“Broadening Perspectives” Course Revisions Improve both LGBTQ+ Student Experiences and non-LGBTQ+ Students’ Content Comprehension

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Abstract

Content in undergraduate biology courses, including animal behavior 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 biology have a lower sense of belonging than their peers. As such, we developed six activities that aimed to expand the representation of marginalized perspectives in the curriculum of an online undergraduate animal behavior course, with a specific focus on topics relating to sex, gender, and sexuality. We assessed the impact of the revisions on student perceptions of concepts in the field of animal behavior and on students’ sense of belonging using a pre and post survey in both an unrevised and revised version of the course. We found that when compared to their non-LGBTQ+ peers, LGBTQ+ students enter the course with a lower sense of belonging in the field of biology, but a better understanding of many concepts in the field of animal behavior that are influenced by cultural biases associated with sex, gender, and sexuality. We also found that our revisions improved the sense of belonging in the field of biology for LGBTQ+ undergraduates. Our revisions improved student comprehension of many animal behavior concepts of interest, such as the prevalence and importance of homosexuality in many animal species. We demonstrate the importance of highlighting marginalized perspectives in undergraduate biology curricula for undergraduate experiences, and we emphasize the role of early career scientists in curriculum development.

Introduction

Efforts to make undergraduate classrooms more inclusive and affirming for LGBTQ+ students are urgently needed. The percentage of the population of the United States that identifies as LGBTQ+ doubled over the past decade, from 3.5% in 2012 to 7.2% in 2022 (Jones 2022). This number is inversely correlated with age, with 19.7% of Generation Z adults (those between the ages of 18 and 25 in 2022) and 11.2% of millennials (those between the age of 26 and 41 in 2022) identifying as LGBTQ+. A traditional incoming undergraduate in 2023 at 18 years old would have been born in 2004, just one year after anti-sodomy laws were ruled federally unconstitutional. This individual would have been 7 years old when "Don't Ask, Don't Tell" was repealed, 11 years old when the Supreme Court federally protected the right to marriage for same-sex couples, and 16 years old when the Supreme Court protected LGBTQ+ employees from discrimination. Undergraduate students in the United States today 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 United States 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 US. In 2021 and 2022, that number rose to 154 and 180, respectively. As of April 18th, 2023, 467 bills have been introduced that aim to restrict LGBTQ+ rights (Choi 2023, ACLU 2023). Much of this anti-LGBTQ+ legislation is targeted directly at the school experience, and all of it has the potential to negatively impact the mental health of LGBTQ+ individuals (Horne et al. 2022) and their academic performance (Fields and Min Wotipka 2022), even for legislation that does not directly affect school experiences.

The need for more inclusive and affirming undergraduate experiences is is particularly important in the context of Science, Technology, Engineering, and Math (STEM) (CITE). LGBTQ+ undergraduates are less likely to major in Science, Technology, Engineering, and Mathematics (STEM) and are more likely to leave STEM majors than their non-LGBTQ+ peers (Greathouse et al., 2018, Hughes 2018, Maloy et al. 2022). Notably, these patterns differ between identities within the LGBTQ+ umbrella and are affected by other intersectional identities (Sansone and Carpenter 2020). Multifaceted stigmas are likely partially responsible for these trends (Freeman 2020, Palmer et al. 2021). LGBTQ+ students report experiencing feelings of alienation due to classroom climate and are selective about their decision to come out in the classroom (Cooper and Brownell 2016). In addition to the potentially unfriendly environment of science courses toward LGBTQ+ students, recent research suggests that content may also be partially responsible for LGBTQ+ students' lack of belonging, particularly in biology (Casper et al., 2022).

Stigmatization against lesbian, gay, bisexual, transgender, and queer (LGBTQ+) identities affects what college instructors choose to teach across many undergraduate fields of study, including biology (Marsh et al. 2022). Some professors may avoid teaching stigmatized subjects (Eickhoff 2021), but often even well-intentioned professors are limited by subject availability in textbooks and research papers (King et al. 2021). 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). They highlighted examples related to humans, but also of plant and animal diversity, and expressed frustration that their peers uncritically accepted the binary teachings of the professors.

Sub-fields of biology are particularly 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 our ability to develop a full understanding of the true nature of animal behavior (Roughgarden 2013, Monk et al. 2019). Undergraduate animal behavior curricula often teaches about sexual selection, Darwin's proposed sex roles, and sexed-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, 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. This field is taught in many undergraduate biology programs as the field of 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 United States (Dona et al. 2020, Tang-Martinez 2020b). Systemic bias and discrimination affects 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).

Efforts to enhance belonging of LGBTQ+ individuals must be considered in the context of the whole class, which includes students of varied identities (Busch et al. 2022). Research suggests that most students may benefit from such efforts, with women and LGBTQ+ students experiencing disproportionate benefits (Busch et al., 2022). However, there is concern that religious individuals might negatively respond to these efforts to improve the belonging of LGBTQ+ students, particularly as Christian students feel a sense of stigmatization against their religious identity in biology classrooms (Barnes et al. 2021) and as Christian students often, but certainly not always, hold anti-LGBTQ+ beliefs (Worthen 2017).

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 in biology courses, 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, no curriculum adaptations have been formally evaluated to test the impact on all students and more specifically LGBTQ+ students.

Current Study

To address this gap in the literature, we set out to expand the content of a large-enrollment online animal behavior course curriculum taught at a large R1 Hispanic Serving Institution in the Southwest, United States to correct for the historical exclusion of the perspectives of LGBTQ+ people, people of color, and women. We focused most of our efforts on expanding the course's coverage of topics related to gender and sexuality. 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 our additional course

modules. This survey aimed to uncover trends in student comprehension of topics related to gender and sexuality and in the sense of belonging for LGBTQ+ students.

We developed a set of Broadening Perspective Activities (BPAs) with the intent to diversity the curriculum and ultimately enhance the sense of belonging of LGBTQ+ students, and to improve all students' understanding of concepts in the field of animal behavior that are affected by cultural biases relating to sex, gender, and sexuality. 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 these revisions might decrease the sense of belonging for some students, particularly for students with religious identities who already experience negative cultural conflict between their religious and STEM identities (Barnes et al. 2021).

Our specific research questions were:

1. To what extent do undergraduate students of varying identities (LGBTQ+, gender, and religious) 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 (protocol number HRP-503a). D. Jackson was funded to perform the curriculum redesign work over the summer of 2021 through ASU's Inclusive Teaching Fellowship. This work was done in consultation with former Teaching Assistants from the summer of 2020 (D. Jackson, A. Biera, C. Hawley, J. Lacson, E. Webb), the professor of the course (K. McGraw), and an Instructional Designer (L. Ott) in the School of Life Sciences Teaching Innovation Center at Arizona State University.

