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EDITED BY
Sheila S. Jaswal,
Amherst College, United States

REVIEWED BY
Stephanie M. Gardner,
Purdue University, United States
Desiree Forsythe,
Chapman University, United States

*CORRESPONDENCE
Elli J. Theobald
✉ ellij@uw.edu

†These authors have contributed equally to this work and are listed alphabetically

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Biology in a social context: a comprehensive analysis of humanization in introductory biology textbooks

Madison Meuler[1], Jiae Lee[2], Katherine Foutch[1], Noor Al-Khayat[3†], Katerina Boukouzis[3†], Priya Christensen[3†], Carmella Crooks[3†], Lubna M. Hassanain[3†], Parnian Karimi[3†], Galina V. Kim[3†], Alyssa Randall[3†], Ingrid K. Redford[3†], Rita Socko[3†] and Elli J. Theobald[3*]

[1]College of Education, University of Washington, Seattle, WA, United States, [2]Department of Biological Sciences, California State University - Long Beach, Long Beach, CA, United States, [3]Department of Biology, University of Washington, Seattle, WA, United States

To grapple with the sterility and Whiteness of Western science, scholars have proposed a pedagogical shift to culturally relevant and/or culturally sustaining pedagogy. A key tenet of culturally relevant pedagogy is a focus on developing students' ability to use the knowledge they obtain to identify, analyze, and solve real-world problems. Thus, the ability to foster this consciousness among students and make justice/injustice visible within biology curricula is an act of humanization. Here, we characterize and quantify the extent to which six prominent introductory biology US-based textbooks include humanizing content. First, we built consensus on what it means to humanize biology in a textbook by iteratively revising a coding protocol until we achieved a continuum of humanization. Our continuum evaluates the quantity, location, and the nature of the humanizing element within the textbook. Then, we used the continuum to collect data through qualitative coding: each chapter of each textbook was coded by two coders who came to consensus on the humanizing elements within. We find that in general, the inclusion of humanizing content in introductory biology textbooks is rare: of the 9,670 pages of textbooks that we analyzed, we found 1,352 humanizing passages but the vast majority of these were discussed in a single sentence (23%) or multiple sentences (61%), rarely multiple paragraphs (13%) or entire sections (2%). Similarly, of the 9,262 questions in the books (e.g., in section or chapter summaries), only 2.5% of them were humanizing and of those, only (64%) provided an answer, and of the ones that provided an answer, we only coded 42% of the answers as humanizing. In addition to quantifying the amount of humanization, we also describe the ways in which the passages were presented. For example, only about 9% of the humanizing passages included nuance, 5% discussed equity/inequity, and only 4% positioned biology as a means to accomplish justice. In all, we present what we believe is the most comprehensive assessment of humanizing elements in introductory biology textbooks and pair that with specific guidance to instructors who seek to include humanizing elements in their classes.

KEYWORDS

socioscientific issues, sociopolitical consciousness, culturally-responsive pedagogy, science and society, humanism in STEM

1. Introduction

Textbooks have long been used as a curricular tool in undergraduate biology classrooms, and the popularization of new pedagogical methods in the life sciences has arguably reinforced the role of textbooks in STEM education. Implementing pedagogical changes such as active learning strategies has shown positive learning outcomes for undergraduate students (Freeman et al., 2014), particularly for students who are historically and currently minoritized within the field of science (Theobald et al., 2020). In order to have available class time for students to engage in active-learning activities, some instructors have adopted a "flipped classroom" model of education which often involves shifting the use of class time from a traditional in-class lecture to in-class active learning strategies (Al-Samarraie et al., 2020). This shift in instructional time requires students to engage in considerable pre-class preparation, which often involves the completion of assigned textbook readings or the screening of videos (Olakanmi, 2017). In addition to the development of flipped classrooms, research has also shown that high-structure biology courses, which often involve assigned textbook readings and accompanying reading quizzes, can lead to increased passing rates, particularly for students from minoritized groups in STEM (Haak et al., 2011; Freeman et al., 2014).

While instructors may have the opportunity to develop pre-class materials of their own to help develop a flipped classroom or a high-structure course, instructors often lack the time and/or institutional support to do so (Brownell and Tanner, 2012). Thus, instructors often rely heavily on textbooks and the subsequent assignment of readings and/or practice problems to bolster their pre-class preparation for students (Jensen et al., 2018). If students are tasked with acquiring knowledge prior to attending class sessions, and this knowledge is to be obtained through reading, then it is important that these reading materials give students a nuanced, thoughtful, and critical look into the field of science.

1.1. Humanization in biology curricula

Science is often hailed as an objective, apolitical field, and is frequently taught as such. In order to grapple directly with the history of racism, sexism, and ableism within Western science education (Sheth, 2019) and increase students' feelings of rightful presence in the classroom (Barton and Tan, 2020), scholars have proposed a pedagogical shift to culturally relevant (Ladson-Billings, 1995) and culturally sustaining (Paris, 2012; Paris and Alim, 2017) pedagogy. A key tenet of Ladson-Billings (1995) culturally relevant pedagogy is a focus on developing a student's sociopolitical consciousness, which Ladson-Billings (2014) defines as a student's ability to use the knowledge they obtain in school to "identify, analyze, and solve real-world problems." Thus, the ability to foster a sociopolitical consciousness among students and make justice/injustice visible within biology curricula is an act of humanization.

Humanizing biology education is a practice that "values and respects students, facilitates meaningful and relevant science learning for their pursuit of personal wellness, and assists them in addressing systemic injustices faced within their lifeworlds" (Elmesky, 2021, p. 857). Discussing biology in a social context has emerged as a proposed priority for the field of science education, with *Vision and Change in Undergraduate Biology Education* (American Association for the Advancement of Science (AAAS), 2009) calling for instructors to recognize the relationship between science and society as a core competency. Past research suggests that positioning science in a social context can be achieved by addressing socioscientific issues (Wang et al., 2017), posing justice-centered questions to students (Freire, 1970), and incorporating ideological awareness into science curricula (Costello et al., 2023).

While previous literature has advocated for the inclusion of humanizing content, efforts to embed these elements into STEM education have faced resistance. Scholars have stated that "socioscientific issues are shrouded in uncertainty as well as a combination of political, ethical, social, and personal conflicts that are not the common fare of science lessons" (Levinson, 2006, p. 1218). While discussions of socioscientific issues in the science classroom could involve important conversations concerning social justice and science, these topics often require educators to discuss political and/or ethical controversies. Due to the controversial and political nature of many of these socioscientific issues, the field of science education continues to debate whether or not these topics belong in humanities curricula rather than in science curricula (Levinson and Turner, 2001). In addition to facing resistance from the field as to whether or not humanizing content belongs in the sciences or the humanities classroom, the idea of embedding such content into biology curricula may also be an intimidating prospect for instructors. For example, previous research suggests that STEM faculty within higher education, when presented with narratives about common, harmful anti-Black racialized experiences, are more likely to respond in a way that avoids discussion of race (King et al., 2023).

