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Re-envisioning Biology Curricula to Include Ideological Awareness

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Abstract

Addressing the challenges facing society and the world will require an understanding of the biases and limitations of science. To combat these challenges, here, we advocate for the incorporation of ideologically aware (IA) material into postsecondary biology curricula. IA materials communicate to students how biases, assumptions, and stereotypes inform approaches to and outcomes of science. By engaging with IA materials, student awareness of the impact of science on social problems is expected to increase. In this paper, we situate this IA approach with two other pedagogical approaches that incorporate societally relevant content: culturally relevant pedagogy and socioscientific issues. We then call for research to test ways of supporting instructor implementation of IA material, to evaluate the impact of IA topics on student academic and sociopsychological outcomes, and to explore how to implement IA material in different cultural and social settings. Throughout, we focus on IA topics in the context of postsecondary biology classrooms but encourage the incorporation of IA materials across scientific disciplines and educational settings. Our hope is that greater inclusion of IA materials will create more transparent, scientifically accurate, and inclusive classrooms.

Keywords Biology education research · Culturally relevant pedagogy · Ideological awareness · Inclusive teaching · Science and society · Socioscientific issues

Introduction

Finding global and local solutions to societal challenges is a central goal of science education. To meet this challenge, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) calls to transform science education systems to support diverse groups of learners as they address urgent environmental, social, and economic issues (UNESCO, 2016). Similarly, Vision and Change, a consensus framework in the US biology community (American Association for the Advancement of Science, 2011), highlights

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the ability to understand the relationship between science and society as a core competency for biology students. This is echoed globally in similar documents across other science education communities (e.g., Australia: Ross et al., 2012; Europe: Osborne & Dillon, 2008; Malaysia: Osman & Marimuthu, 2010).

In practice, biology educators have developed societally relevant course content through two main pedagogical practices: culturally relevant pedagogy (CRP) and socioscientific issues (SSI). CRP empowers "students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes" (Ladson-Billings, 1992), whereas SSI lessons use controversial scientific topics to expose students to diverse perspectives on contemporary social issues (Zeidler & Nichols, 2009). In this paper, we argue that neither approach explicitly focuses on societal topics that unveil systems of oppression, stereotypes, and biases in science. We advocate acknowledging the role of values in science during postsecondary biology lessons and present a new pedagogical approach to do so: ideological awareness (IA). Ideological awareness was coined by Angela Potochnik, a philosopher of science, and stems from her work, exploring the diverse aims of science (Potochnik, 2015, 2017, 2020). Potochnik explains that the aim of science is not truth but human understanding and that, unlike truth, understanding can be influenced by social values through the research questions pursued, the scientists who pursue the research, and the audience for whom the research is relevant (Potochnik, 2015, 2017). Lessons that incorporate IA communicate how biases, assumptions, and stereotypes inherent to social values inform approaches to and outcomes of science (Beatty et al., 2021).

While elements of IA are undoubtably currently discussed in biology classrooms (e.g., Chamany et al., 2008), to our knowledge, investigations into their impacts have not been published extensively (but see Beatty et al., 2021). We envision the study of IA to be among the next frontiers of research on the intersection of biology and society. To this end, we conclude this paper by listing the challenges associated with implementing IA material and identifying future research questions. The central objective of our paper is to invigorate science education research in IA with the ultimate goal of creating more transparent, scientifically accurate, and inclusive postsecondary biology classrooms. We focus on postsecondary biology classrooms because the study of life readily lends itself to discussion of social issues. Social, political, and technological shifts have large impacts on the biological sciences (e.g., inclusive representation of scientists, unequal access to healthcare, genetic modification) (Feliú-Mójer, 2020; Wood et al., 2020) and, therefore, necessitate discussion in biology classrooms. Furthermore, we are all early-career biologists and biology education researchers from higher education institutions in the USA. While our focus is on ideological awareness in the context of biology, we encourage these same principles for teaching societal topics be applied across all scientific disciplines.

