Title: “Broadening Perspectives Activities” Improve both LGBTQ+ Student Experiences and non-LGBTQ+ Students’ Content Comprehension

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Conflicts of Interest: Several of the authors were involved in the development of the curriculum expansion (Broadening Perspective Activities) that we describe in this paper (D. Jackson, A. Biera, C. Hawley, J. Lacson, E. Webb, K. McGraw). This paper should not be construed as a promotion of our curriculum products over similar products, and we make all curricular materials freely available in the supplement.

Abstract

Content in undergraduate biology courses has been historically hetero and cis-normative due to various cultural stigmas, biases, and discrimination. Such curricular content may be partially responsible for why LGBTQ+ students in STEM are less likely to complete their degrees than their non-LGBTQ+ counterparts. We developed Broadening Perspective Activities (BPAs) to expand the representation of marginalized perspectives in the curriculum of an online, upper-division, undergraduate Animal Behavior course, focusing on topics relating to sex, gender, and sexuality. We used a quasi-experimental design to assess the impact of the BPAs on student perceptions of course concepts and on their sense of belonging in biology. We found that LGBTQ+ students entered the course with a lower sense of belonging in biology than their counterparts, but a better understanding of many animal behavior concepts that are influenced by cultural biases associated with sex, gender, and sexuality. However, LGBTQ+ students who took the course with the BPAs demonstrated a greater sense of belonging in biology at the end of the term compared to LGBTQ+ students in the course without BPAs. We also show that students demonstrated improved comprehension of many concepts related to sex, gender, and sexuality after taking the course with BPAs.

Introduction

Efforts to make undergraduate classrooms more inclusive and affirming for LGBTQ+ students are urgently needed. The percentage of the United States (U.S.) population that identifies as LGBTQ+ doubled over the past decade, from 3.5% in 2012 to 7.2% in 2022 (Jones 2023). The percentage of LGBTQ+ individuals within a sample is inversely correlated with age, with 19.7% of Generation Z adults (those between the ages of 20 and 27 in 2024) and 11.2% of millennials (those between the age of 28 and 43 in 2024) identifying as LGBTQ+. A traditional incoming undergraduate in 2024 at 18 years old would have been born in 2006, just 3 years after anti-sodomy laws were ruled federally unconstitutional in 2003. This individual would have been 5 years old when "Don't Ask, Don't Tell" was repealed in 2011, 9 years old when the Supreme Court federally protected the right to marriage for same-sex couples in 2015, and 14 years old when the Supreme Court protected LGBTQ+ employees from discrimination in 2020. Currently, undergraduate students in the U.S. have experienced a wave of progress toward cultural acceptance and legal protections for LGBTQ+ people unlike any other generation before them. However, in recent years, LGBTQ+ communities across the U.S. have faced both cultural and legal backlash, much of which specifically targets the trans community. In 2020, 77 bills targeting LGBTQ+ rights were introduced across the U.S. In 2021 and 2022, that number rose to 154 and 180, respectively. In 2023, 510 bills were introduced at the state level that aimed to restrict LGBTQ+ rights (Choi 2023, ACLU 2023). Much of this anti-LGBTQ+ legislation is targeted directly at the K-12 school experience, and all have the potential to negatively impact the mental health of LGBTQ+ individuals (Horne et al. 2022).

The need for more inclusive and affirming undergraduate experiences is particularly important in the fields of science, technology, engineering, and math (STEM, Cooper et al. 2020). LGBTQ+ undergraduates are less likely to major in STEM disciplines and are more likely to leave STEM majors than their non-LGBTQ+ counterparts (Greathouse et al., 2018, Hughes 2018, Maloy et al. 2022), and sense of belonging has been shown to be associated with persistence in STEM for LGBTQ+ undergraduates (Hughes and Kothari 2021). Research on the specific experiences of LGBTQ+ undergraduates in STEM is very limited (Butterfield et al. 2018), particularly within specific subfields of STEM including biology (Sona et al. 2022). Notably, representation in STEM differs among identities under the LGBTQ+ umbrella and is affected by other intersectional identities (Sansone and Carpenter 2020). Multifaceted stigmas are likely partially responsible for these trends (Freeman 2020, Palmer et al. 2021), and STEM undergraduates with marginalized identities express frustration that they are often asked to work to combat the same stigmas that negatively affect them (Miller and Downey 2020). LGBTQ+ students report experiencing feelings of alienation due to the climate in STEM, which they describe as heterosexist (Linley et al. 2018), and as a result are selective about their decision to come out in the STEM classroom (Cooper and Brownell 2016).

In addition to the potentially unfriendly environment for LGBTQ+ students in science courses, content may also be partially responsible for LGBTQ+ students' lack of belonging, particularly in biology (Casper et al., 2022; Cooper et al., 2020). Conflict between biology course content and the lived experiences of trans, nonbinary, and gender nonconforming undergraduates appear to drive feelings of erasure and alienation based on qualitative interviews (Casper et al. 2022). Stigmatization against LGBTQ+ identities affects what college instructors choose to teach across many undergraduate fields of study, including biology (Marsh et al. 2022). In interviews, trans students report feelings of alienation in undergraduate biology classrooms due to the binary simplification and exclusion of the diversity of life as it relates to sex and gender (Casper et al. 2022). Participants in this study highlighted examples related to humans, but also of plant and animal diversity, and expressed frustration that their peers uncritically accepted the binary teachings of biology professors.

Some biology sub-fields are more prone to excluding LGBTQ+ individuals owing to the content. For example, the field of animal behavior discusses many aspects of behavior related to the concepts of sex and gender, including but not limited to communication between and within sexes, sexual selection, mating systems, and parental care. The extent to which the paradigms for understanding these concepts in animal behavior have been influenced by anti-LGBTQ+ stigma has not been studied, but prominent LGBTQ+ animal behaviorists have argued that binary and cisheteronormative thought has pervaded this field, hindering the field's ability to develop a full understanding of the true nature of animal behavior (Roughgarden 2013, Monk et al. 2019). Undergraduate animal behavior curricula often teach about sexual selection, Darwin's proposed sex roles, and sex-specific behaviors that are presented as ubiquitous across the animal world (Alcock 2009). It neglects, or only briefly discusses as an exception to the rule, the many ways that sex can present as more than a binary, and that homosexual behaviors can be evolutionarily important social behaviors in many animals (Bagemihl 1999, Roughgarden 2013). In this way, these curricula can reinforce students' assumptions that align with western norms about sex, sexuality, and gender, and can fail to encourage critical analysis of the cultural systems of power that influence the production of scientific knowledge. Animal behavior is taught in many classrooms and textbooks with a historical emphasis on ethology and routinely highlights the contributions of male European scientists (e.g. Nico Tinbergen, Konrad Lorenz, and Karl von Frisch), but curricula often exclude many other prominent animal behaviorists including women, people of color, nonbinary and trans people, and people from outside of Europe or the U.S. (Dona et al. 2020, Tang-Martinez 2020b). Systemic bias and discrimination affect access to resources, recognition of contributions, and ability to shape the direction of the field for animal behaviorists across identities of race, gender, class, and nationality (Giurfa and de Brito Sanchez 2020, Tang-Martinez 2020a, Jaffe et al. 2020, Lee 2020).

Recent recommendations to enhance the experiences of LGBTQ+ students in STEM have called for the diversification of curriculum to reflect the full range of gender and sexuality theories and examples in nature, and to present LGBTQ+ role models. They advocate for the inclusion of LGBTQ+ scientists explicitly in the curriculum (Recommendation 10 from Cooper et al. 2020 and Principle 5 from Zemenick et al. 2022), for positive discussions of the diversity of life as it relates to gender and sexuality in the curriculum (Recommendation 11 and 12 from Cooper et al. 2020 and Principle 1 from Zemenick et al. 2022), and for direct engagement with the influence of history and culture on the field of science (Principle 5 from Zemenick et al. 2022). Despite these calls, we are not aware of any inclusive curricular innovations that have been formally evaluated to test the impact on all students and more specifically LGBTQ+ students.