Given the controversial nature and difficulty of embedding these topics into science curricula, we grew curious as to whether or not prominent curricular materials could assist STEM faculty by embedding humanizing content and providing a scaffold for fostering discussions of topics instructors may feel ill-equipped to lead. Given that curricula in the United States can vary based on a variety of variables, such as the instructor, the institution, and the geographical location of the institution, it is challenging to evaluate whether or not humanizing biology content is present or absent in curricular materials across the field of biology education as a whole. While taking a complete census of curricular materials across all instructors of biology is not feasible, we identified one specific type of curricular material that could provide insight as to the content and topics being discussed in a wide array of undergraduate biological courses across the country: textbooks.

1.2. What does "humanization" mean in science?

Before we can assess the extent to which curriculum includes humanizing content, we first have to define the broad, and often ambiguous, term of "humanization." Given the ongoing conversations concerning culturally relevant pedagogy (Ladson-Billings, 1995, 2014), socioscientific issues (Wang et al., 2017), and other related social-justice focused frameworks, we wanted to develop a definition of humanization that was informed by relevant literature. The definition we used to determine the extent to which a textbook

passage was humanizing was closely aligned with that of Elmesky (2021), but also drew upon inspiration from Ladson-Billings (1995) and Freire (1970).

Elmesky (2021) defines humanizing science education as a practice that "values and respects students, facilitates meaningful and relevant science learning for their pursuit of personal wellness, and assists them in addressing systemic injustices faced within their lifeworlds" (Elmesky, 2021, p. 857). Although Elmesky includes a three-pronged definition of humanization, we chose to focus specifically on the element of their definition that describes how humanizing science education "assists [students] in addressing systemic injustices faced within their lifeworlds." This decision was based on the rationale that Elmesky's (2021) definition addresses humanizing biology education as a result of a combination of curriculum, instruction, and pedagogy. While Elmesky's definition addresses humanizing biology education holistically, collecting data from textbooks only provides an indication of curriculum, and not instruction.

Because our analysis focuses on textbooks, we were intentional in thinking about humanization from a curricular standpoint rather than an instructional standpoint. In particular, we struggled to see how we could assess whether or not students felt "valued and respected" by the textbook content. One could argue that if the textbook included harmful stereotypes this could make a student feel disrespected, however, that would have felt as though we were making a large assumption and generalization as to how all students would feel toward particular humanizing content. We applied this same rationale toward the second prong of "facilitates meaningful and relevant science learning for their pursuit of personal wellness." The pursuit of personal wellness will likely look different for every student, and we believe it would be difficult to argue how a passage in a textbook facilitated personal wellness for a student without gathering data from students themselves. We also did not feel as though the inclusion of "you" would be sufficient toward fostering feelings of being valued/respected or personal wellness, and we felt uncomfortable assuming that because a textbook attempted to address the student/reader explicitly, they would automatically feel more valued and respected.

While Elmesky (2021) defines humanizing science education as a practice that "values and respects students, facilitates meaningful and relevant science learning for their pursuit of personal wellness, and assists them in addressing systemic injustices faced within their lifeworlds" (Elmesky, 2021, p. 857), we chose to combine this definition with the concept of Ladson-Billings (1995) sociopolitical consciousness and Freire's (1970) concept of problem-posing education (Figure 1).

Just as Elmesky (2021) identifies a key tenet of humanizing science education as encouraging students to address "systemic injustices faced within their lifeworlds" (Elmesky, 2021, p. 857), Ladson-Billings (1995) advocates for the development of a student's sociopolitical consciousness. As the third tenet of Ladson-Billings (1995, 2014) notion of culturally relevant pedagogy, the idea of a sociopolitical consciousness involves the ability of students "to take learning beyond the confines of the classroom using school knowledge and skills to identify, analyze, and solve real-world problems (2014, p. 75)." Similarly to our approach with Elmesky's (2021) definition, we also chose to focus solely on Ladson-Billings (1995, 2014) tenet of the sociopolitical consciousness rather than on the other two tenets: (1) a focus on student learning and (2) developing students' cultural competence. While these two tenets are critical for culturally responsive science education, we felt as though we would be unable to measure the ability of textbooks to facilitate growth in these areas. Ladson-Billings (1995, 2014) definition of the sociopolitical consciousness, provided us with a concrete basis on which we could develop a coding rubric to assess whether or not a passage was encouraging students to "identify, analyze, and solve real-world problems" (2014, p. 75). The notion of a sociopolitical consciousness closely aligns with Freire's (1970) concept of problem-posing education. Freire (1970) argues that "students, as they are increasingly posed with problems related to themselves in the world and with the world, will feel increasingly challenged and obliged to respond to that challenge" (p. 68–69).

While the work of Ladson-Billings (1995, 2014) and Freire (1970) is not specific to the field of science education, their work provides valuable insight as to what humanization within biology curricula can look like. Thus, we chose to develop a functional definition of humanization by focusing on the theme that emerged from all three scholars (Freire, 1970; Ladson-Billings, 1995; Elmesky, 2021). We operationalized this definition to be: the ability for students to view science in a social context and grapple with real-world problems of social justice within the field of biology (Figure 1).

1.3. Study context

Previous literature shows how science textbooks have been evaluated in the past based on a variety of criteria. For example, biology textbooks have been evaluated for their demographic representation of scientists who are women and/or people of color (Wood et al., 2020; Simpson et al., 2021), their depiction of Eurocentric paradigms of science (Yacoubian et al., 2017), their treatment of the topic of race (Morning, 2008; Willinsky, 2020), their discussion of anthropogenic climate change (Román and Busch, 2016), and their discussion of socioscientific issues at the middle/high school level (Morris, 2014). While this research provides valuable insight into textbook content, we were unable to find any previous literature that has attempted to evaluate the extent to which undergraduate biology textbooks humanize science. Thus, we set out to evaluate the extent to which six prominent biology textbooks used in introductory biology courses in the United States include humanizing science content.

2. Methods

2.1. Iteratively designing the codebook

This project analyzed a total of six prominent introductory undergraduate biology textbooks published within the United States (Supplementary Table S1). We focus on introductory textbooks because introductory courses are gateway, and often gatekeeper, courses for students pursuing STEM degrees: this is one important timepoint in the curriculum in which attrition is particularly high (Harris et al., 2020). Introductory biology specifically is our focus, first because we are biologists, but second because introductory biology in particular is a course that is required of many STEM majors and is often a course non-STEM majors pursue as fulfillment of general