Ideologically Aware Curricula Is a Central but Understudied Component of Culturally Relevant Pedagogy

Culturally relevant pedagogy (CRP) is an evidence-based and equitable pedagogical approach that includes three main components: academic success, cultural competence, and critical or sociopolitical consciousness (Aronson & Laughter, 2016; Favero & van Hoomissen, 2019; Ladson-Billings, 1992, 1995; Fig. 1). Critical or sociopolitical consciousness invites students to "question, challenge, and critique structural inequalities that exist in society" (Young, 2010), reflecting the objectives of IA in the context of science.

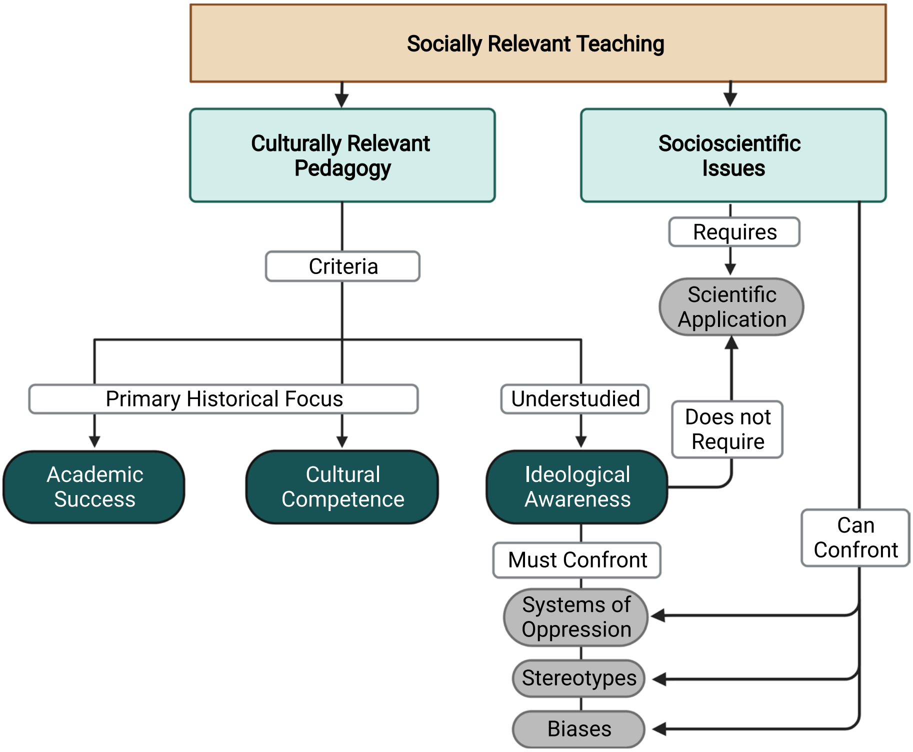

Fig. 1 Concept map depicting the relationship between several similar, but distinct, concepts that relate to socially relevant teaching in biology. We situate IA under the umbrella of culturally relevant pedagogy, which is characterized by three criteria. While academic success and cultural competence have been the primary historical focus of work related to culturally relevant pedagogy, IA is understudied. IA is similar to socioscientific issues but IA must confront systems of oppression, stereotypes, and biases, while SSI requires scientific application