Study Context

Animal Behavior is offered as an online course over the summer and runs for approximately 5 weeks. We studied this course over 3 iterations, Summer 2021 B (185 students), Summer 2022 A (61 students), and Summer 2022 B (138 students). The first summer, we implemented the course without the addition of our Broadening Perspective Activities (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 identical. This is an online course with previously recorded lectures and predeveloped activities, and it was taught by the same professor each time. We lump student responses for both BPA+ courses for all analyses. We filtered the data to only include only students who took both the pre-survey and the post-survey, and to exclude any student who took both the unrevised and the revised course. After filtering, we had a total of 200 responses, with 69 student responses for the BPA- course (37.3% response rate) and 131 student responses for the BPA+ course (66% response rate).

We designed 6 BPAs to add to the online animal behavior course (All BPAs are included in the Supplemental Material). Each activity followed a module in the course on the same topic and aimed to

expand the students' perspectives beyond the standard course content, which is a combination of textbook-type readings, video lectures, interactive visual and group activities, and self-assessment questions. Students could choose to complete 4 of these 6 activities. Some BPAs addressed issues relating to oppression, abuse of power, racism, sexual assault, transphobia, homophobia, and eugenics. We felt that allowing students to choose to opt out of engaging in particular topics that may challenge their emotional well-being was integral to creating an intervention aimed at promoting their belonging (CITE).

The BPAs aimed to meet three goals: 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 Online 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. 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 are asked additional reflection questions that intend 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. They were then provided with reading material that discussed the connections between one of the prominent male European animal behaviorists who was highlighted in the 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 learning content on this topic, but whose early contributions to the field were comparable to the scientists highlighted in the textbook, despite facing numerous discriminatory barriers due to his racial identity (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 learning content 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 that highlighted the ways that homosexual behavior in animals can manifest and play key roles in their social lives (Bagemihl 1999, Roughgarden 2013). Next, they read an excerpt *Evolution's Rainbow: Diversity, gender, and sexuality in nature and people* (Roughgarden 2013) that directly refuted many stereotypes about animal behaviors that are derived from cultural norms spread through European colonialism around sex, gender, and sexuality. Finally, they were asked to reflect on the ways that biologists define sex, their culture defines sex, and how they as an individual would define sex.

3. *Methodology.* Students are asked to reflect on the objectivity of the methods that they have been using to study animal behaviors in this class as part of an experiential project – the Behavior Observation Modules – that is threaded through the semester. They are 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 to access the resources needed to direct their own research programs in the mid-to-late 1900s, including the introduction of novel methodologies. They are asked to reflect on the notion of objectivity in science and on the influence of culture on the scientific process.
4. *Hermaphroditism.* Students are 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 are then provided with another excerpt from the book *Evolution's Rainbow* (Roughgarden 2013), which discusses the occurrence, mechanisms, and functions of hermaphroditism and intersexuality among animals. This reading discusses 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." They are 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 listen 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 are 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 are also asked to consider 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 are asked to consider the cultural influences that shape these understandings. They begin by reading an excerpt that details how the X and Y chromosomes came to be called "sex chromosomes" and the arguments both for and against this classification. They are 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 textbook for this course. Then, students are 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 isn't) incorporated into policy making decisions (Science Vs 2022). For either reading, they are 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 designed pre- and post-course survey instruments to evaluate the specific impacts of these revisions on student abilities to learn animal behavior concepts that might be affected by cultural norms around sex, gender, and sexuality, as well as the sense of belonging of students of different identities. This survey had 25 close-ended questions, 10 sense of belonging questions, and 15 demographic questions. Before finalizing the instrument, A. Biera, E. Webb, and D. Jackson 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. Students took the survey both at the start and at the end of the course, which allowed us to compare the effect of the course with and without the BPAs on their responses.

We developed survey questions within three categories summarizing the aims of adding the BPAs to the course:

1. Sex Category: 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.
2. Sexuality Category: After having taken the course, fewer students will apply western cisheteronormative assumptions to animal behaviors than they did before taking the course.
3. Normativity Category: 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.
4. Belonging Category: After taking the course, students will express a greater sense of belonging in both the course and in the broader field of biology.

We also included survey questions on student demographic information, including LGBTQ+, gender, religious, and racial identities to allow us to test the effects of the BPA activities on students of different identities.

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 items to measure different 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, Slightly Disagree, Disagree, Strongly Disagree, and I Am Unsure. 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.

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 items to measure different concepts relating to sexuality (Table 1). Two 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 Sex questions, and one (Sexuality Question 3) followed the same proportion format as Sex Question 5.

Recognition of the influence of culture on scientific processes

We developed 9 items 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 students' 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 Sex questions.

Student sense of belonging

We implemented 5 items to test students' sense of belonging in the course and 5 items to test their sense of belonging in the field of Biology following methods from (CITE). All of these questions followed the same likert scale format as the Sex questions.

We also included survey questions on student demographic information, including LGBTQ+, gender, religious, and racial identities to allow us to test the effects of the BPA activities on students of different identities. We offered students 2 extra credit points to take the same survey in the first as well as 2 points to take it again in the last week of the class (~1.6% of the total course points).

Analyses

All analyses were conducted in R with the MASS and lm.beta packages or Python with the Pandas, SciPy, NumPy, statsmodels, scikit-learn, and Matplotlib packages (CITE packages). The code used for the data processing and analysis can be accessed here: https://github.com/dannyjackson/StudentSurveyAnalyses. Likert scale student responses were coded into numerical values such that Strongly Disagree = -3, Disagree = -2, Slightly Disagree = -1, Slightly Agree = 1, Agree = 2, Strongly Agree = 3, and I Am Unsure = 0. Student responses of "I Am Unsure" to either of the proportional questions were coded as NA values.

We lumped 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+; Not Man (Woman, Non-Binary, Other) 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 due to small sample sizes, we were not able to. Based on the definition of PEER

identities, Asian students and white students were lumped to form the “not PEER” group. We treated Christian as the marginalized identity because studies have shown that Christian students can feel alienated in undergraduate biology courses (Barnes et al. 2021). We also considered lumping Jewish and Muslim students with Christian students since these religious identities might operate similarly in response to religious stigma in a biology classroom. However, our investigation addresses stigma related to gender identity and sexuality, and due to lack of research on how students of these different identities might respond to issues along this axis of stigma, we decided to consider only Christianity as our religious identity of interest, and we hope that future research will study populations with larger sample sizes of students of other religious identities on this topic. Responses of each student to the five questions that address sense of belonging in the course were summed, as were their responses to the five questions that address sense of belonging in the field of biology.