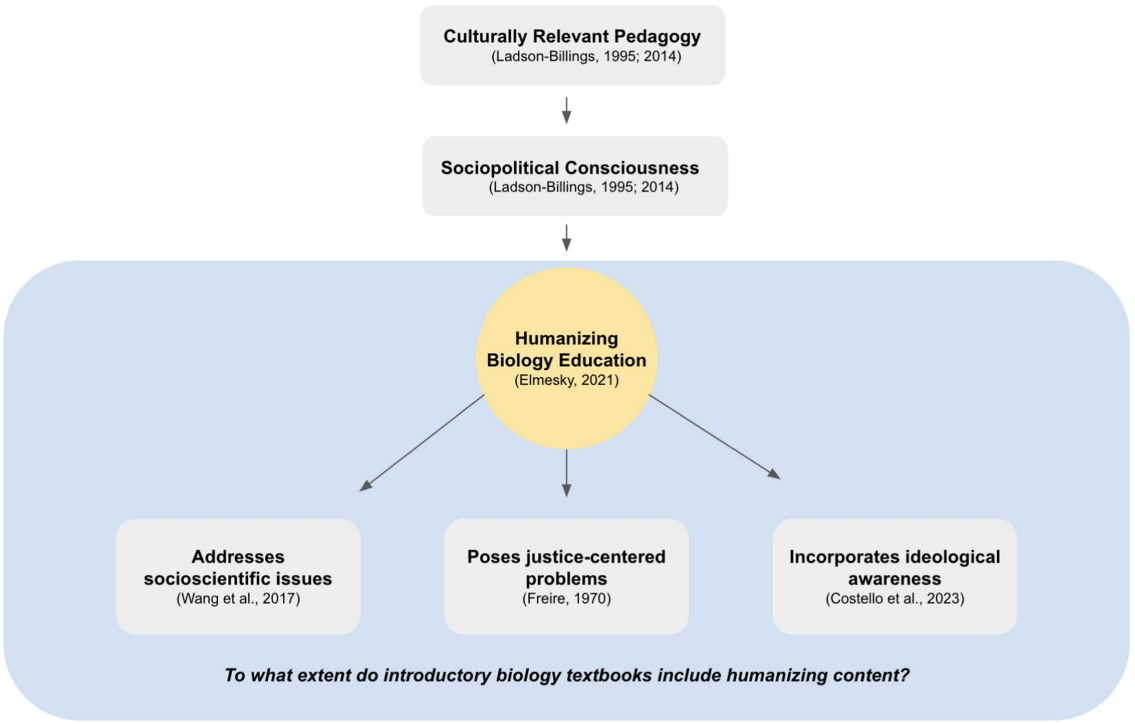

FIGURE 1
Our operational definition of humanizing biology education as informed by relevant research.

education requirements. Thus, this broad-reaching, potentially highly-filtering course has the potential to demonstrate that science is either humanizing or not.

These textbooks were selected as a convenience sample of popular textbooks and many of the books we analyzed were also included in previous textbook research (Wood et al., 2020). It is important to note that we analyzed the textbooks as they exist in print form, and not in their interactive, e-text formats that some textbooks have adopted. Before qualitatively analyzing each textbook, our team worked over the course of roughly 8 weeks to iteratively design a rubric that adequately evaluated humanizing elements within each textbook. Each week, each team member would read through one to three chapters from different textbooks and identify passages in the text that appeared to address a socioscientific issue or address a topic related to science and society in some way. Each team member would then bring their identified passages to a group meeting, where the team would discuss the identified passages and evaluate whether or not they fit our definition of humanizing science content.

2.2. Developing the continuum of humanization

In order to capture the varying extent to which a certain passage from a textbook positioned science in a social context, we created a continuum of humanization (Figure 2).

On the far-left side of the continuum, we placed passages that allude to the social context of science but provide scarce explanations that stress the importance of this social context. For example, the following passage from one of the evaluated textbooks was coded as including "scarce" detail:

> *Unfortunately, human activities are now changing the composition of the atmosphere in ways that most authorities conclude will be damaging or, in the long run, disastrous (Textbook C).*

This passage, which consists of a single sentence, acknowledges the fact that "human activities" are impacting the atmosphere in a way that could be "disastrous," but provides no further detail or explanation as to what these human activities are or what impact they could have. Because this passage acknowledges the problem but does not encourage the student to critically reflect on the social context in which it takes place, it exists on the far-left side of the continuum and is considered to be the least humanizing. While this is an example of a passage that falls on the far-left side of the continuum, we can also look at a passage that falls on the opposite end. For example, here is a passage taken from a textbook's discussion of anthropogenic climate change:

> *In this respect, we in the industrialized world need to pay more attention to lessening the impact each of us makes because, even though the vast majority of the world's population is in developing countries, the overwhelming percentage of consumption of resources occurs in the industrialized countries. Indeed, the wealthiest 20% of the world's population accounts for 86% of the world's consumption of resources and produces 53% of the world's carbon dioxide emissions, whereas the poorest 20% of the world is responsible for only 1.3% of consumption and 3% of carbon dioxide emissions.*

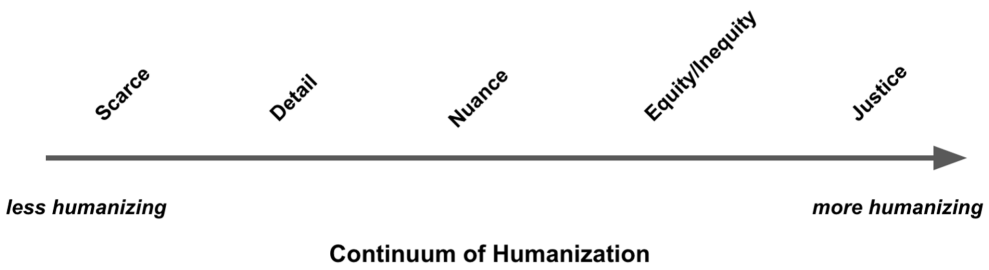

FIGURE 2
Continuum of humanization. To be placed on the continuum, a passage had to position the biology content in a social context.

> *Looked at another way, in terms of resource use, a child born today in the industrialized world will consume many more resources over the course of his or her life than a child born in the developing world (Textbook C).*

This passage does several distinct things that differentiates it from the previous example. Rather than simply acknowledging the social context of the scientific issue, this passage goes into considerable detail and explicitly mentions an inequality that persists between the energy consumption of industrialized countries, where a minority of the world's total population lives, and the energy consumption of "developing" countries, where a majority of the world's population lives. In addition to recognizing the inequity that persists, this passage also includes a call to action to the student. The passage states that "we in the industrialized world need to pay more attention to lessening the impact each of us makes." This particular call to action encourages the student to address the systemic injustice faced by the energy consumption of industrialized nations and the disproportionate impact this energy consumption has on individuals residing in less wealthy nations. Based on this rationale, we coded this passage as falling under the category of "justice." We believe this passage echoed Elmesky's (2021) definition of humanization in which science curricula assists students "in addressing systemic injustices faced within their lifeworlds" (p. 857).

While these two passages serve as examples that fall on opposite ends of the continuum, Table 1 (as well as Supplementary Tables S2–S10) provides example passages that fall at each location on the continuum, differentiated by topics. Table 1 specifically features passages that fell under the topic of climate change.

In addition to establishing the parameters of what type of passages existed on our continuum of humanization, we also defined what did *not* have a place on the continuum. Throughout the process of our iterative design, we had several debates over whether or not rhetorical choices made by the textbook should or should not be considered humanizing content. Specifically, our team debated whether instances in which the textbook attempted to directly address the reader should be coded as an act of humanizing science: could the pronoun "you," in reference to the reader, be seen as an act of humanization? For example, in the following passage, we see the textbook attempt to directly address the reader:

> *In this way, glucose present in the food you digest is actively transported into your body. The glucose molecules eventually diffuse into your bloodstream and are transported to your brain, where they provide the chemical energy you need to stay awake and learn some biology (Textbook E).*

At first, our team was in disagreement as to whether or not a passage like this did or did not fall within our collective definition of humanization. While the passage did make a direct appeal to the reader and provided an example of how biology applies to their own body, we ultimately decided as a team that this passage did not fall along our developed continuum. This passage does not mention anything about the social context of science, nor does it allude to systemic societal injustices (Freire, 1970; Elmesky, 2021), socioscientific issues (Wang et al., 2017), or include ideologically aware material (Costello et al., 2023).