The pillar of CRP concerning critical or sociopolitical consciousness, which is in closest alignment to IA topics, is often not implemented or studied (Fig. 1). Instead, most research on CRP has focused on academic success and cultural competence (Aronson & Laughter, 2016; Favero & van Hoomissen, 2019; Fuller & Torres Rivera, 2021) . Cultural competence refers to how instructors are able to effectively teach students who do not share the same personal characteristics or background of that instructor (e.g., gender, ethnicity, religion, country of origin, sexual orientation) (Tanner & Allen, 2007). Instructors who are culturally competent view student culture as an asset to learning, develop a welcoming learning community among students, and build knowledge of students that they use to differentiate instruction (Tanner & Allen, 2007). Common instructional practices of culturally competent instructors include valuing and validating students' backgrounds, using those differences as a strength in group work, employing student-centered teaching strategies, and developing diverse curricular materials (Favero & van Hoomissen, 2019). Prior studies demonstrate that instructors tend to emphasize the cultural competence aspect of CRP. For example, Morrison and colleagues (2008) conducted a meta-analysis of 45 K-12 research-based studies from 1995 to 2008 that highlighted culturally relevant pedagogy enacted in classrooms. In 42 of the 45 studies, classroom teachers implemented culturally relevant pedagogy through the lens of cultural competence. However, less than one-third of classroom teachers implemented all three aspects (academic success, cultural competence, and sociopolitical consciousness) (Morrison et al., 2008; Young, 2010). To further investigate this finding, Young (2010) studied several teachers at a racially diverse elementary school to determine how they understood culturally relevant pedagogy. When prompted to define culturally relevant pedagogy, none of the participants made any reference to academic success or the need to address sociopolitical consciousness. Instead, the participants defined culturally relevant pedagogy as a tool that uses students' cultural capital to make the curriculum meaningful for students (Young, 2010). This is also seen in studies that investigate the implementation of CRP in undergraduate biology courses. For example, Favero and Van Hoomissen (2019) conducted a study that investigated the impact of including diverse and culturally relevant anatomical and physiological examples (cultural competence) into curricular materials on student engagement. It is also important to note that the researchers of this study conceptualized CRP with no reference to sociopolitical consciousness. Similarly, Fuller and Torres Rivera (2021) conceptualized CRP as cultural competence and investigated the impact of the incorporation of student cultural knowledge into an existing microbiology module on student engagement.

Given the limited progress in diversifying biology, all components of CRP may be essential for instructors to help motivate diverse student groups, increase student interest, improve academic performance, and promote persistence in biology (Favero & van Hoomissen, 2019; Johnson & Elliott, 2020). Furthermore, given that many students enter college with limited knowledge of how science integrates with broader questions of the human experience, utilizing the IA component of CRP can be a method for informing biology students of the intersectionality of science and sociocultural issues (Favero & van Hoomissen, 2019).

Socioscientific Issues Focus on Diverse Perspectives, Not on Biases, Assumptions, and Stereotypes

Lessons centering socioscientific issues (SSI) cultivate critical thinking and argumentative reasoning to make informed decisions about complex real-world problems that sit at the intersection of science and society (Eastwood et al., 2012; Lenz & Wilcox, 2012; Ratcliffe & Grace, 2003; Zeidler & Keefer, 2003; Zeidler & Nichols, 2009; Zeidler et al., 2005). SSI controversies often relate to human or environmental health and require students to employ both scientific knowledge and argumentation to resolve posed problems (Kolstø, 2006; Zeidler & Nichols, 2009). Specifically, students reach informed decisions about these issues by considering the viewpoints of many stakeholders and then engaging in classroom debates (Zeidler & Nichols, 2009; Zeidler et al., 2005). SSI lessons promote scientific literacy, critical thinking, informed decision-making, argumentative reasoning, and reflective reasoning (Dawson & Venville, 2010; Eastwood et al., 2012; Sadler & Zeidler, 2004; Sadler et al., 2006; Zeidler & Nichols, 2009; Zeidler et al., 2005, 2019). Although not its primary focus, SSI lessons expose students to diverse perspectives on controversial issues and thereby promote emotional competence and character development in science classrooms (Gao et al., 2021; Lee et al., 2013). The SSI approach expands on the science, technology, and society (STS) pedagogical model by explicitly applying value systems to societal topics (Zeidler et al., 2005).