Current Study

We set out to expand the course curriculum to correct for the historical exclusion of the perspectives of LGBTQ+ people, people of color, and women for a large-enrollment, online, upper-division (300-level) Animal Behavior course taught at a large R1 Hispanic Serving Institution in the southwestern U.S. To address this goal, we developed a set of Broadening Perspective Activities (BPAs), which primarily focused on expanding the course's coverage of topics related to sex, gender, and sexuality because undergraduate students had drawn the attention of instructors to potentially cisheteronormatively biased content in previous iterations of the course. To assess the impact of the BPAs, we conducted a quasi-experimental study; we designed and implemented a pre- and post-course survey, once with the course in its original form and twice with the course that included the BPAs. The survey aimed to assess students' comprehension of topics related to sex, gender, and sexuality, as well as students' sense of belonging in the course and in biology.

We developed the BPAs with the aims of enhancing the sense of belonging of LGBTQ+ students, and improving all students' understanding of inclusive sex, gender, and sexuality concepts in the field of animal behavior. We also predicted that BPAs might have similarly positive effects on the sense of belonging for students of historically discriminated against gender identities (women, nonbinary, etc.; Busch et al. 2022). However, we considered that the BPAs might decrease the sense of belonging for some students, particularly those who sometimes experience cultural conflict between their religious and STEM identities (Barnes et al. 2021). Additionally, several of our BPAs discuss histories of racism and colonialism within scientific fields and we therefore also considered whether sense of belonging was differentially affected across racial identities.

Our specific research questions were:

1. To what extent do undergraduate students of varying identities (LGBTQ+ identities, genders, and religious affiliations) differ in the foundation of knowledge that they bring into an Animal Behavior course, specifically with respect to concepts relating to sex, gender, and sexuality?
2. To what extent does the addition of BPAs improve student abilities to critically evaluate assumptions in the field of animal behavior that are influenced by cultural norms associated with sex, gender, and sexuality?
3. To what extent does the addition of BPAs affect the sense of belonging across students of LGBTQ+, gender, religious, and racial identities?

Methods

This study was approved by the Arizona State Institutional Review Board (Study 00014133).

Positionality Statement:

In summer of 2021, an institutional Inclusive Teaching Fellowship partially funded the efforts for the curricular redesign, which was a collaboration between former teaching assistants from the summer of 2020 (D. Jackson, A. Biera, C. Hawley, J. Lacson, E. Webb) and the professor of the course (K. McGraw), with consultation from an instructional designer (Lenora Ott) and a biology education researcher (K. Cooper). Some members of the research team identify as members of the LGBTQ+ community and some do not. Although not all authors are comfortable defining their identities in this context, those who are represent various identities including cisgendered, gay, heterosexual, man, Mexican-American, nonbinary, queer, white, woman, and from a non-traditional family. Our different lived experiences as biology researchers, biology education researchers, and educators helped us to collaboratively design and assess inclusive learning materials. Collaboration and communication within the group helped us to identify and reduce potential biases in our research design.

Study Context

The focal Animal Behavior courses were offered online during the summer and ran for approximately 5 weeks. We studied this course over 3 iterations, Summer 2021 session B (i.e. 2nd half of the summer; 185 students), Summer 2022 session A (first half of the summer; 61 students), and Summer 2022 session B (138 students). In the first iteration (Summer 2021B), we implemented the course without the addition of the BPAs (BPA-). For both summer 2022 courses, we implemented the course with the BPAs (BPA+). Aside from the presence or absence of the BPAs, the courses were intended to be as identical as possible. All iterations of the Animal Behavior online course incorporate previously recorded video lectures, textbook-type readings, interactive visual and group activities, self-assessment questions, and predeveloped animal-observation activities. Each iteration was also taught by the same professor.

We added 6 BPAs (Supplementary Material) to the base content of this Animal Behavior course. Each activity followed a module in the course on the same topic. Students were given the choice to complete 4 of the 6 activities for full credit. Some BPAs addressed issues relating to oppression, abuse of power, racism, sexual assault, transphobia, homophobia, and eugenics. As such, we felt that allowing students to choose their activities could increase their sense of value and investment in the activity, both of which are associated with an increased sense of belonging (Trujillo and Tanner 2014), and permit them to avoid some potentially triggering content. Since the content of these activities could challenge the well-being of certain students based on particular experiences that they may have previously had, we also wanted to allow them to opt out of engaging in particular topics to create an intervention aimed at promoting their belonging. Students completed BPAs alone (i.e. not group work).

We aimed to use the BPAs to: 1. Foster critical analytical approaches of students to histories and practices in the field of animal behavior along the axes of race, sex, gender, and sexuality, 2. Present a more comprehensive depiction of the diversity of scientists and scientific approaches that have contributed to this field, and 3. Cultivate a sense of belonging and science identity in historically marginalized undergraduate students. We summarize each BPA in the following section (see Supplementary Material for the full activities). In these BPAs, we highlighted the voices of marginalized communities in the field of animal behavior, and most of the learning content was either written by a member of one such community or heavily featured interviews and stories from that marginalized community, similar to “Scientist Spotlights” (Schinske et al. 2016, Ovid et al. 2023). However, our BPAs are distinct from “Scientist Spotlights” because they specifically highlight content that discusses how a scientist’s own positionality can affect their own research and the practices of the field. Students were often asked reflection questions at the start of the BPAs to encourage them to bring their own perspectives into the course. After engaging with a reading, they were asked additional reflection questions that intended to illuminate the influence of culture on our interpretation of nuanced concepts in biology. The reflection questions do not have correct answers, and student reflections were only graded for completeness.

Broadening Perspectives Activities:

1. *History of Animal Behavior.* Students were asked to reflect on how they would expect the cultural influences on the field of animal behavior to bias the knowledge generated by researchers in this field. Students were then provided with reading material that discussed the connections between one of the prominent male European animal behaviorists who was highlighted in the course’s textbook, Konrad Lorenz, and Nazi ideology (Kalikow 1983, Klopfer 1994). Finally, they read an excerpt on Charles H. Turner, an African-American animal behaviorist who was not highlighted in the course content, but whose early contributions to the field were comparable to the scientists highlighted in the textbook, despite facing numerous racial-discriminatory barriers (Dona and Chittka 2020). With each excerpt, students were asked to reflect on their developing understanding of the influence of culture on the history and processes of animal behavior research. This BPA aimed to encourage students to begin to see the effects of politics and social context on the history of animal behavior, and to start to question whose perspectives held outsized power over the paradigms of this field of study.
2. *Sexual Selection.* After reading a section of the course textbook on sexual selection, students were asked to critically evaluate the types of relationships portrayed in that reading between animals of different sexes and between animals of the same sex. They then read three additional excerpts from *Animal homosexuality and natural diversity* (Bagemihl 1999) and *Evolution’s Rainbow: Diversity, gender, and sexuality in nature and people* (Roughgarden 2013) that highlighted the ways that homosexual behavior in animals can manifest and play key roles in their social lives. Next, they read an excerpt that directly refuted many stereotypes about animal

behaviors that are derived from cultural norms spread through European colonialism around sex, gender, and sexuality (Roughgarden 2013). Finally, they were asked to reflect on how biologists define sex, how their culture defines sex, and how they as an individual would define sex.