Our categorization of these types of rhetorical choices made by textbooks (e.g., making direct appeals to the readers about how science relates to the human body) led us to a simple yet important conclusion: discussing human biology is not synonymous with the act of humanizing biology. Discussing how students can understand their own physiology or health/wellbeing is not, in and of itself, a method of achieving humanizing science education as defined by Elmesky (2021). Humanizing science education requires more than students understanding how science relates to their own bodily functioning–instead, it must encourage students to understand how science interacts with society and how systemic social injustices can be redressed by science.

While the example above does not fall anywhere on the continuum, there were passages in the textbook that addressed the reader directly that our team decided *did* fall on the continuum. For example, the following quote uses the pronoun "you" to address the reader while also highlighting the social context of science:

> *As we hope you have seen throughout this textbook, an understanding of biology is vital to learning and helping to solve many of society's problems. The study of biology has a huge potential for improving people's lives and society at large. Biology offers the opportunity to unlock new diagnoses and treatments for diseases, to improve nutrition and food production, and to maintain biological diversity (Textbook F).*

While this passage directly addresses the reader, it also goes on to explicitly lay out how biology can have societal impacts and describes what those impacts could be. Despite the fact that the social context of science is made clear, this passage remains extremely broad. Rather than mentioning specific examples of which diseases science can help address,

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TABLE 1 Example of how the continuum of humanization is articulated through the topic of climate change.

	Topic: climate change				
Location on continuum	None/scarce	Detail	Nuance	Inequity/equity	Justice
Definition from metadata	A topic is alluded to or mentioned, no other detail provided	A topic is expanded on, perhaps an example is provided that illustrates the topic	A topic is presented in a way that would allow reasonable people to disagree, two sides mentioned, pros and cons to a certain topic/issue, science is only one part of the picture/issue	The passage mentions how a topic and/or issue disproportionately impacts some individuals more than others, recognizes a lack of fairness in a situation, or recognizes that some people are impacted in a way that is different than others, etc.	The passage mentions ways that a certain inequity or injustice can be addressed BY science and explains how science can be used to help strive toward social justice
Passage	*Unfortunately, human activities are now changing the composition of the atmosphere in ways that most authorities conclude will be damaging or, in the long run, disastrous. (Textbook C)*	*Chemical analyses show that CO levels in the current atmosphere are 46% higher than they were at the time of the American Revolution. This rise coincides with major advances in manufacturing and transportation, which are powered by the burning of fossil fuels. These coincidences in timing suggest that human activities are responsible for increasing CO levels. (Textbook D)*	*Progress toward finding solutions to address climate change was made in 2015 when all nations agreed—for the first time—to take steps to reduce CO2 emissions and limit the extent to which global temperatures ultimately rise. This international effort, known as the Paris Agreement, has been ratified by 169 nations, including China, the United States, and all other nations that emit substantial quantities of CO2 and other greenhouse gasses. The effectiveness of the agreement was recently called into question, however, when the United States announced its intention to withdraw from the agreement by 2020. This setback highlights a potential difference between what we know and what we choose to do" (Textbook A)*	*What will be the consequences of contemporary climate change? Without question, some locations will benefit. For example, temperature increase in New England and Scandinavia will mean longer growing seasons. Other regions will suffer. As precipitation patterns change, many places will become drier, including already water-limited areas of the southwestern United States. A number of climate models predict that some of the strongest declines in rainfall will occur in regions that currently produce much of the corn and wheat that feed the world. Already, farmers in southeastern Australia have experienced the worst droughts in a century, and with them unprecedented damage from brushfires. (Textbook D)*	*In this respect, we in the industrialized world need to pay more attention to lessening the impact each of us makes because, even though the vast majority of the world's population is in developing countries, the overwhelming percentage of consumption of resources occurs in the industrialized countries. Indeed, the wealthiest 20% of the world's population accounts for 86% of the world's consumption of resources and produces 53% of the world's carbon dioxide emissions, whereas the poorest 20% of the world is responsible for only 1.3% of consumption and 3% of carbon dioxide emissions. Looked at another way, in terms of resource use, a child born today in the industrialized world will consume many more resources over the course of his or her life than a child born in the developing world. (Textbook C)*

who is impacted by those diseases, and how science can work to equitably treat these diseases, it remains relatively surface level. Thus, our team decided that this passage would fall under the "Detail" section of the continuum.

2.3. Developing the final coding rubric

After iteratively designing the continuum of humanization, we then worked to translate this continuum into a tangible rubric that could be used to code textbook passages systematically. We developed the rubric to include enough rigidity that we could apply it consistently and also enough flexibility that it could be applied widely. We designed this rubric so that it would provide an idea of (1) the location of the passage in the textbook (i.e., whether the passage was in the chapter hook, embedded in the chapter, in a box/figure, or at the end of a chapter), (2) the amount of text that was devoted to the passage (i.e., was the passage a single sentence, multiple sentences, or multiple paragraphs), (3) into which category of humanization (on the continuum) the passage fell, and (4) the topic/subject of the

passage. In order to create a rubric that would allow us to systematically track which topics/subjects were and were not the most commonly associated with humanizing passages, we created a list of nine topics that each passage could be coded as. The original topics were: Disease, Treatment of Disease, Health Generally, Environment, Climate Change, Nutrition/Sustenance, Multiple Ways of Knowing, Ethics, and Human Genetics. We chose our topics after reading through our selected chapters from each textbook that we used to create our rubric. We chose topics based on their level of popularity in the sample passages we analyzed. Some topics were mentioned fairly consistently, such as "disease" or "environment," while other topics, such as "multiple ways of knowing", were entirely absent from the original chapters we assessed. Thus, we chose to track both types of topics: the topics that were popular and (some) of the topics that appeared to be absent. We additionally chose to differentiate "environment" and "climate change" as two separate topics due to the fact that many of the textbooks had chapters that were explicitly labeled "The Anthropocene: Humans as a Planetary Force" (Textbook D), "The Age of Humans" (Textbook F), or "Conservation Biology and Global Change" (Textbook A). Since the textbooks were identifying anthropogenic climate change as a distinct topic from the other chapters dedicated to conservation and ecology more broadly, we chose to use distinct "environment" and "climate change" codes. Our coding scheme also allowed for a passage to be coded as multiple topics. For example, the following passage was coded under the topics Environment, Nutrition/Sustenance, Treatment of Disease, and Ethics:

> *Why should biodiversity be a concern? American biologists Paul Ehrlich and E.O. Wilson have suggested that the loss of biodiversity should be an area of great concern for at least three reasons: 1. Humans depend on plants, animals, and microorganisms for a wide range of foods, medicines, and industrial products. 2. Ecosystems provide an array of essential services, such as clean air and water. 3. Humans have an ethical responsibility to protect what are our only known living companions in the universe (Textbook F).*

In addition to specifying Multiple Topics, we also included an "Other Topic" category whereby ambiguous codes that did not fit into one of the previously outlined topics were placed. After coding was completed, the first author went through these "Other" codes in order to identify if additional topics emerged. From these "Other" codes, an additional topic of "Science as a Discipline" was created for passages that commented on the field of science and/or science education. For example, the following passage was coded under the topic of Science as a Discipline:

> *Evolution by natural selection is one of the best supported and most important theories in the history of scientific research. But like most scientific breakthroughs, this one did not come easily. When Darwin published his theory in 1859 in a book called On the Origin of Species by Means of Natural Selection, it unleashed a firestorm of protest throughout Europe (Textbook E).*

Since this passage discusses how science was received by the public and the social context in which Darwin's theory was proposed, this passage was coded as falling under the topic of "Science as a Discipline" and on the continuum of humanization under "Nuance."