By requiring students to engage with political, ethical, economic, and cultural values held by diverse stakeholders, SSI lessons integrate values into science curricula. For example, an SSI lesson about genetic medicine may ask students to engage with moral dilemmas that families with histories of cystic fibrosis and Huntington's disease face when deciding to get genetically tested (Zohar & Nemet, 2002). In this scenario, the stakeholders are family members holding different sets of values. Should a daughter who values informed decision making get genetically tested if her father does not want to know his probability of developing symptoms? What if the daughter is pregnant? Students employ information about the principles of genetics to debate and eventually reconcile these conflicting viewpoints.

In SSI lessons, a distinction is drawn between knowledge and values. Students with the same scientific knowledge base approach the issue with different values and thereby argue for different solutions to the issue, emphasizing that values are not determined by knowledge (Zohar & Nemet, 2002). However, values held by scientists shape how scientific knowledge is created, rewarded, presented, and applied in society (Brown, 2013; Elliott, 2017). *In this paper, we call for societally relevant biology lessons that explicitly acknowledge how societal values shape scientific practice and applications.* The central objective of IA lessons is to expose students to the embeddedness of dominant ideologies within science (Fig. 1).

Science Inaccurately Taught as a "Value-Free" Process

The pedagogical approaches described above do not always ask students to question assumptions involved in the scientific process. Students undertaking these and similar exercises are often left with a misguided impression that science is a "value-free" enterprise (Murcia & Schibeci, 1999). This impression is not at the fault of students; science is often presented as an objective and "value-free" pursuit that is agnostic to personal beliefs or aspects of one's identity. Any notion that one's values play a part in influencing the final product of scientific inquiry is anathema to the scientific community's status quo (Betz, 2013; Douglas, 2000). However, a closer look at the ways in which science operates—understood through the fields of history and philosophy of science (HPS) and nature of science (NOS)—shows science is subject to the same biases and misunderstandings as any human endeavor. The values held by scientists can fundamentally influence which questions are prioritized, what science is funded, the results that are published, and the way those results are presented to the public and in the classroom (Brown, 2013; Douglas, 2009). Perhaps, more fundamentally, values also shape the makeup of the scientific community by influencing who has opportunity and power within scientific institutions (Elliott, 2017).

Most understandings of how science operates include some description of the interaction between science and society. Synthesizing nature of science (NOS) understandings from the previous decades, the consensus approach common in the 90 s and 00 s highlighted both the social embeddedness of science as well as the role of creativity in the scientific process (Abd-El-Khalick & Lederman, 2000; McComas et al., 1998). More recently, the family resemblance approach to nature of science adds to this, discussing the ways that science is influenced by financial and political systems of power (Kaya & Erduran, 2016) and acknowledging the potential for bias to influence scientists (Irzik & Nola, 2014). However, this approach needs to be extended to more directly address the ways that societal influences interact with individual positionalities (Secules et al., 2021) to create biased outcomes. *Ultimately, it is impossible for human beings to study, consume, or teach science without some influence of their values, the lens through which they* *see the world*. Our nuanced understandings of how individually and societally held values shape scientific processes and applications are rarely applied to our pedagogical practices, which is the aim of our ideological awareness approach. Instead of ignoring and minimizing the role of values in science, we argue that best practices would be a thorough acknowledgment of the way our values affect research and teaching. We further argue that, by acknowledging the role of values in science, we have the opportunity to become better researchers and teachers.