Regression analysis:

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 (Q34) excluded pre-course survey responses.

Results

Participant Demographics.

LGBTQ+ students made up 26.1% of survey responses in the BPA- course and 26.72% of those from the BPA+ course (Table 2). Of the total LGBTQ+ students across all courses, 7 identified as lesbian, 8 as gay, 24 as bisexual, 3 as transgender, 10 as queer, 5 as asexual, 5 as pansexual, 2 as non-binary, 1 as aromantic, 1 as biromantic, and 1 as confused. Many students identified as more than one of the above categories. Students of any gender other than a man made up 84.06% of the survey responses from the BPA- course and 76.34% of those from the BPA+ course. Students of a Christian identity made up 46.38% of the BPA- course and 34.35% of the BPA+ course. Students of a PEER racial identity made up 26.09% of the BPA- course and 25.19% of the BPA+ course. All demographics are reported in Supplemental Table 1 and 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, gender, and sexuality

The full results of the linear models of each survey question are presented in Table 3. LGBTQ+ identity had an effect on the models of students' prior knowledge for 12 questions: Sex 1-3, Sexuality 1-5 and 11, and Normativity 3, 7, and 8 (Sex: Q1: $F_{1,198} = 19.92$, $p < 0.001$, Q2: $F_{1,198} = 19.23$, $p < 0.001$, Q3: $F_{1,198} = 26.13$, $p < 0.001$, Sexuality Q1: $F_{2,197} = 8.547$, $p < 0.001$, Q2: $F_{1,198} = 4.839$, $p = 0.029$, Q3: $F_{2,197} = 21.15$, $p < 0.001$, Q4: $F_{1,197} = 13.53$, $p < 0.001$, Q5: $F_{1,198} = 5.756$, $p = 0.017$, Q11: $F_{1,197} = 2.385$, $p = 0.095$, Normativity: Q3: $F_{2,197} = 10.05$, $p < 0.001$, Q7: $F_{3,195} = 10.10$, $p < 0.001$, Q8: $F_{2,196} = 14.75$, $p < 0.001$). LGBTQ+ students were more likely than their non-LGBTQ+ peers to demonstrate resistance to strict sex categories (Sex Q1) and to demonstrate a nuanced understanding of sexed physiologies (Sex Q2: ß = -0.986, $p < 0.001$, CI = [-1.430, -0.543], Sex Q3: ß = -1.128, $p < 0.001$, CI = [-1.563, -0.693]). They were also more likely to recognize contextual evolutionary value of homosexual behaviors, sexual transitions, and non-monogamy in animals (Sexuality Q1: ß = -0.746, $p = 0.001$, CI = [-1.177, -0.314]), Q2: ß = -0.548, $p = 0.029$, CI = [-1.038, -0.057]), Q3: ß = -1.524, $p < 0.001$, CI = [-2.073, -0.975]), Q5: ß = -0.565, $p = 0.017$, CI = [-1.029, -0.101]), to predict a higher rate of homosexuality in animals (Sexuality Q4: ß = 0.191, $p < 0.001$, CI = [0.090, 0.293]), and to resist applying gender norms to animal behaviors (Sexuality Q11: ß = XXX, $p = 0.045$, CI = [-1.097, -0.013]). They were also more likely than their peers to acknowledge the difference between sex and gender (Normativity Q3: ß = -0.856, $p = 0.003$, CI = [-1.421, -0.291]), and to acknowledge that LGBTQ+ identities and associated behaviors are natural and widespread throughout the animal world (Normativity Q7: ß = 0.911, $p = 0.001$, CI = [0.357, 1.465]), Q8: ß = -0.845, $p = 0.002$, CI = [-1.378, -0.312]).

Gender identity had an effect on students' prior knowledge for 3 questions (Sexuality Q7: $F_{2,196} = 4.269$, $p = 0.015$; Q8: $F_{1,198} = 4.158$, $p = 0.043$; Q9: $F_{\#} = \#$, $p = \#$). Students of any a gender other than man were more likely to believe that biological parents are better caretakers than non-biological parents (Sexuality Q7: ß = -0.6149, $p = 0.041$, CI = [-1.203, -0.027]; Q8: ß = -0.567, $p = 0.043$, CI = [-1.115, -0.019]), and that animal males are more likely to cheat than females (Sexuality Q9: ß = 0.643, $p = 0.028$, CI = [0.069, 1.218]).

Religious identity had an effect on students' prior knowledge for 5 questions (Sex Q4: $F_{1,198} = 7.325$, $p < 0.007$, Normativity Q3: $F_{2,197} = 10.05$, $p < 0.001$, Q5: $F_{2,197} = 7.959$, $p < 0.001$, Q7: $F_{3,195} = 10.10$, $p < 0.001$, Q8: $F_{2,196} = 14.75$, $p < 0.001$). Christian students were more likely than their peers to assume that sex categories implied universal truths about species traits and behaviors (Sex Q4: ß = 0.664, $p = 0.007$, CI = [0.180, 1.148]. They were also more likely than their non-Christian peers to believe

that sex and gender are equivalent (Normativity Q3: ß = 0.557, p = 0.033, CI = [0.045, 1.069]), to believe that the scientific definition of sex includes social norms, behaviors, and roles (Normativity Q5: ß = 0.837, p = 0.004, CI = [0.274, 1.400]), and to believe that LGBTQ+ identities and associated behaviors are not natural and are not found in non-human animals (Normativity Q7: ß = -0.616, p = 0.015, CI = [-1.112, -0.119], Q8: ß = 0.773, p = 0.002, CI = [0.288, 1.257]).