2.4. Collecting data

Once our continuum was established, we collected data through qualitative coding: each chapter of each textbook was coded by two coders who came to consensus on the humanizing elements within. Approximately every five chapters, each team member changed (1) who they were paired with to consensus code and (2) which textbook they were coding. This coding protocol helped ensure that each team member coded chapters across all six textbooks and coded chapters with a variety of team members over time. As a team, it took us roughly 17 weeks to code every chapter in all six textbooks. Collectively, this involved reading and coding over 9,670 pages across 343 chapters in 6 textbooks.

2.5. Evaluating questions

In addition to applying this rubric to text passages, we also applied the rubric to assess the extent to which the questions posed by the textbook were humanizing. We coded questions that were featured (1) within a section, (2) at the end of a section (for example, section 23.5 of Chapter 23), or (3) at the end of a chapter. We omitted questions that were embedded in the text and that were largely meant as rhetorical. For example, we did not code questions like the following that were embedded within a larger paragraph of text:

> *What is necessary for monomers to be linked together? Monomers polymerize through condensation reactions, also known as dehydration reactions (Textbook E).*

Instead, we chose to exclusively focus on questions that instructors could realistically assign or recommend as extra practice to students, such as those featured at the end of a section in a chapter, or at the end of the chapter itself. The rubric used to code the questions was identical to the rubric used to code the text, with the exception of three categories. In addition to coding whether or not the question asked was considered humanizing, we also analyzed (1) what the question was labeled as (e.g., if the textbook somehow indicated that this question was a "science and society" question), (2) whether or not an answer was provided to the question by the textbook, and (3) whether or not the answer, if provided, was humanizing. For example, for the following question, both the question and the answer were coded as humanizing:

***Question**: Explain how the planting of trees in poor city neighborhoods could decrease the inequality in physical and mental health among people in poor and wealthy neighborhoods (Textbook E).*

***Answer**: Exposure to nature has a number of physical and mental health benefits, such as reduced stress and depression and reduced rates of obesity and diabetes. Since poor neighborhoods tend to have less access to natural areas than do wealthy city residents, planting trees in poor neighborhoods could help to decrease health inequality among poor and wealthy people (Textbook E).*

However, not all questions that were coded as "humanizing" had an accompanying answer that was also humanizing. For example, the following question was coded as falling under "equity/inequity" on the continuum of humanization yet provided an answer that was coded as NOT humanizing and thus did not fall anywhere on the continuum:

***Question**: In the coming decades, climate change may have significant effects on the growth and productivity of plants, in particular the crops on which we depend for our food. Discuss the physiological effects, and possible genetic responses in terms of plant breeding, of the following: a. In Pakistan, reduced rainfall causes a reduction in wheat yields (Textbook B).*

***Answer**: The effects of reduced rainfall could include dehydration and osmotic stress. Genetic responses might include alterations in leaf anatomy, with a thicker cuticle to reduce evaporation; a more extensive root system to obtain water; and accumulation of solutes in the roots, which would reduce root water potential and result in more water uptake in dry soils (Textbook B).*

Of the questions that were coded as falling somewhere along the continuum of humanization, we also analyzed whether or not these humanizing questions were explicitly labeled as a question that was meant to relate to "society" in some manner. For example, although each textbook had a different system for labeling their questions, most of them included some variation labels such as "society" or "science, technology, and society."

2.6. Statistical analyses

To make quantitative comparisons between books and passages or questions across topics within books, we used chi-square analyses. All models were fit in R Version 4.0.5 (R Core Team, 2021).

3. Results

3.1. Text

Out of the 9,670 pages analyzed across all 343 chapters in the six textbooks, we found a total of 1,352 humanizing passages. To understand if these passages are distributed evenly across the six textbooks, we first had to understand if the books have the same number of chapters and the same number of pages. We found that among the six textbooks we analyzed, the textbooks had the same distribution of chapters ($X^2 = 0.434$, df = 5, $p = 0.994$), but not of total pages ($X^2 = 214.6$, df = 5, $p < 0.0001$). We also asked if the distribution of humanizing passages was even across textbooks, and found that the distribution of humanizing content was not consistent across books ($X^2 = 52.312$, df = 5, $p < 0.0001$). Given that the textbooks have a different distribution of pages, this difference in distribution of humanizing content could be explained by differences in the number of pages per textbook. To test this hypothesis, we then compared the distribution of chapters and pages to the distribution of humanizing passages across the textbooks and found that the distribution of humanizing passages across chapters is consistent between books ($X^2 = 8.989$, df = 5, $p = 0.11$) but the distribution of humanizing passages across pages is not ($X^2 = 271.34$, df = 5, $p < 0.0001$). In other words, some books have longer chapters than other books, and as a result less humanizing content per page, but the number of humanizing passages per chapter is relatively consistent across books (Supplementary Figure S1).

Given that the purpose of this study is not to better understand each textbook specifically, but rather to get a holistic picture of introductory biology content within textbooks, for subsequent analyses, we combined the data from each textbook and report overall summaries.

The majority of the humanizing passages (61%) consisted of multiple sentences, while 23% consisted of a single sentence (Figure 3A). The minority consisted of multiple paragraphs (13%) or a whole section of the text (2%). The vast majority of the humanizing passages were embedded in the chapter (83%) and only a few were called out within chapters in a box or figure (6%). 7% of the passages were featured in the opening of a chapter (Chapter Hook) and 3% were featured in the chapter close/extension or unit summary (1%; Figure 3B).

Among the content coded as humanizing, over half (54%) of the passages were coded as falling under the category of "detail" along our proposed continuum of humanization (Figure 4). About a quarter of the passages (26%) were included with "scarce" detail included. Only 9% of passages were discussed with nuance, while 5% of passages were coded as equity/inequity and 4% as justice. The distribution of passages along the continuum was not uniform ($X^2 = 87.569$, df = 4, $p < 0.0001$).

In addition to understanding where on the continuum these passages fell, we also analyzed which topics were most often discussed within a humanizing context. Many of the passages (26%) covered multiple topics, but generally there were a wide range of topics that included humanizing elements. The topics that were most commonly represented among the humanizing passages included environmental topics (25%), disease (15%), nutrition and sustenance (12%), health generally (12%), and treatment of disease (11%). Human genetics (6%), climate change (6%), science as a discipline (5%), and Ethics (5%) were more uncommon topics of humanizing passages, and multiple ways of knowing was a topic that was rarely found in humanizing passages (2%). Chi-squared analyses showed that within a level of the continuum, the passages were not distributed evenly across topics (Figure 5, Table 2).

3.2. Questions

The six textbooks analyzed cumulatively featured 9,262 questions. A total of 236 of these 9,262 (2.6%) were coded as humanizing (Figure 6).