3. _Methodology._ Students were asked to reflect on the objectivity of the methods that they had been using to study animal behaviors in this class as part of an experiential project that is threaded through the semester. They were then provided with an excerpt from the paper *The history and impact of women in animal behaviour and the ABS: a North American perspective* (Tang-Martínez 2020) that details the history of discrimination against women in the field of animal behavior, with emphasis on the ways that the field of animal behavior changed when women could access resources needed to direct their own research programs in the mid-to-late 1900s, including the introduction of novel methodologies. They were asked to reflect on the notion of objectivity in science and on the influence of culture on the scientific process.
4. _Hermaphroditism._ Students were first asked to reflect on the traits that are shared between males and those that are shared between females, as well as those that differ among males and those that differ among females. They were then provided with an excerpt from the book *Evolution's Rainbow* (Roughgarden 2013), which discusses the occurrence, mechanisms, and functions of hermaphroditism and intersexuality among animals. This reading highlights the important social roles of nonreproductive intersex individuals in some nonhuman species and directly confronts societal assumptions with statements like, "The mention of infertility plays to the prejudice that something is 'wrong' with intersexes. But the story is more complicated" (Roughgarden 2013, p. 36). They were asked to reflect on how intersexuality or hermaphroditism might affect the natural history of an animal, and on their opinion about the use of sexed terms (e.g. penis) for animals of various sexes (e.g. female hyenas).
5. _Migration._ Students listened to an audiobook recording of the essay, *Like the Monarch, Human Migrations During Climate Change* by Sarah Stillman (Stillman 2021). This essay describes the effects of climate change on the migrations of many species, including humans, and how the language that we use to describe those migratory behaviors affects our cultural understanding of them. They were asked to reflect on the influence of the field of animal behavior on socio-political events, and how language shapes our understanding of the natural world. They were also asked to consider via written responses the role of local communities in animal behavior research, and the interactions between popular culture and animal behavior research.
6. _Human Behavior._ Having learned about the biological and evolutionary bases for human behaviors as a final module in the course, in this BPA the students were asked to consider the cultural influences that shape these understandings. They began by reading an excerpt from *Sex Itself: The Search for Male and Female in the Human Genome* (Richardson 2015) that details how the X and Y chromosomes came to be called "sex chromosomes" and the arguments both for and against this classification. They were asked to reflect on the influence of language on their own studies of animal behavior, on the unique importance of their own cultural perspective, and on the cultural biases in the course textbook. Then, students were given the choice to listen to one of two podcast episodes. The first tells the story of Dr. Mary Koss, a professor at the University of Arizona, who co-published the first national study on rape in 1987, and who faced bias from her colleagues based on her gender identity (This American Life 2022). The second is an investigation into the scientific literature on the benefits and potential risks of gender-affirming healthcare for trans people, and the cultural phenomena that shape how that science is (or is not) incorporated into policy-making decisions (Science Vs 2022). For either reading, they were asked to reflect on the decisions that researchers make when designing their studies that might be culturally influenced, on the moral responsibility of scientists, and on the ways that personal experiences can reveal flaws in culturally biased research.

Survey

We survey instrument to evaluate the specific impacts of these BPA course additions on student abilities to learn animal behavior concepts that might be affected by cultural norms around sex, gender, and sexuality, as well as students' sense of belonging in the course and in biology broadly. The survey consisted of 25 close-ended content questions, 10 sense-of-belonging questions, and 15 demographic questions. All content and belonging survey questions are provided in **Table 1** and a copy of the full survey can be found in the Supplemental Material**.** Students completed the survey at the beginning of the course (pre-survey), as well as at the end of the course (post-survey). Students were offered students 2 extra credit points to take each survey (~1.6% of the total course points).

We developed survey questions to address three cognitive learning goals (sex, sexuality, and normativity categories) and two affective learning goals (belonging in course and belonging in biology) that the BPAs were backward-designed to address (Allen and Tanner 2007, Wiggins and McTighe 1998). BPAs 2, 3, 4, and 6 specifically addressed sex and sexuality, but all 6 BPAs had the potential to affect students' understanding of normativity and their sense of belonging. Our BPA specific learning goals were:

1. Sex Category: Students will implement a more nuanced understanding of sex. They will question statements that assume sex is a simple binary, that the behaviors associated with the sex categories of "male" and "female" do not vary across animal species, and that animals only exist as more than one sex in their lifetimes.
2. Sexuality Category: Students will question cisheteronormative assumptions related to animal behaviors.
3. Normativity Category: Students will display a better understanding of how cultural norms impact scientific studies, and that language plays a role in shaping those norms.
4. Belonging in Course Category: Students will express a greater sense of belonging in the course.
5. Belonging in Biology Category: Students will express a greater sense of belonging in the broader field of biology.

Sex category: Nuanced or binary conception of sex in animals

To assess whether the addition of BPAs to the course resulted in a more nuanced understanding of sex in animals, we developed 5 survey questions to measure concepts related to sex that can be affected by binary thinking (Table 1). We presented students with a statement that implied that the sex binary is universal (Sex Question 1), two statements that implied that sex hormones are always associated with sex categories (Sex Questions 2 and 3), a statement that implies sex categories are associated with an essential truth across all species (Sex Question 4), and a question about the proportion of animals that transition between sexual categories (Sex Question 5). For the first four questions, students were presented with a position statement and then several Likert-scale answer options: strongly agree, agree, slightly agree, I am unsure, slightly disagree, disagree, strongly disagree. For the fifth close-ended survey question, students were asked about their expected proportion of animal species that meet a criterion, and for these they were presented with the options: 0%, 5%, 20%, 33%, 66%, 80%, 95%, 100%, and I am unsure.

Sexuality category: Nuanced or cisheteronormative conception of sexuality in animals

To assess the impact of the BPAs on student understandings of sexuality in animals, we developed 11 survey questions to measure different concepts relating to sexuality (Table 1). Items investigated student understandings of the evolutionary role of homosexuality (Sexuality Question 1, 3, and 4), of hermaphroditism (Sexuality Question 2), and of monogamy (Sexuality Question 5, 9, 10) in animal species. We also presented students with statements related to the nuclear-family construct (Sexuality Questions 6, 7, 8) and about the evolutionary benefit of aggression in males (Sexuality Question 11). Ten of these questions followed the same Likert scale format as the questions described in the sex category, and one (Sexuality Question 3) followed the same proportion format as Sex Question 5.

Normativity category: Recognition of the influence of culture on scientific processes

We developed 9 survey questions to test the impact of BPAs on student understandings of the impact of cultural normativity on the scientific process. These investigated the role of language (Normativity Questions 1, 3, and 4), biases (Normativity Question 2), and social constructs (Normativity Questions 5 and 6) in shaping our understanding of animal behaviors. We also investigated student beliefs that LGBTQ+ identities are natural (Normativity Questions 7 and 8) and investigated if students believed that their understanding of nature influenced their sense of self (Normativity Question 9). All of these questions followed the same Likert scale format as the questions described in the sex category.

Belonging categories: Student sense of belonging in the course and in biology

We used 5 survey questions to test student sense of belonging in the course and 5 questions to test their sense of belonging in the field of biology following methods from a previously developed and validated scale (Anderson-Butcher and Conroy 2002). All of these questions followed the same Likert scale format as the questions in the sex category.

Validity and Reliability of Survey Questions

The sets of questions assessing nuanced or binary conception of sex or animals, nuanced or cisheteronormative conception of sexuality in animals, and recognition of the influence of normed culture on scientific processes were developed by members of the author team who were graduate students in biology and had previously worked as teaching assistants for the Animal Behavior course (A. Biera, C. Hawley, D. Jackson, J. Lacson, E. Webb). These questions were reviewed by the professor of the course who is an expert in the field of animal behavior (K. McGraw), a biology-education researcher (K. Cooper), and an instructional designer (L.Ott). Before finalizing the instrument, three researchers performed think-aloud interviews with 6 undergraduate students to evaluate the cognitive validity of the survey (Trenor et al. 2011). For each interview, the interviewer read each survey question, then interviewees were asked to state what they believe the question is asking, and then interviewees were asked to respond to the question. Survey questions were then revised based on interviewee responses between each interview; after the six interviews, no additional changes were warranted.

Our questions were designed to explore student responses broadly across the category of interest, not to collectively test a latent construct. Within the sexuality category, for example, students are asked to respond to the statement, “Homosexual behaviors are not evolutionarily advantageous,” as well as to the statement, “All animals are cared for by their parents when they are young.” While both survey questions can illuminate students’ degree of reliance on cisheteronormative assumptions in their interpretations of animal behaviors, these questions are intentionally distinct from each other. We therefore present the analyses of students’ responses to each individual content question, to demonstrate the boundaries of the effect of the BPAs on students’ cisheteronormative assumptions. Additionally, we conducted a collective analyses of all questions in each content category (sex, sexuality, normativity). We dropped the two questions that were not on a Likert scale (Sex Q5 and Sexuality Q4) from collective analyses. The collective analyses should be interpreted cautiously since the questions were not developed to test a latent construct. However, both sets of belonging questions

(Belonging in Biology and Belonging in Course) were meant to be treated as a single construct (Anderson-Butcher and Conroy 2002).

We assessed the validity of each construct using confirmatory factor analyses (CFAs) as a correlated five-factor model, in which all categories are treated as a single factor (sex, sexuality, normativity, belonging in course, and belonging in biology). Summary statistics indicated that student responses to some questions deviated from normality (Supplemental Tables 2 and 3), so we used a robust maximum likelihood estimator with the Satorra-Bentler correction in the CFAs. Evaluation of these statistics suggested that collective assessment of the survey questions within categories is only supported for the two affective learning goal categories (belonging categories) and not for any of the cognitive learning goal categories, although both Sex and Sexuality had nearly significant omega values for the post-course survey responses. We assessed the consistency of the questions within each category using McDonald's omega (Hancock et al. 2010). This measure does not assume equivalence of factor loadings in the model, which is especially important given our study's broad range of questions within each category, some of which directly target the latent construct much more than others. Like the CFAs, omega values indicated that only the two affective learning goal categories were consistent, although omega values for Sex and Sexuality approached significance. We present results of collective analyses of each cognitive category for reference, but these results should be very cautiously interpreted given the results of the CFA and the McDonald's omega values. We do not present individual results for each question in the Belonging categories and only present the results of the collective analyses because these were previously designed with the intention of collective analysis (unlike our cognitive categories), and because collective analysis is supported by the results of the CFA and the omega values for these question sets.