Finding 2: Students enrolled in the BPA+ course demonstrate higher post-course knowledge with respect to concepts relating to sex, gender, and sexuality

The full results of the linear models of each survey question are presented in Table 4. The course that students took had an effect on students' post-course responses for 10 questions (Figure 1): Sex 1-5, Sexuality 3, 4, 6, 7, and 11. (Sex Q1: $F_{5,193} = 13.85$, $p < 0.001$, Q2: $F_{6,193} = 13.97$, $p < 0.001$, Q3: $F_{4,194} = 18.69$, $p < 0.001$, Q4: $F_{5,194} = -1.114$, $p < 0.001$, Q5: $F_{3,195} = 10.35$, $p < 0.001$, Sexuality Q3: $F_{3,196} = 20.48$, $p < 0.001$, Q4: $F_{5,191} = 17.69$, $p < 0.001$, Q6: $F_{4,193} = 18.17$, $p < 0.001$, Q7: $F_{4,195} = 10.03$, $p < 0.001$, Q11: $F_{3,196} = 20.77$, $p < 0.001$). For 8 of the 10 questions, student responses moved in the intended direction. 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: ß = -1.156, p < 0.001, CI = [-1.792, -0.520]), to demonstrate a nuanced understanding of sexed physiologies (Sex Q2: ß = -0.536, p = 0.020, CI = [-0.988, -0.084], Sex Q3: ß = -0.573, p = 0.011, CI = [-1.011, -0.135]), to assume that sex categories do not imply universal truths about species traits and behaviors (Sex Q4: ß = -1.114, p < 0.001, CI = [-1.666, -0.561]), and to predict a higher proportion of animal species that transition between sexes in their lives (Sex Q5: ß = 0.114, p = 0.001, CI = [0.046, 0.183]). They were also more likely to resist applying gender norms to animal behaviors (Sexuality Q11: ß = -0.477, p = 0.033, CI = [-0.914, -0.039]), to recognize contextual evolutionary value of sexual transitions in animals (Sexuality Q3: ß = -0.546, p = 0.027, CI = [-1.031, -0.061]), and to predict a higher proportion of animals that exhibit homosexual behaviors (Sexuality Q4: ß = 0.132, p = 0.004, CI = [0.043, 0.220]). However, for 2 of the 10 questions, student responses moved in the opposite of the intended direction. Students who took the BPA+ course were more likely than their peers in the BPA- course to believe parental care is universal (Sexuality Q6: ß = 1.206, p = 0.002, CI = [0.443, 1.969]) and to believe that biological parents are better caretakers than non-biological parents (Sexuality Q7: ß = 0.803, p < 0.021, CI = [0.123, 1.483]),

Finding 3: Student identities (LGBTQ+, gender, and religious) predict undergraduate students' post-course knowledge with respect to concepts relating to sex, gender, and sexuality

The full results of the linear models of each survey question are presented in Table 4. Regardless of course type, LGBTQ+ identity had an effect on the models of students' post-course responses for 12 questions: Sex 1, 3, and 4, Sexuality 2-5 and 10, and Normativity 3, 4, 7, and 8 (Sex: Q1: $F_{5,193} = 13.85$, $p < 0.001$, Q3: $F_{4,194} = -0.701$, $p = 0.007$, Q4: $F_{5,194} = 5.974$, $p < 0.001$, Sexuality Q2: $F_{6,190} = 9.777$, $p < 0.001$, Q3: $F_{3,196} = 20.48$, $p < 0.001$, Q4: $F_{5,191} = 17.69$, $p < 0.001$, Q5: $F_{6,191} = 10.80$, $p < 0.001$, Q10: $F_{5,193} = 3.280$, $p = 0.007$, Normativity: Q3: $F_{2,197} = 75.86$, $p < 0.001$, Q4: $F_{2,197} = 42.22$, $p < 0.001$, Q7: $F_{5,193} = 28.45$, $p < 0.001$, Q8: $F_{5,192} = 20.81$, $p < 0.001$). Gender identity had an effect on students' post-course responses for 5 questions (Sex Q2: $F_{6,193} = 13.97$, $p < 0.001$; Q3: $F_{4,194} = 18.69$, $p < 0.001$; Sexuality Q1: $F_{2,196} = 20.47$, $p < 0.001$; Q5: $F_{6,191} = 10.80$, $p < 0.001$; Q6: $F_{4,193} = 18.17$, $p < 0.001$). Religious identity had an effect on students' post-course responses for 3 questions (Sexuality Q2: $F_{6,190} = 9.777$, $p < 0.001$; Q7: $F_{4,195} = 10.03$, $p < 0.001$; Normativity Q2: $F_{5,194} = 7.463$, $p < 0.001$).

The effect of LGBTQ+ identity on post-survey answers followed similar trends to the pre-course survey, but differed in several ways. Unlike the trends prior to taking the course, LGBTQ+ students were more likely than their non-LGBTQ+ peers to assume that sex categories implied universal truths about

species traits and behaviors (Sex Q4: ß = -1.251, p =0.006, CI = [-2.131, -0.371]), they were more likely to recognize contextual evolutionary value to polyandry (Sexuality Q10: ß = -0.852, p = 0.015, CI = [-1.535, -0.168]), and they were more likely to believe that it is important to distinguish between sex and gender when talking about biology (Normativity Q4: ß = 0.588, p = 0.005, CI = [0.178, 0.998]). Compared to the pre-course survey trends, LGBTQ+ identity no longer had a significant effect on students' ability to demonstrate a nuanced understanding of sexed physiologies (Sex Q2: ß = -0.617, p =0.099, CI = [-1.350, 0.117]), to recognize contextual evolutionary value of homosexual behaviors (Sexuality Q1), or their ability to resist applying gender norms to animal behaviors (Sexuality Q11: ß = -0.377, p = 0.113, CI = [-0.844, 0.090]).

Gender identity did not have an effect on any of the same survey questions between pre- and post-course surveys. However, similar to the the pre-course survey, gender identity had an effect on post-survey questions related to non-monogamy and parental care (Sexuality Q5: $F_{6,191} = 10.80$, $p < 0.001$, Q6: $F_{4,193} = 18.17$, $p < 0.001$). In the post-course survey, students of any gender other than man were more likely to not recognize the contextual evolutionary value of non-monogamy in animals Q5: ß = 1.081, p = 0.022, CI = [0.161, 2.002]) and to believe parental care is universal (Sexuality Q6: ß = 0.807, p = 0.028, CI = [0.089, 1.524]). The post-course survey also demonstrated several new trends related to gender identity for questions Sex 2, 3, and Sexuality 1 (Sex Q2: $F_{6,193} = 13.97$, $p < 0.001$; Q3: $F_{4,194} = 18.69$, $p < 0.001$; Sexuality Q1: $F_{2,196} = 20.47$, $p < 0.001$). Students of any gender other than man were more likely to apply gender norms to their understanding of sexed physiologies (Sex Q2: ß = 0.495, p = 0.034, CI = [0.038, 0.951], Sex Q3: ß = 0.806, p = 0.002, CI = [0.293, 0.595]), and to not recognize the contextual evolutionary value of homosexual behaviors in animals (Sexuality Q1: ß = 0.420, p = 0.038, CI = [0.024, 0.817]).