Of these 236 humanizing questions, 46 (19.4%) of them were explicitly accompanied by the label of "society," "science, technology, and society," or something similar (Figure 7A). The remaining 190 questions were either unlabeled or labeled as other types of questions, such as "analysis" or "quantitative" questions. While each textbook may have had a different rationale behind explicitly labeling questions as "society," at least one of the books we analyzed explained that this decision was to allow instructors to identify which assessment questions addressed the core competencies discussed in the *Vision and Change in Undergraduate Biology Education* (2009) report. As previously mentioned, *Vision and Change* proposes that the "ability to understand the relationship between science and society" is one of the six core competencies of undergraduate biology education. *Vision and Change* states that examples of this core competency being applied to biology practice include "evaluating the relevance of social contexts to biological problems," "developing biological applications to solve societal problems," and "evaluating ethical implications of biological

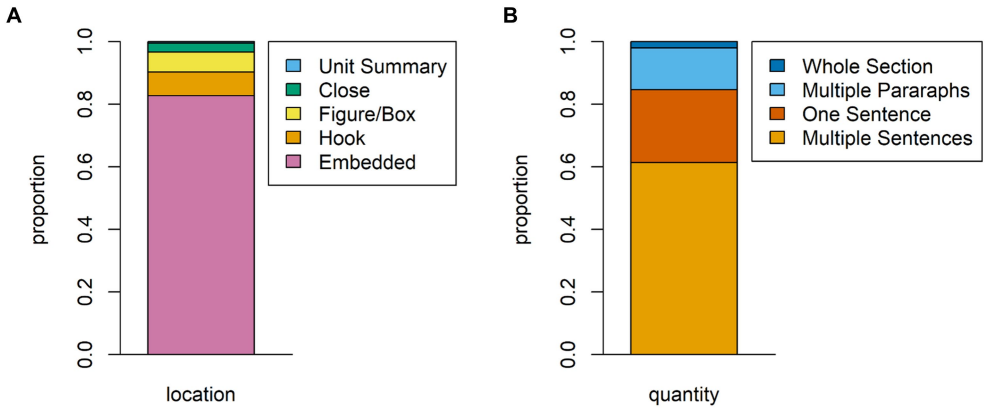

FIGURE 3
Distribution of humanizing passages by location in the textbooks **(A)** and the quantity of text dedicated to the content **(B)**.

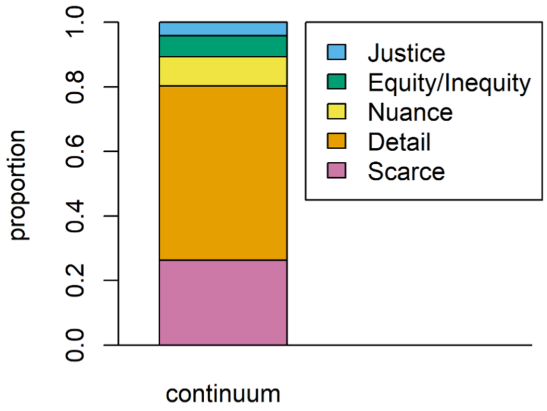

FIGURE 4
Distribution of humanizing passages within each level of the continuum.

research" (p. 17). Thus, in many ways, this core competency aligns with our continuum on assessing the humanizing quality of textbook passages and questions. While some of the textbooks may have attempted to assess this core competency by explicitly including "society" questions, our analysis revealed that only 2.6% of the total questions asked across all six textbooks could be coded as falling somewhere along the continuum of humanization.

Of the 236 questions that were coded as humanizing, 152 (64.4%) provided students with an answer. Of these 152 answered questions, only 64 (42.1%) of these questions were coded as having an answer that was humanizing (Figure 7B).

4. Discussion

Understanding the degree to which introductory biology textbooks include humanizing content provides valuable insight as to how the field of biology education can envision a future where humanism is embedded and prioritized. In short, we found that the inclusion of humanizing content and text is rare across the six introductory biology textbooks that we analyzed (Figure 3) and humanization by the inclusion of justice is particularly rare (Figure 4). Some topics were more likely to include humanizing elements (Figure 5), for example topics that can be categorized as environment or health. Humanizing content related to other topics, such as ethics or multiple ways of knowing, was extremely rare (Figure 5). When a topic did include humanizing content, it was most likely to be presented with detail or scarce supporting information as opposed to including nuance (Figure 5).

Just as humanizing content in the text of each book was relatively sparse (Figure 3), the inclusion of humanizing assessment questions was also quite rare (Figure 6). When humanizing assessment questions were included, the questions were not always accompanied by an answer that we also considered humanizing (Figure 7). While some textbooks attempted to include "society" labels to certain questions, not all of the humanizing questions we identified were accompanied by these labels (Figure 7).

These findings are not particularly surprising, given recent (and not-so-recent) calls for culturally relevant (Ladson-Billings, 1995) and/or culturally sustaining (Paris, 2012; Paris and Alim, 2017) pedagogy, and pedagogy that enhances ideological awareness (Costello et al., 2023). By qualitatively analyzing humanization within these textbooks, we have been able to identify patterns and/or trends in humanizing biology content that could provide a helpful framework for how instructors can incorporate humanization into their own classrooms. While it is not feasible to create the perfect equation and/or recipe for including humanizing content into a textbook, a classroom, or an entire curriculum, below, we have developed a list of suggestions to educators for how they can approach this goal.

4.1. Suggestions to educators

Each instructor needs to make specific decisions unique to the course(s) that they teach, and these decisions may vary by context. For example, an instructor teaching an introductory biology course to first-year undergraduate students will likely need to make different decisions about how to incorporate humanizing curricula

FIGURE 5
Distribution of humanizing passages across topics and across levels of the continuum.

TABLE 2 Distribution of topics across each level of the continuum is not even (for any of the levels of the continuum).

	X^2	df	p
Scarce	240.72	9	<0.0001
Detail	517.36	9	<0.0001
Nuance	61.02	9	<0.0001
Equity inequity	61.22	9	<0.0001
Justice	48.19	9	<0.0001

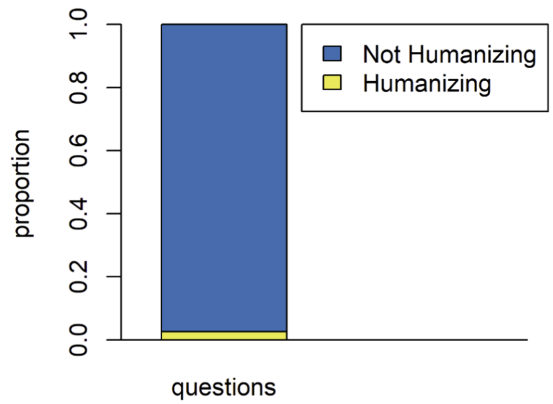

FIGURE 6
Most of the questions incorporated into introductory biology textbooks were not humanizing.

compared to an instructor teaching an upper-division course to fourth-year undergraduates. Despite the fact that these curricular choices differ from instructor to instructor, and in different course contexts, there are several organizing strategies that could guide instructors in their inclusion of humanizing content. Dewsbury and Brame (2019) have developed an extensive interactive tool for instructors to consider how to integrate inclusive teaching into their practice.[1] In addition to the items outlined by Dewsbury and Brame (2019), we provide a list of recommendations that, while not exhaustive, highlights major themes we identified throughout our analysis of these six texts.