Analyses

All analyses were conducted in R (Ihaka and Gentleman 1996) with the MASS (Ripley et al. 2013) and lm.beta (Behrendt 2023) packages or Python (Python 2021) with the Pandas (McKinney and Team 205), SciPy (Virtanen et al. 2020), NumPy (McKinney 2012), statsmodels (Seabold and Perktold 2010), scikit-learn (Pedregosa et al. 2011), and Matplotlib (Hunter 2007) packages. The code used for the data processing and analysis can be accessed here: https://github.com/dannyjackson/StudentSurveyAnalyses. We grouped student responses for both BPA+ courses for all analyses. We filtered the data to include only students who took both the pre-survey and the post-survey, and to exclude any student who took the course twice. After filtering, we had a total of 200 responses, with 69 student responses for the BPA- course and 131 student responses for the BPA+ course. Likert scale student responses were coded into numerical values: Strongly Disagree = -3, Disagree = -2, Slightly Disagree = -1, I Am Unsure = 0, Slightly Agree = 1, Agree = 2, Strongly Agree = 3. However, for the proportional questions, student responses of "I Am Unsure" were coded as NA values.

We grouped student responses to demographic questions into binary categories for LGBTQ+ identity, gender, religion, and race. We were interested in the marginalized identity for each of these categories, so we coded students as LGBTQ+ or Not LGBTQ+; Woman/Nonbinary/Other (hereafter referred to as Woman/NB) or Man; Christian or Other/Non-Religious; and Persons Excluded because of their Ethnicity/Race (PEERs) or not (Asai 2020). We considered treating nonbinary, Jewish, Muslim, and Asian identities as separate categories, but we regrettably were not able to due to small sample sizes. Based on the definition of PEER identities, Asian students and white students were grouped to form the "not PEER" group. We treated Christian as the category of interest because studies have shown that Christian students can feel alienated in the field of biology (Barnes et al. 2021). We also considered combining Jewish and Muslim students with Christian students since these religious identities might operate similarly in response to non-cisheteronormative content in a biology classroom. However, given our sample sizes and the evidence from previous research that Christian students feel alienated in

Biology classrooms (Barnes et al. 2021), we decided to consider only Christianity as our religious identity of interest rather than risk grouping religious identities without justification. We hope that future research will study populations with larger sample sizes of students of other religious identities on this topic.

For most of the questions, we considered a shift toward “Strongly Disagree” to be in line with a more nuanced and less culturally biased understanding of the concept. We explicitly outline the direction of the shift for each question that indicates the more nuanced and less culturally biased understanding of the concept in Table 1. For the collective analyses of questions in the Sex, Sexuality, Belonging in Course, and Belonging in Biology categories, we summed student responses across all questions without needing to correct for directionality of intended outcome, so a negative shift in the collective models is in line with a more nuanced understanding. We excluded the two questions that asked students to estimate a proportion from the collective models and only included Likert scale questions. For the collective analysis of the Normativity category, most, but not all, of the questions were phrased such that a shift toward “Strongly Agree” was the intended outcome. Therefore, for the collective model, but not for the individual question models, we reverse-coded the scores of the questions in the Normativity category that favored a shift toward “Strongly Disagree” by multiplying scores by -1 to standardize the direction the scores before summing each student’s responses to the questions within this category. We therefore considered a positive shift in the collective model of the Normativity category to be aligned with a more nuanced and less culturally biased understanding.

We used analyses of covariance (ANCOVA) to model pre-course survey responses to each question with identity variables as the main effects. We modeled the post-course survey responses to each question using the main effects of course type (either BPA- or BPA+ course) and identity variables and the interactive effects of course type and identities, while controlling for pre-survey responses by adding it as a covariate. We used the model of pre-course survey responses to test the hypothesis that student identities affect their understanding of the topic of sex, gender, and sexuality in nonhuman animal behaviors before they enter the class. We used backward stepwise model selection by Akaike information criterion (AIC) for each survey question to select the simplest explanatory model. We include LGBTQ+ identity, gender identity, and religion as the identity-related predictors in models of content- and attitude-focused questions. However, because some of our interventions dealt with topics related to historical racism and discrimination, we included the racial identity category (PEER vs. not PEER) as a predictor variable for the sense of belonging questions. We have no reason to assume that a student’s racial identity might affect their understanding of concepts related to sex, gender, and sexuality, so we did not include race in the analysis of the conceptual questions. We did not include interactions among identity-related variables as predictors in the models due to a lack of sufficient representation in our population. However, we acknowledge the importance of intersectionality in shaping student’s experiences and perceptions, and our results should be interpreted cautiously with this in mind. For post-course survey questions, we also included the pre-course survey response as a predictor variable to account for students’ prior knowledge. AIC model selection on only one question (Normativity Q9) excluded pre-course survey responses. To control for multiple hypothesis testing, we used the Benjamini-Hochberg procedure and ranked p-values for each identity within each of the content categories (sex, sexuality, normativity) using a false-discovery rate of 0.05 (Benjamini and Hochberg 1995). Corrected p-values were used to determine significance, and raw p-values can be found in the supplement (Supplemental Tables 5 and 6).

Results

Participant Demographics

Of students who participated in the study, 26.5% identified as LGBTQ+, holding identities including gay, bisexual, transgender, queer, asexual, pansexual, non-binary, aromantic, biromantic and confused. Additional student demographics are summarized in Table 2.

Finding 1: Student identities (LGBTQ+, gender, and religious) predict the foundation of knowledge that undergraduate students bring to an animal behavior course with respect to concepts relating to sex, sexuality, and normativity.

LGBTQ+ students demonstrated a foundation of knowledge that was less influenced by cisheteronormative assumptions about animal behavior than their non-LGBTQ+ peers (Table 3). LGBTQ+ students were more likely than their non-LGBTQ+ peers to demonstrate resistance to strict sex categories (Sex Q1) and a nuanced understanding of sexed physiologies (Sex Q2 & Q3, Table 3). They were also more likely to recognize contextual evolutionary value of homosexual behaviors, sexual transitions, and non-monogamy in animals (Sexuality Q1, Q2, Q3, Q5) and to predict a higher rate of homosexuality in animals (Sexuality Q4, Table 3). Further, results indicated that LGBTQ+ students were more likely than their peers to acknowledge the difference between sex and gender (Normativity Q3), and to acknowledge that LGBTQ+ identities and associated behaviors are natural and widespread throughout the animal world (Normativity Q7, Q8, Table 3).

Gender identity had an effect on students' prior knowledge for 1 question: women/NB students were more likely to express cisheteronormative assumptions by relating gender stereotypes to animal behaviors (Sexuality Q9, Table 3).

Religious identity had an effect on students' prior knowledge for 5 questions, and in 4 of the 5 questions Christian students were more influenced by cisheteronormative assumptions than their non-Christian peers (Table 3). Christian students were more likely than their peers to assume that sex categories implied universal truths about species traits and behaviors (Sex Q4, Table 3). They were also more likely than their non-Christian peers to answer questions in ways that indicate that sex and gender are equivalent (Normativity Q3) and that LGBTQ+ identities and associated behaviors are not natural and are not found in non-human animals (Normativity Q7, Q8, Table 3). However, Christian students were more likely than their non-Christian peers to report that the scientific definition of sex includes social norms, behaviors, and roles (Normativity Q5, Table 3).

Finding 2a: Students enrolled in the BPA+ course demonstrate higher post-course knowledge with respect to concepts relating to sex.