Religious identity also did not have an effect on any of the same survey questions between pre- and post-course surveys, and had a new effect on Sexuality 2, 7, and Normativity 2 (Sexuality Q2: $F_{6,190} = 9.777$, $p < 0.001$; Q7: $F_{4,195} = 10.03$, $p < 0.001$; Normativity Q2: $F_{5,194} = 7.463$, $p < 0.001$). Christian students were more likely than their non-Christian peers to not recognize contextual evolutionary value of sexual transitions (Sexuality Q2: ß = 1.133, p = 0.003, CI = [0.401, 1.866]), to believe that biological parents are better caretakers than non-biological parents (Sexuality Q7: ß = 1.169, p = 0.006, CI = [0.334, 2.004]), and to believe that our cultural biases do not limit our ability to understand the natural world (Normativity Q2: ß = -0.938, p = 0.001, CI = [-1.490, -0.387]).

Finding 4: Student identities (LGBTQ+, gender, and religious) interact with BPAs to influence students' post-course knowledge

The full results of the linear models of each survey question are presented in Table 4. The interaction of course and LGBTQ+ identity had an effect on students' post-course responses to 3 questions (Sex Q4: $F_{5,194} = 5.974$, $p < 0.001$, Sexuality Q2: $F_{6,190} = 9.777$, $p < 0.001$); Normativity Q9: $F_{6,193} = 3.412$, $p = 0.003$). 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: ß = 1.347, p = 0.014, CI = [0.274, 2.419]) and were more likely to recognize contextual evolutionary value of sexual transitions in animals (Sexuality Q2: ß = 1.155, p = 0.034, CI = [0.089, 2.220]) than their non-LGBTQ+ peers who took the BPA- course, while LGBTQ+ individuals showed no difference between courses on these subject. 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, while non-LGBTQ+ individuals demonstrated no difference (Normativity Q9: ß = 0.730, $p < 0.027$, CI = [0.083, 1.377]).

The interaction of course and gender identity had an effect on students' post-course responses to 1 question (Sexuality Q6: $F_{4,193} = 18.17$, $p < 0.001$). Students who identify as a man that took the BPA+ course were more likely to believe parental care is universal than their peers that identify as a man in the

BPA- course (Sexuality Q6: ß = -1.150, p = 0.008, CI = [-1.995, -0.304]). The course type had no effect on students of a gender identity other than man.

The interaction of course and religious identity had an effect on students' post-course responses to 5 questions (Sexuality Q2: $F_{6,190} = 9.777$, $p < 0.001$; Q7: $F_{4,195} = 10.03$, $p < 0.001$, Q10: $F_{5,193} = 3.280$, $p = 0.007$, Normativity Q2: $F_{5,194} = 7.463$, $p < 0.001$, Q8: $F_{5,192} = 20.81$, $p < 0.001$. Christian students who took the BPA+ course were less 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: ß = -1.463, p = 0.002, CI = [-2.404, -0.523], Q10: ß = -1.374, p = 0.029, CI = [-2.604, -0.143]). Christian students who took the BPA+ course were more likely to believe that our cultural biases limit our ability to understand the natural world and to acknowledge that LGBTQ+ identities and associated behaviors are natural and widespread throughout the animal world (Normativity Q2: ß = 0.816, p = 0.021, CI = [0.122, 1.509], Q8: ß = -0.997, p = 0.031, CI = [-1.899, -0.095]) than their Christian peers who took the BPA- course, while course type had no effect on non-Christians no effect. 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, while course type had no effect on Christian students for this subject (Sexuality Q7: ß = -1.530, p = 0.005, CI = [-2.583, -0.476]).

Finding 5: Do the course revisions affect students' sense of belonging across LGBTQ+, gender, religious, and racial identities?

LGBTQ+ Students Enter the Course With a Lower Sense of Belonging in Biology

Prior to taking the course, LGBTQ+ identity had an effect on students' sense of inclusion in the field of biology (Belonging Q2: $F_{1,198} = 6.055$, $p = 0.015$) but did not have an effect on their sense of inclusion in the course itself (Belonging Q1: $F_{1,198} = 2.905$, $p = 0.090$) (Figure 2, Table 3). LGBTQ+ students expressed a lower sense of belonging than their non-LGBTQ+ peers in the field of biology (Belonging Q2: ß = -1.528, p = 0.015, CI = [-2.752, -0.303]).

BPAs Improve LGBTQ+ Students' Sense of Belonging in Biology

The interaction between LGBTQ+ identity and the course type had an effect on students' sense of inclusion in the course after having taken this course (Figure 3, Belonging Q2: $F_{5,194} = 5.508$, $p < 0.001$, Table 4). The addition of the BPA to the course improved LGBTQ+ students' sense of belonging in the field of biology but had no effect on non-LGBTQ+ students' sense of belonging (Belonging Q2: ß = 2.934, p = 0.037, CI = [0.197, 0.498]). None of the identity categories that we investigated had an effect on students' sense of inclusion in the course after having taken this course (Belonging Q1: $F_{2,197} = 11.57$, $p < 0.001$).

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 overwhelming positive effects of the curriculum addition. We demonstrate a path for other instructors to improve the experiences of LGBTQ+ students in their own courses. We also highlight the importance of paid graduate student curriculum development experiences with staff and faculty support.

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. LGBTQ+ students are also more likely to feel that they do not belong in the field of Biology. Importantly, we found that adding content to a course that discusses the complexity of sex, gender, and sexuality has a positive effect on LGBTQ+ students' sense of belonging in Biology, and does not have a negative impact on students of marginalized gender, religious, or racial identities. This demonstrates both an urgent need for curriculum interventions on behalf of LGBTQ+ undergraduates and an effective approach for developing those interventions in a short time frame. The curriculum development was performed over a single summer, mainly by a single graduate student but with the support of a team of graduate students, an instructional designer, and the faculty in charge of the course. The graduate student was already familiar with the course and entered the experience with a clear understanding of the changes that needed to be made, and additional time would need to be allotted for graduate students who might do similar work on an unfamiliar course. We also created a tool for measuring the impact of course changes on student understandings of biology concepts related to sex, gender, and sexuality.

The addition of our Broadening Perspectives Activities 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 themes of both sex and sexuality. 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 statement, our BPAs had no impact. But for the second and third statements, the addition of our BPAs improved, respectively, Christian and non-LGBTQ+ student scores. It is remarkable that some students shifted their paradigms in response to these activities across all identities. 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 course taken, non-LGBTQ+ students lagged behind their LGBTQ+ peers on 12 concepts. When taking the BPA+ version of the course compared to the BPA- course, non-LGBTQ+ students improved on two important concepts. 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. We hope that these students will carry this feeling forward throughout their career, and will feel empowered to contribute their voices to the various STEM fields that they will enter.

The effects of gender identity on student knowledge and the interaction between gender and our BPAs were very unexpected. Students of marginalized gender identities – any identity other than "man" – were more likely to have culturally imposed beliefs about parental care and nonmonogamy. 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. None of our activities discussed parental care directly, and it is hard to understand the cause of this trend. However, a potential solution would be directly addressing cultural norms about both parental care and nonmonogamy in our future iterations of the course.