4.1.1. Consider using the continuum of humanization as a curricular tool

First, we would like to suggest that the continuum of humanization that we developed to evaluate textbooks, and presented here, could be used as a tool for reflection. We envision that instructors could use the continuum to evaluate their own course and the curriculum within, with the explicit purpose of "moving up" the continuum. In the supplemental materials of this paper (Supplementary Tables S2–S10), we have included tables with example textbook excerpts for each topic (Environment, Disease, Treatment of Disease, Health Generally, Ethics, Multiple Ways of Knowing, Science as a Discipline, Human Genetics, and Nutrition/Sustenance) that fall at each location on the continuum. We hope this can serve as a resource for instructors to imagine how slight changes in how they address and/or discuss topics with their students can influence where on the continuum they fall. While providing examples of how science interacts with society is a step in the right direction, it also matters *how* such examples are

1 https://lse.ascb.org/evidence-based-teaching-guides/inclusive-teaching/

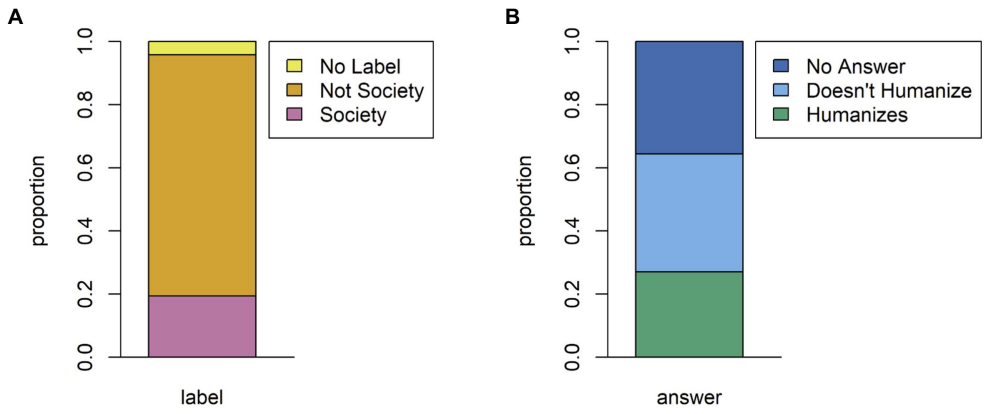

FIGURE 7
Distribution of humanizing questions with "society" labels **(A)** and questions that provide answers and if those answers humanize **(B)**.

discussed. Are students asked to consider who is impacted by a certain scientific finding? Who has access to science, and who does not? Are certain individuals impacted more than others on the basis of their demographic features such as race, gender, and/or other characteristics?

4.1.2. Pose justice-centered problems to students

Second, a "problem-posing" model of science education could be built around content that humanizes science. More specifically, building from the work of Freire (1970), biology education could explicitly present students with problems of justice and ask students to reflect on how science can and should address these issues. While there may not exist a perfect ratio, percentage, or quantity of questions that should be humanizing in nature, each instructor can evaluate for themselves whether or not they are prioritizing humanizing questions in their classrooms.

Friere conceptualizes problem-posing education as a method by which students are asked to critically reflect on issues central to society. Freire (1970) explains that "students, as they are increasingly posed with problems related to themselves in the world and with the world, will feel increasingly challenged and obliged to respond to that challenge" (pp. 68–69). Thus, if we adopt Freire's (1970) perspective on problem-posing education and apply it to the idea of humanizing biology education, it becomes increasingly clear that humanizing biology content can and should be embedded within the questions asked of students. The current lack of prioritization of humanizing biology content within questions asked of students was widely evident within our study. Out of the 9,262 questions that were featured across the six textbooks analyzed, only 236 (2.6%) of the questions asked were coded as humanizing according to our continuum. These data suggest that while it is rare for textbooks to include humanizing biology content within their text, it is even more rare for them to ask students humanizing assessment questions.

Problem-posing as a model to increase students' sense of rightful place in the classroom is consistent with inclusive teaching (Dewsbury and Brame, 2019), particularly the notion that curriculum can foster a sense of belonging for students or promote engagement and self-efficacy. For example, when students work on problems that are particularly relevant to their life experiences or are perceived as relevant to their daily lives, students have an increased sense of belonging (Hurtado et al., 2007; Harackiewicz and Hulleman, 2010).

4.1.3. Incorporate explicit discussion of ethics, historical context, or social implications

We are not alone nor the first to make these suggestions. Recent work by Costello et al. (2023) centers Ideological Awareness in curriculum and the suggestions we make here echo their suggestions. Similarly, Chamany et al. (2017) make a similar plea to instructors to include the history and context in their curricula. By inviting students to use their moral compass to interrogate the ethics of science (American Association for the Advancement of Science (AAAS), 2009), students have opportunities to practice developing their sociopolitical consciousness (Ladson-Billings, 2014).

With the orientation of progress over perfection, and to add to the calls to increase the humanizing content in biology, educators who seek progress by including humanizing content could consider the following reflection questions as they are revising their curricula:

- What is the historical, social, and/or cultural context of the scientific discovery?
- How and by whom was the discovery made? Who was excluded from the process?
- How and by whom is the discovery used today? Who is excluded from the benefits?
- How has the discovery been used for good? How has the discovery been used in pursuit of justice?
- How has the discovery been used for harm? How has the discovery been used to perpetuate (or create) injustices?

4.2. Suggestions for future research

Our data suggest that humanizing content in prominent introductory biology textbooks is relatively rare. While our analysis was textbook-specific, we wonder if the content within these textbooks is indicative of a general lack of humanizing content across biology

curricula as a whole. It is unclear how reliant instructors are on textbooks for content coverage in their class, despite increasing calls for high-structure courses (Haak et al., 2011; Freeman et al., 2014) and the preparatory work that is central to this class structure. Thus, is the lack of inclusion of humanizing content in textbooks indicative of lack of humanizing content in introductory biology courses?

Similarly, it is worth continued effort to understand the impacts of humanizing content on student learning, and student experiences. For example, Zohar and Nemet (2002) found that including explicit instruction on the moral dilemmas in human genetics increased students' inclusion of correct biological knowledge in constructing arguments. Furthermore, Favero and Van Hoomissen (2019) experimented by including culturally relevant anatomical and physiological examples in their traditional human biology classes. Their process provided students opportunities to explore medical journals that reported concrete examples in which ancestry, sex, and socioeconomic status impacted health-related outcomes for humans being treated for disease. The strength of this approach is that it exposes students to primary literature and research in the area while simultaneously providing the content that textbooks noticeably lack. Finally, Aronson and Laughter (2016) present a synthesis of research investigating the impact of Culturally Relevant Education across Math, Science, History/Social Studies, and English Language Arts (primarily in K-12 classrooms) and find many examples of increased engagement and motivation and ultimately increased acquisition of academic skills and content. It would also be worth thoroughly exploring the impacts of humanizing content on undergraduate students in STEM. For example, asking if students gain competency with STEM knowledge and skills and if students' sense of belonging, self efficacy, and science identity increases as a result of this content.