Biology Curricula that Acknowledge Biases and Assumptions

Instead of presenting science as an objective, "value-free" process, biology educators can teach biology content in an ideologically aware way that highlights how dominant ideologies and paradigms shape our biological knowledge base and the application of that knowledge base (Beatty et al., 2021; Potochnik, 2020; Fig. 1). IA lessons contextualize science within its sociopolitical landscape and invite students to question, challenge, and critique structural inequalities (Ladson-Billings, 1995). For example, an IA lesson focusing on biological misconceptions about human racial groups (i.e., the incorrect assumption that races are human subspecies or that genetic variation exists primarily among races) clarifies how racial biases have supported pseudoscientific eugenics movements and continue to inform modern medical practices (Donovan et al., 2019; Hubbard, 2017; Saini, 2019). Similarly, an IA lesson covering the inaccurate application of cisnormative terminology to describe the diversity of sexual systems found in nature (i.e., the use of transphobic terminology; Baeckens et al., 2020) underscores how cultural norms restrict understanding of the natural world (Monk et al., 2019; Saguy et al., 2021). As mentioned above, an SSI lesson on genetic medicine might engage students in moral debates over individual decisions to get genetically tested (Zohar & Nemet, 2002). An IA lesson on genetic medicine would additionally engage students in considering how structural inequities shape medical knowledge and practices. The IA lesson could highlight the history of medical research centering on and benefiting white-cisgendered men (Oh et al., 2015; Perez, 2019) and/or include discussion about how (dis)ability status will likely impact access to gene editing (Feliú-Mójer, 2020; see additional IA examples in Fig. 2). By explicitly acknowledging biases, stereotypes, and assumptions during SSI lessons and by emphasizing the IA component of CRP, we expect to see an increase in student awareness of the impact science has on social problems (Beatty et al., 2021).

Hesitancy to Incorporate Societally and Culturally Relevant Activities

Despite the benefits of societally and culturally relevant topics, most science instructors do not implement them in their classrooms (Boutte et al., 2010; Favero & van Hoomissen, 2019; Sleeter, 2012). Preliminary evidence suggests that instructors are similarly hesitant to incorporate IA material (Beatty et al., in review). This is, in part, due to the perception of STEM as neutral, apolitical, and culture free (Boutte et al., 2010; Favero & van Hoomissen, 2019), which is an outdated and incorrect view of the nature of science. Instructors portray the field of science as objective and unbiased to maintain student trust in science (Chen & Xiao, 2021; Nielsen, 2020; Beatty et al., in review). For example, in one study that surveyed instructor attitudes, an instructor claimed that addressing these topics in the classroom would, "…undermine students' faith in the objective nature of science—the goal we strive to achieve even when we fall short…" (Beatty et al. in review). This example

Example Activity	Description of Activity	Optional: Disciplinary Content Addressed	Ideological Awareness Components of Activity: Go beyond disciplinary content to...
Designer Babies	Students discuss hypothetical pre-natal gene editing based on medical necessity and cosmetic adaptations. They consider the ethical implications of gene editing and the societal implications.	Inheritance, Human Reproduction, Biotechnology, CRISPR-Cas9	...address the societal and ethical implications of eugenics and "preferential" genes. ...address how this can lead to biases against disabilities.
Disparities in Healthcare	Students learn about the healthcare disparities among people with historically excluded identities, as well as the sources for, effects on, and solutions for healthcare disparities on marginalized communities.	Human Disease and Health	...consider how exclusion leads to biased research participation and preferential treatment in healthcare.
Representation in STEM	Students dissect a research article discussing gender and racial/ethnic representation within introductory science textbooks (Wood et al., 2020).	Diverse Content Depending on the Scientific Discovery	...discuss historical and contemporary exclusion from science. ...assess the portrayal of science as exceptional and exclusionary.
Integration of Evolution and Religion	Students discuss the potential for the co-existence of evolution and religion by discussing the limitations of science and differential interpretation of the world around us.	The Nature of Science, Evolution, Inheritance, Human Origin, Biogeography	...examine biases in the teaching of evolution. ...evaluate the prospect for co-existance of scientific and religious beliefs.
Race, Ancestry, and Ethnicity	Students use morphological and genetic phylogenetic trees to understand biological constructs (ancestry) and social constructs (race).	Evolution, Human Origin, Phylogenetics, Biogeography	...address the misconceptions about race as a biological construct. ...discuss how racial biases and essentialism have supported eugenics and healthcare disparities.

