enhance scientific literacy skills, it is necessary to provide students with more than content knowledge and give them opportunities to practice applying their knowledge to real-world issues (11). Writing assignments can be used to improve scientific literacy by challenging students to apply their content knowledge to broader issues (37). Their reflections are effective assignments to increase students' personal awareness and allow them to consider social issues with respect to various contexts, including race/ethnicity, cultural, and socioeconomic (38). By providing students with this reflective practice, it may allow students to apply their scientific knowledge to real-world issues from their various perspectives.

One of the goals of the reflection essays was for students to identify ways the course content is related to their personal lives. In agreement with this goal, students reported that the reflection essays were helpful in connecting the course content to their personal lives. When students are able to make this connection, students show increased interest in science (39). In introductory biology courses, asking students to connect science to their personal lives leads to increased academic performance and higher persistence in STEM fields (40). By including social issues in biology courses, instructors may potentially increase student interest and persistence in STEM fields, especially female and PEER students. Further studies are necessary to determine how social issues in biology courses may impact student academic performance and persistence in STEM fields.

Limitation

This study provides a limited sampling of biology students enrolled in an upper division biology course. Students enrolled in the course to fulfill a laboratory elective, and it was not required for all biology majors. Given that most of the students were in their fourth year, it is possible that students may not remember whether social issues were covered in previous biology courses. Students have difficulty in accurately recalling content knowledge acquired in their previous courses (41). Learning the loss may be more prominent when students are required to master topics at a lower cognitive domain without the application of the content knowledge (42). For example, if students were exposed to social issues in lecture and were not asked to discuss these topics, then they may be less accurate in their memory. To confirm the upper-division students' perspectives and experiences, it may be necessary to survey lower-division students and faculty teaching biology courses about whether they incorporate social issues into their curricula.

Conclusion

This study reveals that while social issues are covered minimally within biology courses, most students agree with the integration of social issues in biology courses, particularly

female and PEER students. Students find reflection essays to be an effective means to relate to and apply content knowledge to their personal lives and social issues.

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ADDITIONAL FILES

The following material is available online.

Supplemental Material

Supplemental material (jmbe00194-23-s0001.docx). Appendices 1 to 3.

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