The inclusion of BPA activities in a course (BPA+) had an effect on students' post-course responses for 7 individual questions (Figure 1): Sex 1-5, Sexuality 4 and 6. For 6 of the 7 questions, student post-course responses moved in the intended direction, demonstrating responses that were less influenced by cisheteronormative biases (Table 4, Supplemental Figure 1). That is, students who took the BPA+ course were more likely than their peers in the BPA- course to demonstrate resistance to strict sex categories (Sex Q1), to demonstrate a nuanced understanding of sexed physiologies (Sex Q2, Sex Q3), to assume that sex categories do not imply universal truths about species traits and behaviors (Sex Q4), and to predict a higher proportion of animal species that transition between sexes in their lives (Sex Q5) in their post-course responses (Table 4, Supplemental Figure 1). They were also more likely to predict a higher proportion of animals that exhibit homosexual behaviors (Sexuality Q4, Table 4, Supplemental Figure 1). However, for 1 of the 7 questions, student post-course responses moved in the opposite of the intended direction and demonstrated more cisheteronormative assumptions: students who took the BPA+ course were more likely than their peers in the BPA- course to believe parental care is universal (Sexuality Q6; Table 4, Supplemental Figure 1). Whether students were enrolled in a BPA+ course did not predict their responses to any of the questions assessing assumptions of normativity (Table 4).

Finding 2b: Regardless of course type, LGBTQ+ students demonstrate knowledge less influenced by cisheteronormative assumptions related to sex, sexuality and normativity, and both Women/NB students and Christian students demonstrate more culturally biased knowledge at the end of the course.

Regardless of the presence or absence of BPAs and accounting for pre-course knowledge, LGBTQ+ students consistently demonstrated knowledge that was less influenced by cisheteronormative assumptions than their non-LGBTQ+ peers at the end of the course (Table 4). They were less likely to assume that sex categories were universally applicable (Sex Q1) and were less likely to recognize that sex categories implied universal truths about species traits and behaviors (Sex Q3-4, Table 4). They were also more likely to identify the evolutionary value of sexual transitions in animals (Sexuality Q2) and of nonmonogamy (Sexuality Q5, Q10, Table 4). LGBTQ+ students also completed the course expressing an understanding of the influence of cultural normativity on scientific studies; they demonstrated a greater understanding that sex and gender do not mean the same thing and that it is important to distinguish between the two (Normativity Q3-Q4) and that LGBTQ+ identities and associated behaviors are natural and widespread in the animal world (Normativity Q7-Q8, Table 4).

Gender identity predicted the knowledge that students took away from the course for only 1 question, Sex Q3, and for both of the collective analyses of Sex and Sexuality questions (Table 4). Women/NB students were more likely to apply gender norms to their understanding of sexed physiologies than their peers that identify as men and expressed more cisheteronormative assumptions across the collective Sex and Sexuality questions after accounting for students' pre-course knowledge (Table 4).

Religious identity predicted post-course knowledge for 2 Sexuality questions (Q2 and Q7), for 1 Normativity question (Q2), and for the collective analysis of all Sexuality questions (Table 4). In all instances, Christian students left the course with a more cisheteronormative perspective than their non-Christian peers, after accounting for students' pre-course knowledge (Table 4). They were less likely than their non-Christian peers to recognize contextual evolutionary value of sexual transitions (Sexuality Q2), and more likely to agree that biological parents are better caretakers than non-biological parents (Sexuality Q7), and to that our cultural biases do not limit our ability to understand the natural world (Normativity Q2, Table 4). They expressed more cisheteronormative knowledge in the collective Sexuality analysis than their non-Christian peers (Table 4).

Finding 2c: BPAs were disproportionately effective for non-LGBTQ+ and Christian students

We found that the BPA intervention disproportionately affected students based on LGBTQ+ identity in their post-course responses to 2 questions (Sex Q4 and Normativity Q9) and in the collective score for all Sex questions (Table 4, Supplemental Figure 1). Non-LGBTQ+ students who took the BPA+ course were less likely to assume that sex categories imply universal truths about species traits and behaviors (Sex Q4) than their non-LGBTQ+ peers who took the BPA- course (Table 4, Supplemental Figure 1). This appeared to close the gap between LGBTQ and non-LGBTQ pre-course knowledge for this topic (Supplemental Figure 1). Non-LGBTQ+ students also shifted in the collective score for Sex in the direction that we had intended (Table 4, Supplemental Figure 1). LGBTQ+ individuals showed no difference between courses on these questions (Table 4, Supplemental Figure 1). However, LGBTQ+ individuals who took the BPA+ course were more likely to affirm that studying the natural world influences their understanding of themself and other humans than LGBTQ+ individuals who took the BPA- course, again in line with our intended outcomes (Table 4, Supplemental Figure 1). Non-LGBTQ+ individuals demonstrated no difference (Normativity Q9; Table 4, Supplemental Figure 1).

The interaction of course and gender identity did not significantly predict students' post-course responses to any questions (Table 4).

The interaction of course and religious identity had an effect on students' post-course responses to 5 questions (Sexuality Q2, Q7, Q10, Normativity Q2, Q8) and for the collective score for all Sexuality questions (Table 4, Supplemental Figure 1). Christian students who took the BPA+ course consistently shifted their perceptions in the intended direction (Table 4, Supplemental Figure 1). They were more likely to recognize contextual evolutionary value of sexual transitions and of polyandry in animals than their Christian peers who took the BPA- course (Sexuality Q2, Q10; Table 4, Supplemental Figure 1). Christian students who took the BPA+ course were more likely to believe that our cultural biases limit our ability to understand the natural world (Normativity Q2) and to acknowledge that LGBTQ+ identities and associated behaviors are natural and widespread throughout the animal world (Normativity Q8) than their Christian peers who took the BPA- course, while course type had no effect on non-Christians no effect (Table 4, Supplemental Figure 1). However, non-Christian students who took the BPA+ were more likely to believe that biological parents are better caretakers than non-biological parents than their non-Christian peers in the BPA- course, which is in the opposite direction of our intended outcomes. Course type had no effect on Christian students for this subject (Sexuality Q7; Table 4, Supplemental Figure 1). Christian students in the BPA+ course shifted in the intended direction for the collective score of all Sexuality questions compared to Christian students in the BPA- course, while non-Christian students showed no differences between BPA conditions (Table 4).

Finding 3: BPAs improve LGBTQ+ students' sense of belonging in biology

LGBTQ+ students entered the course with a lower sense of belonging in the field of biology than their non-LGBTQ+ peers (Belonging C2; Table 5), but LGBTQ identity did not have an effect on students' sense of belonging in the course itself (Belonging C1; Table 5). After taking this course, the interaction between LGBTQ+ identity and the course type had an effect on students' sense of inclusion in the field of biology (Belonging C2; Table 6). The addition of the BPAs to the course had a disproportionate effect on LGBTQ+ students' sense of belonging in the field of biology, and closed the belonging gap demonstrated at the beginning of the course (Belonging C2; Table 6, Figure 2). Neither gender, religion, nor race predicted students' sense of inclusion in any model (Belonging C1 and C2; Tables 5-6).

Discussion

The central goal of this study was to investigate the effects of a curriculum addition on LGBTQ+ students' sense of belonging, and on all students' understanding of concepts in Animal Behavior related to sex, gender, and sexuality. Our study found largely positive effects of the curriculum addition. We demonstrate an intervention with the potential to lessen students' cisheteronormative assumptions in biology, while simultaneously improving the belonging for LGBTQ+ individuals in biology.

Students differ in the knowledge that they bring to a classroom based on their identities, and the knowledge that they take from the course.

We found that LGBTQ+ students are more likely to enter undergraduate biology courses with nuanced and complex understandings of sex, gender, and sexuality than their non-LGBTQ+ peers. This novel finding supports longstanding theoretical work that has advocated for the acknowledgement of student's past experiences and prior knowledge within the academic context (Lemke 2001) by quantifying the differences in student perceptions on issues related to their lived experiences. We also showed that, regardless of the presence or absence of BPAs, student identities predicted what knowledge they took from the class for concepts related to sex, gender, and sexuality. Not only are students entering the classroom with different knowledge from their lived experiences, but that knowledge shapes how they engage with classroom materials. Our findings support the perspectives presented by authors reflected in our BPAs, who argue that LGBTQ+ and other marginalized perspectives in the field of animal behavior provide unique and valuable contributions because the lived experiences of scientists of different identities prepare them to ask different questions than their non-LGBTQ+ peers (Bagemihl 1999, Giurfa and de Brito Sanchez 2020, Jaffe et al. 2020, Lee 2020, Roughgarden 2013, Tang-Martinez 2020a). For example, prior to taking the course, LGBTQ+ students were more likely to disagree with statements that devalued the role of homosexual behaviors in evolutionary contexts than their peers. This quantitative finding helps to explain patterns found in qualitative studies of LGBTQ+ students' sense of belonging in biology, which have documented friction between the lived experiences of LGBTQ+ students and curricular content (Casper et al. 2020).