Fig. 2 Example IA activities. Five example activities are presented including a description of the activity, the potential disciplinary content to be covered, and the component of each, classifying it as ideological awareness. These examples are provided to clarify the material that IA activities can cover and do not serve as guides on how to incorporate IA activities into course content

showcases that even instructors who acknowledge the shortcomings of objectivity in science struggle with the internalized pressure to portray science as an objective field in their teaching. As a result, faculty often teach the basic mechanisms of biology without providing real-word context (Tanner & Allen, 2007), which leads to science students having a worse understanding of the nature of science and how science interacts with society when compared to their peers (Irmak, 2020).

Additionally, instructors report a lack of readiness, experience, and comfort with the materials as main reasons for not incorporating societally relevant topics into their curriculum (Chen & Xiao, 2021; Nielsen, 2020; Beatty et al., in review). As many STEM educators do not have any training or exposure to these topics, faculty members lack awareness of sociopolitical injustices and feel confused about how to increase student consciousness regarding structural inequalities that exist in society (Young, 2010). CRP is often oversimplified as a cultural celebration that is removed from academic achievement, reduced into fixed steps to follow, equated to topics of ethnicity or race, and assumed that solely attending to culture will bring about equity (Sleeter, 2012). This oversimplification further contributes to limited instructor understanding of societally and culturally relevant pedagogy. Interestingly, another common reason instructors choose to omit potentially controversial societal curricular materials is the view that students at the introductory level in tertiary education are not cognitively mature enough to participate in discussions responsibly. However, this has been highly disputed through practice with students considerably earlier in their education. For example, previous work describes successful discussions on contentious political races in elementary school (Payne & Journell, 2019) and transgender topics among third- and fourth-grade students (Hermann-Wilmarth et al., 2017; Ryan et al., 2013).

Social and institutional pressures also limit the implementation of a societally relevant curriculum. Instructors are responsible for meeting core content curricular goals and often report difficulty with seamlessly integrating societally relevant materials into the packed core curriculum, pigeonholing instructors in the existing curricular design with little influence on its adaptation (Beatty et al., in review). When instructors choose to implement changes to their curriculums, they often lack the necessary resources, including curricular assignments and guides, textbooks, assessments, and proper training (Chen & Xiao, 2021; Nielsen, 2020; Beatty et al., in review). Lastly, instructors fear repercussions at all levels, including public pushback from students and parents, lack of institutional support, and, in worst-case scenarios, legal disputes and termination.

Emerging Research Questions

Given these common hesitancies, future research is needed to (1) test ways of supporting instructor implementation of IA material, (2) understand the influence of IA curricula on student outcomes and diversity, inclusion, and equity efforts, and (3) explore how to best implement IA materials in different cultural and social settings across the globe.

1. How can we effectively train instructors and support implementation of IA materials?

A recent study exploring the shift in teacher perception of societally relevant topics has found that exposing teachers to SSI materials created a shift from the traditional view of adhering strictly to the core content to embracing the inclusion of societally relevant curriculum (Leung, 2022). In line with this study, we expect effective instructor training on ideological awareness topics to address instructor hesitations and promote incorporation of IA material. Specifically, we expect training will need to emphasize the subjectivity of science and increase instructor self-efficacy by allowing instructors space to learn, practice, and teach societally and culturally relevant materials. However, research on how to best train instructors is still required. Open research questions include: Should IA training be included in general workshops about teaching and learning? If so, would IA training contribute to oversimplification of complex societal topics? If not, how would specialized IA training be developed and delivered?

Second, we need to understand that supportive infrastructures at the institutional level, discipline level, and instructor level ensure a successful transition to societally relevant curriculum (Chen & Xiao, 2021). Particularly, when it comes to concerns of pushback from those in positions of power, we expect a system of open institutional and departmental support will provide instructors with the assurances necessary to experiment with their curricula without fear of retribution. Furthermore, we expect building systems of support among colleagues will allow instructors to better overcome issues related to changing classroom dynamics, navigating student-held values, and scaffolding student engagement with social issues (Lee & Yang, 2019). Specifically, collaborative action research (see Castro Garcés

& Martínez Granada, 2016) holds promise for supporting instructors as they incorporate more IA topics into their courses. Collaborative action research enables instructors to work as a team to redesign curricula, which allows for collaborative evaluation of new practices and ultimately a deeper understanding of their collective experience. The experiences and outcomes of collaborative action research can then be shared to the administrative level, providing those in positions of power with the information necessary to support teaching staff. Future research is required to explore which systems provide support to instructors implementing IA material and how to establish such systems.