4.3. Caveats

The intention of this analysis is not to outline a perfect "recipe" or "equation" for how much humanizing content should be included within biology textbooks. While our data does suggest that humanizing biology content in the six introductory textbooks we analyzed is relatively rare, we do not intend to suggest specific textbook edits. We are a group of educators and education researchers, so would rather position our work as inspiration for instructors. Although we developed our continuum of humanization as a way of assessing textbook content, we also speculate that this framework could be a helpful resource for instructors to use in order to embed more humanizing content into their own courses. That said, there are some important caveats to the work we present here.

First, our analysis focuses on introductory biology textbooks instead of texts used in upper-division or courses in other STEM disciplines (e.g., Chemistry, etc.). Although we are unaware of any such analysis, we have no reason to suspect that the qualitative patterns we present here are demonstrably unique because of our focus on introductory biology. From personal experience, it seems like few textbooks meaningfully and thoroughly humanize STEM content: many of the authors of this paper are undergraduate students majoring in STEM - thus, we took several STEM courses in the few years prior to the publication of this article. That said, the sample of textbooks we analyzed may not be representative of all textbooks across divisions (upper and lower-division courses) or across disciplines (e.g., Chemistry, Physics, Math, etc.) so the results presented here should be considered within this context.

Second, our definition of humanization (Figure 1) is intentionally broad. We developed this definition with guidance from several complementary lines of research but there may be differing views of humanization, some of which might be considerably more specific than ours. We chose to keep our definition broad so that we were more likely to capture instances of humanization in the introductory textbooks that we explored.

Similarly, despite our broad definition of humanization, some readers may disagree with our continuum. For example, "scarce humanization" is on one extreme and we anticipate that some readers will disagree with the positioning of some passages on the continuum at all, even if we categorize them as "scarce." Similarly, it is also possible that readers may disagree with our operational definition of "justice." To us, justice implies action (i.e., to achieve equity) thus is positioned near equity/inequity but one step farther. Finally, it is possible that readers will disagree with our positioning of equity/inequity and justice on the continuum. On one hand we are sympathetic to this argument but ultimately, we maintain that curricula that highlight the ways in which biology as a field can help bring justice to the world are curricula that should be highlighted, centered, and celebrated.

Finally, we recognize that our list of suggestions for educators is not exhaustive. Rather, our suggestions intentionally build on the continuum that we created and the literature informing our definition of humanization. Furthermore, our final suggestion lists questions that educators could consider when developing curriculum. Because our list is not exhaustive we may have omitted resources that many instructors might find useful.

5. Conclusion

Science, as a discipline, is practiced, learned, and communicated in a social context. Acknowledgement of the role science plays in perpetuating and/or ameliorating issues of societal injustice are exceedingly rare in prominent textbooks intended for use in undergraduate biology classrooms. Shifting toward a humanizing model of biology education may be one strategy by which instructors can work to ensure that they are adequately addressing, and assessing, one of the six major core competencies of biology (American Association for the Advancement of Science (AAAS), 2009). Because biology is a wide-ranging discipline that spans topics of ecology, genetics, cellular biology, molecular biology, and physiology, just to name a few, there is likely not a single, universally applicable approach that all instructors can use to embed humanizing content into their curricula. Despite the challenge of developing a generalizable approach to humanizing biology content, this group of authors propose one possible method of scaffolding this process for instructors. Our proposed continuum of humanization will hopefully help instructors reflect on how they can embed more humanizing content into their science classrooms. While

humanizing content currently appears to be quite rare in undergraduate biology textbooks, we are hopeful that biology education, as a discipline, can strive toward a future in which humanizing science content is prioritized within curricula.

6. Positionality statement

Here we describe our positionality as a research team. This project was a team effort that resulted from the deep collaboration of 14 individuals. Our identities are the starting point for why we are interested in equity-oriented STEM education. And also, our identities are fluid—changing and growing—and this statement was written collectively in early 2023.

We are all educators in many capacities. We are or have been: undergraduate TAs, graduate TAs, informal educators, college professors, and middle school and high school science teachers. We met through our collective experience and commitment to teaching introductory biology for undergraduate students.

We are also all students. We are always learning in classes and outside of classes. We learn because of our curiosity and because of our pursuit of progress over perfection.

Our identities and our positions in society underscore our understanding of the importance of humanizing science and are the lenses through which we examined introductory biology textbooks for this study.

MM is a White, cisgender woman who is an early-career education researcher and a Teaching Associate for undergraduate biology students. She recently graduated with her M.Ed. in Science Curriculum & Instruction from the University of Washington.

JL is an instructor for introductory biology at a large public 4-year university in the USA that serves students in historically marginalized groups. She is a cisgender Asian woman at a research intensive university mentoring undergraduates from diverse backgrounds.

KF is a cisgender White woman who recently graduated with her M.Ed. in Science Curriculum & Instruction from the University of Washington and now works as a middle school science teacher.

NA-K is a first generation Iraqi-British cisgender woman and a naturalized American citizen. She is a Biochemistry student at the University of Washington.

KB is a fourth-year undergraduate Biology: Physiology student at the University of Washington. She identifies as a cisgender, White, Greek-American woman from a privileged background. She grew up in a variety of locations around the United States.

PC is a biracial second-year undergraduate Indian-American woman studying public health and biochemistry. She was raised in predominantly white communities ranging from rural Midwest to Seattle suburbs. She is upper middle class, cisgender, and neurotypical.

CC is a fourth-year Public Health student at the University of Washington. She is a Venezuelan-American, and a cisgender woman.

LH is a second-year undergraduate Biochemistry and Medical Anthropology student at the University of Washington. She has lived in the US and internationally.

PK is a fourth-year Biology student at the University of Washington. She is an Iranian cisgender woman, a naturalized Swedish citizen and a first-generation immigrant to the US.

GK is a female-identifying fourth year undergraduate student, born in Kazakhstan and raised in Russia before moving to the U.S. as a teenager. She is pursuing a B.S. in Biology and has peer-educator experience. Her multi-cultural heritage and experience as a first-generation immigrant inspired her interest in equity-minded, accessible STEM education.

AR is a fifth-year undergraduate Medical Anthropology student at the University of Washington. She was born in rural Alaska and raised in a military family, growing up in various diverse communities within the U.S. She is a cisgender White woman.

IR is a fourth-year Biochemistry, Neuroscience and Scandinavian Area Studies student at the University of Washington. She is a cisgender White woman.

RS is an undergraduate Psychology student at the University of Washington. She is a Portuguese-Polish cisgender White woman and first-generation immigrant to the US.

ET is a cisgender, currently able-bodied White woman. She is an ecologist and education researcher who has taught middle school, high school, and college science since 2006. She believes that science is for everyone, kindness is everything, and we should be striving for progress, over perfection.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MM, KF, and ET conceptualized the project. JL and ET secured funding for the project. MM, JL, KF, NA-K, KB, PC, CC, LH, PK, GK, AR, IR, RS, and ET developed the methodology. MM, JL, KF, NA-K, KB, PC, CC, LH, PK, GK, AR, IR, and RS collected the data. MM and ET curated the data. MM, KB, CC, PK, GK, AR, IR, RS, and ET conducted the formal analysis. MM and ET managed the project administration. MM, JL, KF, NA-K, KB, PC, CC, LH, PK, GK, AR, IR, RS, and ET wrote, reviewed, and edited the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1165239/full#supplementary-material

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