Efforts to expand course content had largely positive impacts on student learning, but the effects differed across identities.

The addition of the BPAs had many positive effects on the understandings of all students regardless of identity. Students left the BPA+ class with a greater understanding of the diversity of life as it relates to sex, gender, and sexuality. This understanding applied to topics within the sex and sexuality categories. The addition of the BPAs even improved student abilities to extend their critical analysis to a higher level and adjust their normative assumptions about the world in a limited capacity. We had hoped that these activities would increase students' likelihood of agreeing with statements like, "The language that we use affects our ability to understand the natural world," and "Our cultural biases limit our ability to understand the natural world," or even, "Sex and gender mean the same thing." For some, like the first two statements, our BPAs had no impact. But for the third statement, the addition of our BPAs improved both Christian student and non-LGBTQ+ student scores. It is remarkable that some students shifted their paradigms in response to these activities across all identities and given that some students have noted their peers use scientific rational to justify their anti-LGBTQ+ beliefs (Cech and Waidzunas 2010), curricular changes like ours may have positive effects on the campus climate for LGBTQ+ students. We did observe the undesirable trend that students left the BPA+ course with more culturally biased understandings for on topics related to parental care. None of our Broadening Perspectives Activities directly addressed this concept, and we hope that future iterations of this course will seek to address this misconception.

Both before and after the course, and regardless of the integration of BPAs, non-LGBTQ+ students lagged behind their LGBTQ+ peers on adopting non cisheteronormative views. When taking the BPA+ version of the course compared to the BPA- course, non-LGBTQ+ students improved on one important concept. This demonstrates both a marginally positive impact of our work and a great need for new approaches to foster diverse understandings of sex, gender, and sexuality among non-LGBTQ+ students in biology courses. LGBTQ+ students who took the BPA+ course also expressed a greater sense that the field of Biology could be an avenue through which they could understand their own place in the natural world compared to their peers in the BPA- course. Sense of belonging is associated with a sense that the work students are asked to do in an academic context is worthwhile (Freeman et al. 2007), and our BPAs facilitated a connection between LGBTQ+ student identities and their field of study.

The effects of gender identity on student knowledge and the interaction between gender and our BPAs were very unexpected. Women/NB students were more likely to have culturally imposed beliefs about parental care and nonmonogamy prior to the course. It is interesting that this was the only difference that we uncovered, since STEM fields with higher percentages of women are also likely to have a higher degree of openness to LGBTQ+ scientists, suggesting some difference between women and men with respect to LGBTQ+ issues (Yoder et al. 2016). Our BPAs influenced students who identify as a man to demonstrate more culturally imposed beliefs about parental care on their understandings of animal behavior compared to their peers who don't identify as a man, which is the same trend that we observed for all students regardless of their identity. Gender did not have an effect on student learning for any of the other concepts, many of which are more directly related to LGBTQ+ identities.

Likewise, our BPAs interacted with religious identities in complicated ways, with some desirable and some undesirable outcomes. As a result of the BPAs, Christian students demonstrated a decrease in the effect of cultural biases on their understanding of the value of sexual transitions in the animal world, as well as of polyandry, which aligned with our intended outcomes. Interestingly, Christian students overall were less likely than their non-Christian peers to believe that our cultural biases do not limit our ability to understand the natural world. But Christian students who took the BPA+ course were more likely than their Christian peers in the BPA- course to express this belief, demonstrating that the BPAs ameliorate but do not fully resolve identity-based discrepancies in critical analyses. This trend may influence the effectiveness of curriculum interventions on student understandings, as a belief that culture can impact our beliefs is central to the development of a critical cultural practice. Christian students demonstrated more binary and culturally influenced understandings of Animal Behavior concepts related to sex, gender, and sexuality than their non-Christian peers both before and after taking our course. Similarly, acceptance rate of evolution is predicted by religious identity (Glaze et al., 2014, Hill, 2014, Rissler et al., 2014), and our approach to teaching LGBTQ+ related concepts followed several guidelines outlined for fostering the acceptance of evolution in religious students (Barnes and Brownell 2017). Our work here contributes to the growing body of literature on how to resolve cultural conflicts between religious paradigms and biological science in an undergraduate course.

Efforts to improve curricula had positive effects on student sense of belonging, with no negative effects on any studied identity

LGBTQ+ identity was the only significant predictor of the sense of belonging in the field of biology for students prior to taking this course. LGBTQ+ students who took the course with the addition of our BPAs expressed a positive trend in their sense of belonging, demonstrating that our activities not only improved their sense of belonging but also counteracted the pre-existing negative effects of the BPA- course. While many studies have documented the challenges faced by LGBTQ+ undergraduates in STEM (Greathouse et al. 2018, Hughes 2018, Miller and Downey 2020, Hughes and Kothari 2021, Maloy et al. 2022, Casper et al. 2022, among others), and others have demonstrated positive cultural changes to improve LGBTQ+ student experiences, to our knowledge this is the first study to demonstrate an effective curricular intervention that improves the sense of belonging of LGBTQ+ students in Biology.

Our surveys found no effect of gender, racial, or religious identities on students' sense of belonging. This is surprising, since other studies have found that students of marginalized identities along these axes do feel excluded from STEM (Rodriguez and Blaney 2021). Our course was entirely online, and the majority of the students in our course were completing their entire undergraduate studies online. We know little about the effect of an online curriculum compared to an in-person curriculum on student sense of inclusion, and it could be that students who are entirely online experience less identity-based stigma. For in person courses, transgender and nonbinary students cite both exclusionary curriculum practices alongside exclusionary cultural norms as reasons for their low sense of belonging in biology courses (Casper et al. 2022). It is unknown if those same stigmatizing experiences occur at a similar rate for students in an online curriculum. This indicates a potentially rich avenue of research into expanding access to and interest in STEM fields.

We believe that the context in which our team was empowered to enact this work was important to the success of this project. This inclusive curriculum development was one of several projects funded by the first year of Arizona State University School of Life Science's Inclusive Teaching Fellowship. An LGBTQ+ Ph.D. student (D. Jackson) proposed this work following their experiences as a teaching assistant on the same course, and multiple other Ph.D. students with different identities and perspectives contributed to the development of this project (A. Biera, C. Hawley, J. Lacson, and E. Webb). The professor of the course, K. McGraw, encouraged and actively participated in the development of the BPAs, and we drew from his expertise as well as the expertise of an education developer (Lenora Ott) and an education research professor (K. Cooper). We demonstrated measurable impacts on undergraduate student learning from this work, and on marginalized undergraduate students' sense of inclusion. These findings emphasize the value of funded opportunities for scientists of marginalized identities to make changes to course curriculum at early career stages. LGBTQ+ scientists leave STEM at every stage of their career at higher rates than their non-LGBTQ+ peers (Freeman 2018), and programs that incorporate the perspectives of early career LGBTQ+ scientists can help improve the culture for younger scientists.

Limitations

To maximize the anonymity of students in the study, we did not collect grade point average and as such, did not control for it in our analyses. Additionally, students were only required to complete 4 of the 6 BPA activities, and for purposes of anonymity we were also unable to collect data on which ones each student chose to complete. The BPAs were graded just on completion, which differs from the grading approach of the rest of the course, and we could not untangle whether the impacts we observed were derived from the novel curricular content or from the novel pedagogical approach. Future studies can assess whether engaging in specific BPAs predicts the effectiveness of integrating BPAs in biology courses on student outcomes. These findings should not be generalized beyond the population we sampled from; students at a research-intensive institution taking an upper-level animal behavior course.

Conclusions

We developed Broadening Participation Activities (BPAs) to expand the representation of marginalized perspectives in the curriculum of an online, upper-division, undergraduate animal-behavior course. In this study, we used a quasi-experimental design to assess the impact of the BPAs on undergraduates' cisheteronormative assumptions on topics related to sex, gender, and sexuality, as well as on students' sense of belonging to the course and to biology more broadly. We found that LGBTQ+ students came into the course with fewer cisheteronormative assumptions than their straight and cis peers. The BPA activities effectively reduced students' cisheteronormative assumptions related to topics of sex and were found to be disproportionately effective for non-LGBTQ+ and religious students. Further, BPAs closed a sense of belonging gap in biology for LGBTQ+ students; despite entering the class with a lower sense of belonging in biology than their peers, LGBTQ+ students in the courses with BPA activities left the course with a similar sense of belonging in biology. This study demonstrates the potential for BPA activities to lessen students' cisheteronormative views associated with content presented in an Animal Behavior course and to strengthen the belonging of LGBTQ+ students in biology.