Likewise, our BPAs interacted with religious identities in complicated and sometimes undesirable ways. Christian students demonstrated an increase in the effect of cultural biases on their understanding of the value of sexual transitions in the animal world, as well as of polyandry. 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 both before and after taking our course. More research into how to resolve cultural conflicts between religious paradigms and biological science in an undergraduate course is needed to understand how to improve this trend.

Our surveys found no effect of gender, racial, or religious identities on students' sense of belonging. This is surprising, since numerous 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. 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.

Conclusions

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Figures

Table 1: Survey Questions.

These survey questions were given to students during the first and last week of their course. The sense of belonging questions were asked before all other questions to avoid priming students to think about our themes of interest before providing their responses. All other questions were delivered in a random order to students. All questions were presented with 6 point likert scale responses from “Strongly Disagree” to “Strongly Agree” with no 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.
1	The sex of an animal can be categorized as either male or female.
2	In any given pair of a male and a female, the male will have higher levels of testosterone than the female.
3	In any given pair of a male and a female, the female will have higher levels of estrogen than the male.
4	Two males of different species will have more in common with each other than a male and a female of different species.
5	Excluding insects, what proportion of animal species exist as more than one sex during their life?
	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
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.
3	Homosexual behaviors are not evolutionarily advantageous.
4	What proportion of sexual animal species exhibit homosexual behaviors?
5	Monogamous species have a greater evolutionary advantage over non-monogamous species.
6	All animals are cared for by their parents when they are young.
7	Any animal would be better off if it were raised by their biological parents than by other members of the same species.
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.
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.
10	Polygyny (1 male mating with multiple females) is always more evolutionarily advantageous than polyandry (1 female mating with multiple males).
11	More aggressive males produce more offspring than less aggressive males.
	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.
2	Our cultural biases limit our ability to understand the natural world.

3	Sex and gender mean the same thing.
4	It is important to distinguish between sex and gender when talking about biology.
5	The scientific understanding of sex includes social norms, behaviors, and roles associated with being a particular sex.
6	The scientific understanding of gender includes norms, behaviors, and roles associated with a particular gender.
7	LGBTQ+ identities and associated behaviors are natural in a biological sense.
8	The behaviors associated with LGBTQ+ identities are exclusive to humans, and are not represented in the animal world.
9	Studying the natural world influences my understanding of myself and other humans.
	Belonging Questions: After taking the course, students will have a higher sense of belonging in the course and in the field of biology.
1.1	I feel comfortable in BIO 331
1.2	I am a part of BIO 331
1.3	I am committed to BIO 331
1.4	I am supported by BIO 331
1.5	I am accepted in BIO 331
2.1	I feel comfortable in the Biology community
2.2	I am a part of the Biology community
2.3	I am committed to the Biology community
2.4	I am supported by the Biology community
2.5	I am accepted by the Biology community

Table 2: LGBTQ+ Demographics

Counts of students who identified as each LGBTQ+ identity. Students were able to select more than one identity.

Identity		Number of students who exclusively selected this identity	Number of students who selected this and at least one other identity
Lesbian		2	5
Gay		4	4
Bisexual		19	5
Transgender		1	2
Queer		4	6
Asexual		0	5
Decline to state		2	0
Other, please describe	Pansexual	4	1
	Non-binary	0	2
	Aromantic	0	1
	Biromantic	0	1
	Confused	0	1

Table 3: Pre-course Question Effects.

Results of the ANCOVA models for each question. Blank squares were excluded from the model based on our AIC backward stepwise model selection process. Bolded values are significant, and colors indicate if they were significant in the intended (purple) or the unintended (yellow) direction.

Question	Intercept	LGBTQ+	Gender	Religion	Adj R-squared
Sex_1	**1.1497**	**-1.244**			0.08681734
Sex_2	**1.4014**	**-0.9863**			0.08391353
Sex_3	**1.5238**	**-1.1276**			0.11211157
Sex_4	-0.1057			**0.6641**	0.0308034
Sex_5	**0.1169**		0.0618		0.0091447
Sexuality_1	**2.0412**	**-0.7457**	-0.4095		0.07050014
Sexuality_2	-0.2449	**-0.5476**			0.01892583
Sexuality_3	**0.9156**	**-1.5237**		0.372	0.16838291
Sexuality_4	**0.3033**	**0.1911**			0.05951362
Sexuality_5	**-0.6803**	**-0.565**			0.02334143
Sexuality_6	**-1.8115**			0.3569	0.00982034
Sexuality_7	**0.9839**	-0.4648	**-0.6149**		0.03181078
Sexuality_8	0.1429		**-0.5669**		0.01562367
Sexuality_9	-0.216	-0.3854	**0.6432**		0.01984542
Sexuality_11	**0.9926**	**-0.555**		-0.3649	0.01372591
Sexuality_10	0.381		0.5115		0.008458
Normativity_1	**1.67**				-2.22E-16
Normativity_2	**1.75**				0
Normativity_3	**-1.2827**	**-0.8558**		**0.5572**	0.08333752
Normativity_4	**1.3074**		0.4603	-0.3274	0.01545782
Normativity_5	0.0581	-0.4926		**0.8374**	0.06537083
Normativity_6	**1.4084**		0.3205	-0.2768	0.01471919
Normativity_7	**0.4923**	**0.9111**	0.5065	**-0.6155**	0.1211614
Normativity_8	**-1.0348**	**-0.8451**		**0.7726**	0.1219539
Normativity_9	**2.2276**			-0.2406	0.01066515

Belonging_1	**12.0612**	-0.8537			0.0094805
Belonging_2	**11.6599**	**-1.5278**			0.02477512

Table 4: Post-course Question Effects.

Results of the ANCOVA models for each question. Blank squares were excluded from the model based on our AIC backward stepwise model selection process. Bolded values are significant, and colors indicate if they were significant in the intended (purple) or the unintended (yellow) direction.