2. What is the best way to teach IA topics in biology classrooms? And what is the influence of IA curricula on student outcomes and diversity, equity, and inclusion efforts?

Although instructors are beginning to implement IA topics in their biology courses (Beatty et al., 2021), research still needs to be done on how to teach IA material and the impact of different content delivery methods on student outcomes, including student academic performance, persistence in STEM, their ability to connect and apply science to society, and social-psychological outcomes, such as scientific self-efficacy, student empathy, and interest in science. Further research is required to explore how factors such as student identity, instructor identity, geographical region, and political climate may all greatly affect the impact of IA curriculum. Previous research suggests that student identity may alter perceptions of and responses to IA topics. Henning et al. (2019) found that a number of hidden student identities played a role in perceptions of active learning environments. Similarly, students who are strongly committed to facets of their political identity are more likely to view their instructor as having a political bias (Linvill, 2011). Instructor identity will also likely impact both how students perceive instructor empathy toward IA material, as well as how instructors choose to teach the material. Finally, the effect of incongruent student-instructor identities may impact the efficacy of IA material.

As one of the foremost concerns with education at this time is to create an inclusive and equitable environment, with the goal of increasing diversity in STEM, it is critical we understand the impacts of the IA curriculum on persons excluded because of their ethnicity or race (hereafter PEERs) and other marginalized groups. There is always the concern that addressing issues associated with personal identities may make marginalized students feel tokenized (Greene, 1990) or disproportionately and negatively impact them (Zuberi, 2001; Pearson et al., 2022) . However, previous work testing the impacts of IA in the undergraduate biology classroom showed that students who self-identify as PEERs approved of IA activities even more than their non-PEER classmates (Beatty et al., 2021). As a main component of CRP, IA activities have the potential to validate student identities and promote an inclusive curriculum (Favero & van Hoomissen, 2019). Future research will navigate the best use of IA in curricular materials to have lasting positive effects that are inclusive of all students in biology.

3. How does IA content need to be altered across geographic regions?

Lastly, we expect that the implementation of IA components will need to vary based on geographic region. For example, discussion of the Tuskegee Study, an unethical research study conducted on Black men with syphilis in the American South, will likely have greater relevance and impact on students from the USA than on students outside the USA. For this reason, foundational research into IA curricula will include exploring its use across cultures and societies. Future questions include: Are certain regions more likely or less likely to implement IA curriculum? Are there similarities or differences across cultures that determine IA effectiveness? There is currently little literature exploring these questions (but see Lee et al., 2006; Ryder & Banner, 2011; Tidemand & Nielsen, 2017; Andersson-Bakken et al., 2020). Regions spanning the globe (Osman & Marimuthu, 2010; AAAS, 2011; Ross et al., 2012; Osborne & Dillon, 2008) have publicly announced their commitment to prioritizing the integration of scientific and societal content. In order to effectively do so, IA materials must be tested on students across different regions.

Conclusion

Identifying and addressing global challenges requires an understanding of the limitations of science from shortcomings inherent to the discipline. Promoting activities in biology that incorporate ideological awareness encourages students to critically question historical and contemporary science, and the ways in which human bias influences what questions are asked and what conclusions are drawn from data. Though instructors may be hesitant to incorporate materials they perceive as potentially controversial in their courses, the benefits of including ideologically aware materials outweigh the costs of problematically presenting biology as "value-free." Focused inquiries are needed to explore the development of ideological awareness in biology curricula as calls increase to present a more accurate depiction of biology as an ever-evolving field.

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Declarations

Competing interests The authors declare no competing interests.

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