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Tables

Table 1: Survey Questions.

Survey questions that were given to students during the first and last week of their course. All questions were presented with 6 point Likert scale responses from “Strongly Disagree” to “Strongly Agree” with “I don’t know” as a neutral option, except for Sex Question 5 and Sexuality Question 4, which were presented with a range of possible proportions.

Question	**Sex Questions:** After having taken the course, students will better recognize that sex is more complex than a simple binary, that the behaviors associated with the sex categories of “male” and “female” vary across animal species, and that many animals exist as more than one sex in their lifetimes.	**Intended Response:** The intended response is in the direction of a more nuanced perspective that is less influenced by cisheteronormative assumptions.
1	The sex of an animal can be categorized as either male or female.	Towards Strongly Disagree
2	In any given pair of a male and a female, the male will have higher levels of testosterone than the female.	Towards Strongly Disagree
3	In any given pair of a male and a female, the female will have higher levels of estrogen than the male.	Towards Strongly Disagree
4	Two males of different species will have more in common with each other than a male and a female of different species.	Towards Strongly Disagree
5	Excluding insects, what proportion of animal species exist as more than one sex during their life?	Towards a greater proportion
	Sexuality Questions: After having taken the course, fewer students will apply western cisheteronormative assumptions to animal behaviors than they did before taking the course.	
1	Heterosexual behaviors, defined as mating with another animal of a different sex, are inherently more evolutionarily advantageous than homosexual behaviors. By "evolutionarily advantageous" we mean the animal will have higher fitness or produce more offspring. By "homosexual behaviors" we mean mating with another animal of the same sex	Towards Strongly Disagree
2	Species that stay the same sex throughout their entire lives have more evolutionary advantage (have higher fitness or will produce more offspring) than species that change sexes throughout their entire lives.	Towards Strongly Disagree
3	Homosexual behaviors are not evolutionarily advantageous.	Towards Strongly Disagree
4	What proportion of sexual animal species exhibit homosexual behaviors?	Towards Strongly Disagree
5	Monogamous species have a greater evolutionary advantage over non-monogamous species.	Towards Strongly Disagree
6	All animals are cared for by their parents when they are young.	Towards Strongly Disagree
7	Any animal would be better off if it were raised by their biological parents than by other members of the same species.	Towards Strongly Disagree

8	Any nonhuman animal that is raised by their biological parents is better off than another animal that isn't raised by their biological parents.	Towards Strongly Disagree
9	In animals, males are more likely to cheat on their partner than females. By "cheating" we mean mating with an animal outside of a pair-bond.	Towards Strongly Disagree
10	Polygyny (1 male mating with multiple females) is always more evolutionarily advantageous than polyandry (1 female mating with multiple males).	Towards Strongly Disagree
11	More aggressive males produce more offspring than less aggressive males.	Towards Strongly Disagree
	Normativity Questions: After taking the course, students will better recognize the influence of the impact of cultural normativity on scientific studies, and the role that language plays in shaping those norms.	
1	The language that we use affects our ability to understand the natural world.	Towards Strongly Agree
2	Our cultural biases limit our ability to understand the natural world.	Towards Strongly Agree
3	Sex and gender mean the same thing.	Towards Strongly Disagree
4	It is important to distinguish between sex and gender when talking about biology.	Towards Strongly Agree
5	The scientific understanding of sex includes social norms, behaviors, and roles associated with being a particular sex.	Towards Strongly Agree
6	The scientific understanding of gender includes norms, behaviors, and roles associated with a particular gender.	Towards Strongly Agree
7	LGBTQ+ identities and associated behaviors are natural in a biological sense.	Towards Strongly Agree
8	The behaviors associated with LGBTQ+ identities are exclusive to humans, and are not represented in the animal world.	Towards Strongly Disagree
9	Studying the natural world influences my understanding of myself and other humans.	Towards Strongly Agree
	Belonging in the Course (Belonging C1): After taking the course, students will have a higher sense of belonging in the course. BIO 331 is the course code for the Animal Behavior course at ASU.	
1.1	I feel comfortable in BIO 331	Towards Strongly Agree
1.2	I am a part of BIO 331	Towards Strongly Agree
1.3	I am committed to BIO 331	Towards Strongly Agree
1.4	I am supported by BIO 331	Towards Strongly Agree
1.5	I am accepted in BIO 331	Towards Strongly Agree
	Belonging in Biology (Belonging C2): After taking the course, students will have a higher sense of belonging in the field of biology.	
2.1	I feel comfortable in the Biology community	Towards Strongly Agree

2.2	I am a part of the Biology community	Towards Strongly Agree
2.3	I am committed to the Biology community	Towards Strongly Agree
2.4	I am supported by the Biology community	Towards Strongly Agree
2.5	I am accepted by the Biology community	Towards Strongly Agree

Table 2: Survey Respondent Demographics

Demographics of students by identity category as they were coded in the analyses for the ANCOVA models.

Identity category	Identity	Percent of students surveyed
LGBTQ status	LGBTQ+	26.5%
	Not LGBTQ+	73.5%
Gender identity	Women/NB	79.0%
	Man	21.0%
Religious affiliation	Christian	38.5%
	Other religious identity	61.5%
Racial identity	PEER	25.5%
	Not PEER	74.5%

Table 3: Pre-course Question Effects.

Results of the ANCOVA models for each question on the pre-course survey, organized by category: Sex, Sexuality, and Normativity. Blank squares were excluded from the model based on our AIC backward stepwise model selection process. Bolded betas are significant after p-value correction with the Benjamini-Hochberg procedure, and colors indicate direction of significance. Purple indicates that the group of interest expressed lesser cisheteronormative assumptions and yellow indicates that the group of interest expressed greater cisheteronormative assumptions than their respective reference group. For each model, the sign of the beta indicating less cisheteronormative assumption is reported in the last column. For the collective models, we summed the Likert scale questions within each category (Sex Q1-4, Sexuality Q1-3 and 5-11, Normativity Q1-9) after reverse coding the relevant questions. We then analyzed these summative scores with the same procedure as the individual questions after reverse coding the questions. An asterisk indicates that the question was reverse coded in the collective model of that category.

Category	Pre-course Question	LGBTQ+	Women/NB	Christian	Adj R-squared	Sign of Beta Indicating Less Cisheteronormative Assumption
Sex	Collective	**-3.947**			0.144	Negative
	1	**-1.244**			0.087	Negative
	2	**-0.986**			0.084	Negative
	3	**-1.128**			0.112	Negative
	4			**0.664**	0.031	Negative
	5		0.062		0.010	Positive
Sexuality	Collective	**-5.600**			0.088	Negative
	1	**-0.746**	-0.410		0.071	Negative
	2	**-0.548**			0.0190	Negative
	3	**-1.524**		0.372	0.168	Negative
	4	**0.191**			0.060	Positive
	5	**-0.565**			0.023	Negative
	6			0.357	0.010	Negative
	7	-0.465	-0.615		0.032	Negative
	8		-0.567		0.016	Negative
	9	-0.385	**0.643**		0.020	Negative
	10		0.512		0.008	Negative
	11	-0.555		-0.365	0.014	Negative

Normativity	Collective				0.000	Positive
	1				<0.001	Positive
	2				<0.001	Positive
	3	**-0.856**		**0.557**	0.083	Negative*
	4		0.460	-0.327	0.015	Positive
	5	-0.493		**0.837**	0.065	Positive
	6		0.321	-0.277	0.015	Positive
	7	**0.911**	0.507	**-0.616**	0.121	Positive
	8	**-0.845**		**0.773**	0.122	Negative*
	9			-0.241	0.011	Positive

Table 4: Post-course Question Effects.