Question	Intercept	Course	LGBTQ+	Gender	Religion	Course:LGBTQ+	Course:Gender	Course:Religion	pre_Q
Sex_1	0.3986	**-1.1562**	**-1.5226**	0.4761		0.8954			**0.4313**
Sex_2	0.3623	**-0.5358**	-0.6167	**0.4947**	0.128	0.59			**0.5033**
Sex_3	0.1926	**-0.5731**	**-0.7008**	**0.8056**					**0.4437**
Sex_4	**0.7015**	**-1.1135**	**-1.2508**	0.5182		**1.3467**			**0.1948**
Sex_5	**0.0949**	**0.1144**	0.0532						**0.3293**
Sexuality_1	**0.6793**			**0.4202**					**0.3716**
Sexuality_2	**-0.6979**	0.028	**-1.2411**		**1.1334**	**1.1547**		**-1.4634**	**0.3642**
Sexuality_3	**0.714**	**-0.5463**	**-0.6512**						**0.4068**
Sexuality_4	**0.1328**	**0.1317**	**0.1454**		-0.061	-0.1315			**0.4425**
Sexuality_5	**-1.2915**	0.6812	**-1.0186**	**1.0811**		0.7734	-1.0718		**0.4718**
Sexuality_6	**-2.155**	**1.2061**		**0.8069**			**-1.1498**		**0.4496**
Sexuality_7	**-0.8619**	**0.8033**			**1.1689**			**-1.5295**	**0.4129**
Sexuality_8	**-0.4394**		-0.388						**0.4189**
Sexuality_9	-0.1062			0.5542					**0.4126**
Sexuality_11	**0.9145**	**-0.4765**	-0.3773						**0.4859**
Sexuality_10	0.0356	0.2547	**-0.8518**		0.7587			**-1.3738**	**0.2048**
Normativity_1	**1.694**			0.2193					**0.1693**
Normativity_2	**1.3959**	-0.0991		0.392	**-0.9383**			**0.8156**	**0.2498**
Normativity_3	**-0.6737**		**-0.544**						**0.5769**
Normativity_4	**0.6865**		**0.5884**						**0.5227**
Normativity_5	0.1188								**0.4448**
Normativity_6	**0.9663**								**0.4461**
Normativity_7	0.2717	0.1165	**0.8261**		-0.116			0.6022	**0.5771**
Normativity_8	-0.4725	0.0568	**-0.7603**		0.3605			**-0.9966**	**0.5454**

Normativity_9	**2.28**	-0.5903	-0.0798	-0.1531		**0.7348**	0.5704		
Belonging_1	3.0503				-1.3487				**0.6378**
Belonging_2	**8.2133**	-0.7961	-1.181		-0.6804	**2.9343**			**0.3474**

Figure 1: Change in survey responses by course type.

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. 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.

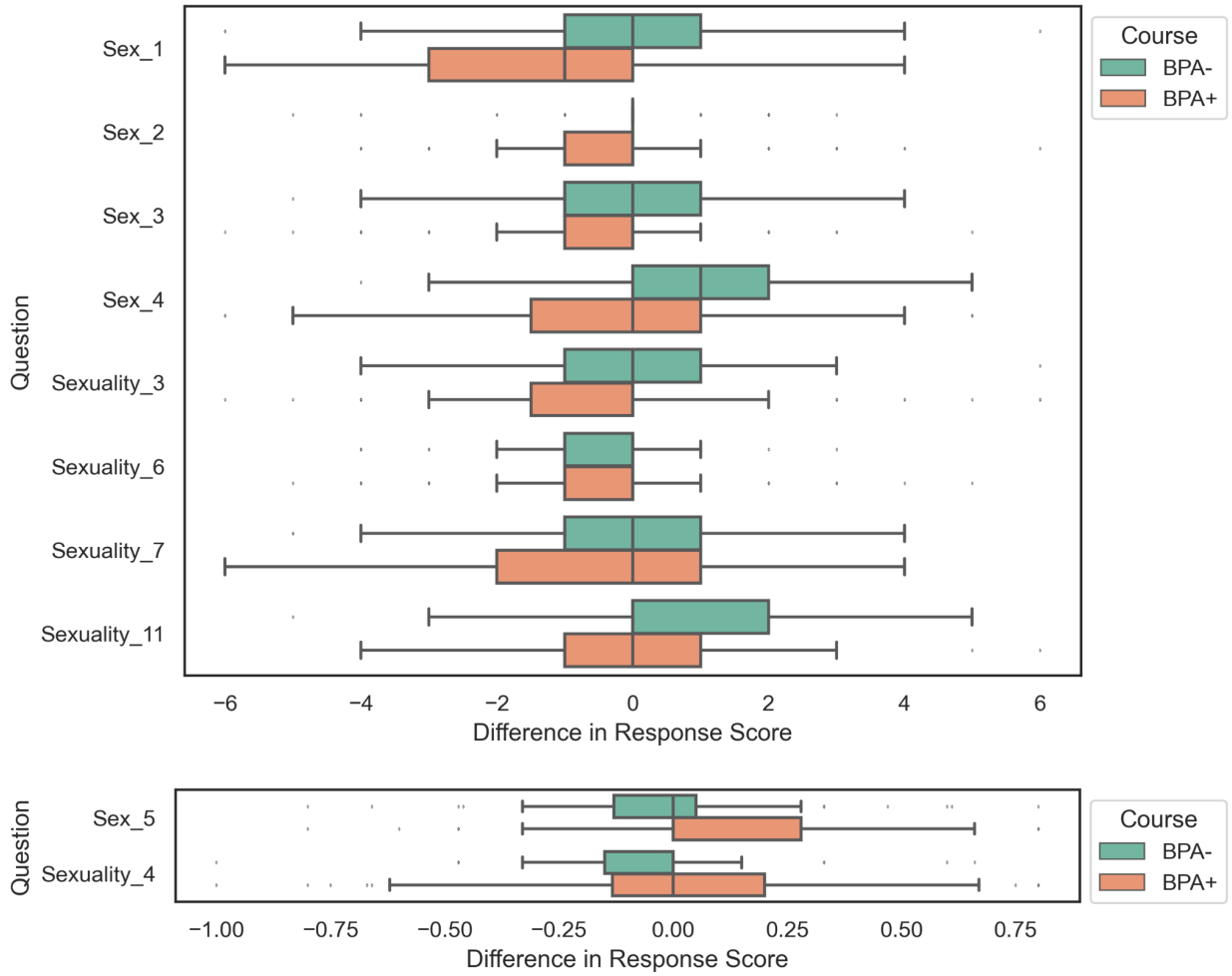


Figure 2. Pre-Course Sense of Inclusion in Biology by Identity

A negative number indicates a greater feeling of exclusion, and a positive number indicates a greater feeling of inclusion in the field of biology.

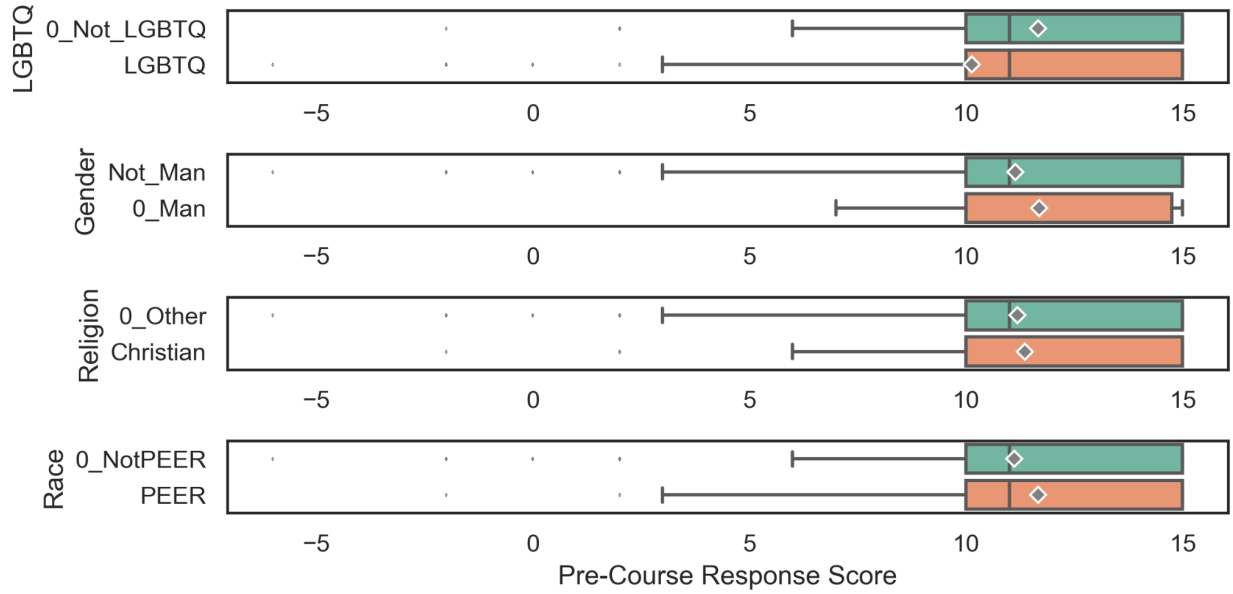
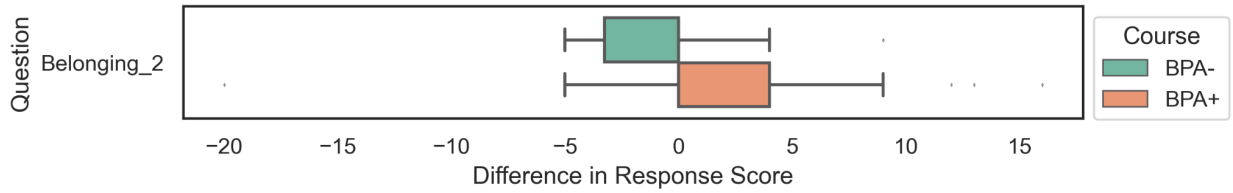


Figure 3: Effect of course type on Sense of Belonging in the Field of Biology for LGBTQ+ Students

A more negative number indicates a shift towards feeling excluded in the field of biology, and a more positive number indicates a shift in attitude towards feeling included in the field of biology after having taken the course.



Supplemental Table 1: Demographics

Student demographics by category as presented in the survey to the students.

		Unrevised Course		Revised Course	
		Pre Survey	Post Survey	Pre Survey	Post Survey
LGBTQ+ Identity					
	Yes	17	16	32	35
	No	49	51	92	92
	Decline to state	3	2	7	4
Gender Identity					
	Man	11	11	31	31
	Woman	56	54	92	92
	Nonbinary	2	2	3	3
	Other	0	0	1	2
	Decline to state	0	2	4	3
Religious Identity					
	Christian - Catholic	9	10	18	22
	Christian - Church of Jesus Christ of Latter-day Saints	3	1	3	1
	Christian - Protestant (e.g. Baptist, Lutheran, Methodist, Nondenominational, Presbyterian)	17	17	15	18
	Muslim	1	1	4	3
	Jewish	1	1	0	0
	Buddhist	0	0	2	3
	Hindu	1	0	1	2
	Agnostic (does not have a definite belief about whether God exists or not)	20	22	38	39
	Nothing in particular	5	1	16	17
	Atheist (believes that God does not exist)	7	8	14	11

	Other (please describe)	2	3	12	10
	Decline to state	3	4	8	6
Racial Identity					
	White/Caucasian	42	42	77	77
	Hispanic, Latinx, or Spanish origin	13	12	25	24
	Asian	6	7	14	13
	Decline to state	2	4	6	7
	Black or African American	3	2	3	3
	Other (please describe)	2	1	3	3
	Pacific Islander	0	0	2	2

Supplemental Table 2: Demographics

Student demographics by category as coded in the analyses for the ANCOVA models.

Course	LGBTQ+	Gender	Religion	Race	Count
BPA-	Not LGBTQ+	Man	Other	Not PEER	4
				PEER	3
			Christian	Not PEER	2
				PEER	1
		Not Man	Other	Not PEER	14
				PEER	3
			Christian	Not PEER	18
				PEER	6
	LGBTQ+	Man	Other	Not PEER	0
				PEER	1
			Christian	Not PEER	0
				PEER	0
		Not Man	Other	Not PEER	9
				PEER	3
			Christian	Not PEER	4
				PEER	1
BPA+	Not LGBTQ+	Man	Other	Not PEER	13
				PEER	2
			Christian	Not PEER	8
				PEER	4
		Not Man	Other	Not PEER	34
				PEER	3
			Christian	Not PEER	18
				PEER	14
	LGBTQ+	Man	Other	Not PEER	3
				PEER	1
			Christian	Not PEER	0

				PEER	0
		Not Man	Other	Not PEER	22
				PEER	8
			Christian	Not PEER	0
				PEER	1

Supplemental Table 3. Responses to the question, “What, if anything, about this course, BIO 331, made you feel included as part of the biology community?” from LGBTQ+ students whose sense of belonging improved after taking this course and who mentioned the Broadening Perspectives Activities.

I’m not sure about including this and I don’t currently reference it in the text at all.

Change in Sense of Inclusion in Biology Score	**Student Quotes**
+5	“I like how in-depth we learned about the different genders and orientations in the animal kingdom. I felt included in general because nothing was off topic and everything was used as a learning experiment.”
+5	“The class has opened me up to a variety of scientific perspectives, which helped me to feel included.”
+6	“The instructors were all very kind, and I found the broadening perspectives activities to be very inclusive.”
+4	“I was encouraged to go out into the field and do my own observations, as well as voice my own opinion through the various BPA activities [Broadening Perspective Activities] and assignments.”