Results of the ANCOVA models for each post-course survey question. Blank squares were excluded from the model based on our AIC backward stepwise model selection process. Bolded betas are significant after p-value correction with the Benjamini-Hochberg procedure, and colors indicate direction of significance for identity factors. Purple indicates a modeled effect indicating lesser cisheteronormative assumptions and yellow indicates a modeled effect indicating greater cisheteronormative assumptions than their respective reference group. To determine whether the reference or non-reference group drove patterns of interaction terms, models of significant interactions are presented in Supplementary Figure 1. For each model, the sign of the beta indicating less cisheteronormative assumption is reported in the last column. For the collective models, we summed the Likert scale questions within each category (Sex Q1-4, Sexuality Q1-3 and 5-11, Normativity Q1-9) after reverse coding the relevant questions. We then analyzed these summative scores with the same procedure as the individual questions after reverse coding the questions. An asterisk indicates that the question was reverse coded in the collective model of that category.

Category	Post-course Question	BPA+	LGBTQ+	Women /NB	Christian	BPA+ : LGBTQ+	BPA+ : Women/ NB	BPA+ : Christian	Pre-Course Response	Adj R-squared	Sign of Beta Indicating Less Cisheteronormative Assumption
Sex	Collective	**-3.583**	**-4.267**	**2.312**		**3.043**			**0.421**	0.328	Negative
	1	**-1.156**	**-1.523**	0.476		0.895			**0.431**	0.245	Negative
	2	**-0.536**	-0.617	0.495	0.128	0.590			**0.503**	0.281	Negative
	3	**-0.573**	**-0.701**	**0.806**					**0.444**	0.263	Negative
	4	**-1.114**	**-1.251**	0.518		**1.347**			**0.195**	0.111	Negative
	5	**0.114**	0.053						**0.329**	0.124	Positive
Sexuality	Collective	1.132	**-2.802**	**2.816**	**4.685**			**-7.358**	**0.735**	0.408	Negative
	1			0.420					**0.372**	0.164	Negative
	2	0.028	**-1.241**		**1.133**	1.155		**-1.463**	**0.364**	0.212	Negative
	3	-0.546	-0.651						**0.407**	0.227	Negative
	4	**0.132**	0.145		-0.061	-0.132			**0.443**	0.299	Positive
	5	0.681	**-1.019**	1.081		0.773	-1.072		**0.472**	0.230	Negative
	6	**1.206**		0.807			-1.150		**0.450**	0.258	Negative
	7	0.803			**1.169**			**-1.530**	**0.413**	0.154	Negative

	8		-0.388						**0.419**	0.171	Negative
	9			0.554					**0.413**	0.172	Negative
	10	0.255	**-0.852**		0.759			**-1.374**	**0.205**	0.054	Negative
	11	-0.477	-0.377						**0.486**	0.230	Negative
Normativity	Collective								**0.263**		Positive
	1			0.219					**0.169**	0.079	Positive
	2	-0.099		0.392	**-0.938**			**0.816**	**0.250**	0.140	Positive
	3		**-0.544**						**0.577**	0.429	Negative*
	4		**0.588**						**0.523**	0.293	Positive
	5								**0.445**	0.173	Positive
	6								**0.446**	0.172	Positive
	7	0.117	**0.826**		-0.116			0.6022	**0.577**	0.409	Positive
	8	0.057	**-0.760**		0.361			**-0.9966**	**0.545**	0.335	Negative*
	9	-0.590	-0.080	-0.153		**0.735**	0.570			0.068	Positive

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Table 5: Pre-course Effects of Identity on Belonging.

Results of the ANCOVA models for collective results of pre-course survey sense of belonging questions. Blank squares were excluded from the model based on our AIC backward stepwise model selection process. Bolded betas are significant, and colors indicate direction of significance. Purple indicates that the group of interest expressed greater sense of belonging and yellow indicates that the group of interest expressed lower sense of belonging than their respective reference group. *Sign of beta indicating less intended outcome.

Category	Question	LGBTQ+	Women/NB	Christian	Race (PEER)	Adj R-squared	Intended direction*
Belonging in Course	Collective	-0.854				0.009	Positive
Belonging in Biology	Collective	**-1.528**				0.025	Positive

Table 6: Post-course Effects of Identity on Belonging.

Results of the ANCOVA models for collective results of post-course survey sense of belonging questions. Blank squares were excluded from the model based on our AIC backward stepwise model selection process. Bolded betas are significant, and colors indicate direction of significance. Purple indicates a modeled effect indicating lesser cisheteronormative assumptions and yellow indicates a modeled effect indicating greater cisheteronormative assumptions than their respective reference group. To determine whether the reference or non-reference group drove patterns of interaction terms, models of significant interactions are presented in Figure 2. *Sign of beta indicating less intended outcome.

Category	Question	BPA+	LGBTQ+	Women /NB	Christian	Race (PEER)	BPA+ x LGBTQ+	BPA+ : Women/ NB	BPA+ : Christian	BPA+ x Race (PEER)	Pre-Course Response	Adj R-squared	Intended Direction
Belonging in Course	Collective				-1.349						**0.638**	0.096	Positive
Belonging in Biology	Collective	-0.796	-1.181		-0.680		**2.934**				**0.347**	0.102	Positive

Figure 1: Change in survey responses by course type

Box and whisker plots of median, interquartile range, and total range excluding outliers for all questions in which BPA treatment was significant in the model. Plots depict the difference between a student's post-course response minus pre-course response to visualize changes in student response scores. For the top plot of Likert scale questions (Strongly Agree to Strongly Disagree), a negative number indicates a shift towards "Disagree," and a positive number indicates a shift in attitude towards "Agree" after having taken the course. Arrows on the y-axis indicate the intended direction of the intervention, indicating that students shifting in that direction would hold a less cisheteronormative view. For the bottom plot of proportional questions (0% to 100%), a negative number indicates a shift towards "0%," and a positive number indicates a shift in attitude towards "100%" after having taken the course.

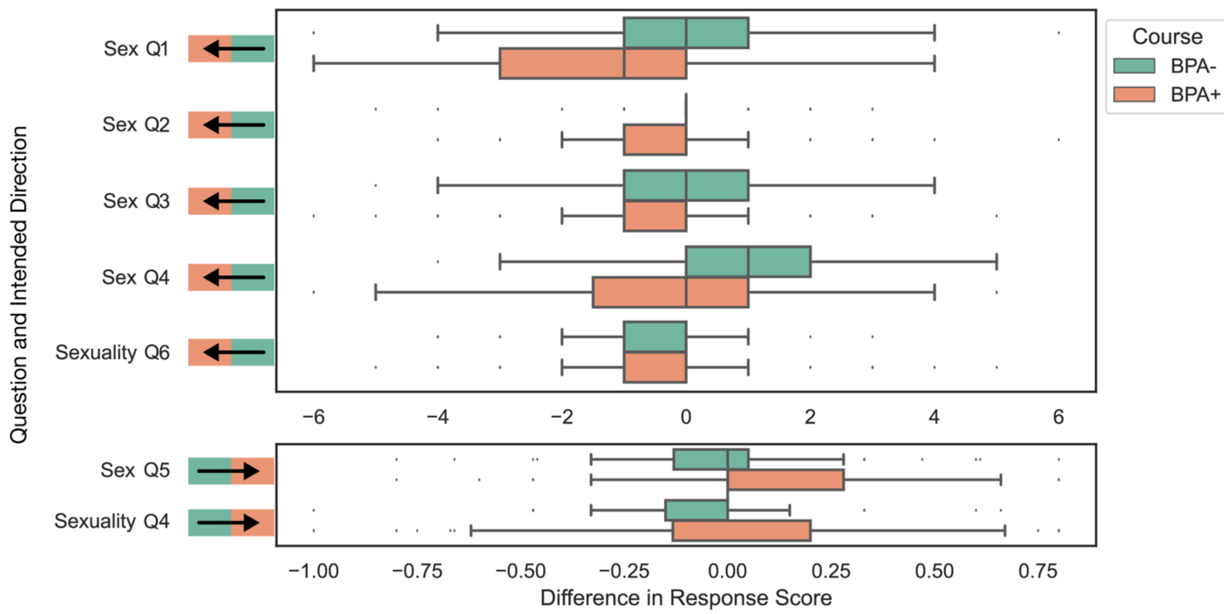

Figure 2: Effect of Course Type on Sense of Belonging in the Field of Biology for LGBTQ+ Students

Model fit of post-course sense of belonging in the field of biology by BPA treatment and LGBTQ identity. A more negative number indicates a lower sense of belonging and a more positive number indicates a higher sense of belonging in the field of biology.