"It's completely erasure": A Qualitative Exploration of Experiences of Transgender, Nonbinary, Gender Nonconforming, and Questioning Students in Biology Courses

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ABSTRACT

Biology is the study of the diversity of life, which includes diversity in sex, gender, and sexual, romantic, and related orientations. However, a small body of literature suggests that undergraduate biology courses focus on only a narrow representation of this diversity (binary sexes, heterosexual orientations, etc.). In this study, we interviewed students with queer genders to understand the messages about sex, gender, and orientation they encountered in biology and the impact of these messages on them. We found five overarching themes in these interviews. Students described two narratives about sex, gender, and orientation in their biology classes that made biology implicitly exclusionary. These narratives harmed students by impacting their sense of belonging, career preparation, and interest in biology content. However, students employed a range of resilience strategies to resist these harms. Finally, students described the currently unrealized potential for biology and biology courses to validate queer identities by representing the diversity in sex and orientation in biology. We provide teaching suggestions derived from student interviews for making biology more queer-inclusive.

INTRODUCTION

The number of individuals who openly identify with a gender that does not match the sex they were assigned at birth is growing each generation (GLAAD and Harris Poll, 2017; Jones, 2021). However, educational research on how to support this growing segment of the population is lagging behind that of other historically marginalized groups, especially at the college level (Dickey *et al.*, 2016; Coleman *et al.*, 2020). This produces a noticeable gap in understanding the factors that contribute to the success of these students in academic settings (Freeman, 2018). In this study, we explored how messages about sex, gender, and orientation in biology courses influenced the experiences and persistence in science, technology, engineering, and mathematics (STEM) fields of students whose gender does not match the sex they were assigned at birth.

Sex, Gender, and Orientation in Biology[1]

Biology as a discipline is the study of the vast variation in ways organisms live. This includes variation in sex, gender, and sexual, romantic, and related orientations. From

[1]An annotated bibliography of approachable papers and books capturing the diversity of sex, gender, and reproduction found across organisms can be found in the Supplemental Material.

Stephanie Gardner, *Monitoring Editor*

Submitted Dec 23, 2021; Revised Jul 11, 2022; Accepted Jul 26, 2022

CBE Life Sci Educ December 1, 2022 21:ar69

DOI:10.1187/cbe.21-12-0343

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a broad biological perspective, the generally accepted defining feature of sex or mating type is the type of gametes an individual produces (Urry *et al.*, 2017), and from there life diverges. There is large diversity in how gametes are characterized and related to sex or mating type. Some species have gametes of different sizes, and size is used to identify sex. Other species have gametes that are the same size and do not technically have a sex; instead, mating type is differentiated by other features of the gametes (Billiard *et al.*, 2011). In addition, species vary in who produces what gametes: Some species produce multiple gamete types in one body, some species separate gamete types into different bodies, and some species have individuals that change the gametes they produce over their lifetime (Bachtrog *et al.*, 2014). Many species produce two types of gametes, eggs and sperm. Other species, such as some fungi, have mating types that number in the thousands (Heitman *et al.*, 2007). Finally, even the many mechanisms that determine the sex of an individual in different species are not fixed but shift over evolutionary time, indicating that biological variation in sex can and does change in response to changing environments (Bachtrog *et al.*, 2014; Pennell *et al.*, 2018). Variation is the overarching theme when it comes to sex and mating types across the biological world.

In humans, two gamete types are typically produced in different bodies. However, almost all other sexual characteristics vary in a continuous manner (Lande, 1980; Poissant *et al.*, 2010; Mittleman *et al.*, 2017). As in other organisms, sex in humans is an amalgamation of many traits (including primary and secondary sexual characteristics). These traits are polygenic, determined not just by a few genes on X and Y chromosomes, but also by a myriad of genes on autosomal chromosomes and by the environment in which an individual develops (Fausto-Sterling, 2012). Polygenic traits by their nature vary continuously. Biologically, then, there is nothing binary about sex, even in humans. Even gametes, which may seem binary, are likely impacted by many genes and thus vary continuously within a species. That human sex is a spectrum is illustrated by the experiences of intersex individuals whose bodies (chromosomes, gonads, and/or genitals, among other traits) do not match Western cultural binary assumptions about sex (Hull *et al.*, 1982; Sanz, 2017).

When we move beyond primary sexual characteristics, life is equally complex. Organisms of the "same sex" can exhibit different bodies and behaviors (observed in studies of alternative reproductive tactics; Oliveira *et al.*, 2008) that some researchers have even taken to calling different "genders" (Roughgarden, 2013). In this paper we define "gender" as the way an individual wants to be related to by others. Although it is often assumed in humans that gender aligns with sex (i.e., that individuals assigned female at birth will want to be related to as women), in a recent national survey, an estimated 12% of people aged 18–35 describe their gender as not aligned with the sex assigned to them at birth (GLAAD and Harris Poll, 2017). Some individuals describe their experience of gender as neither woman or man, both woman and man, or as completely outside these binary categories and therefore use a wide variety of labels to characterize their experiences of gender (e.g., transgender, agender, bigender, nonbinary, genderfluid, gender neutral; Harrison *et al.*, 2012). Recent research has begun to document the ways that genes and the environment (including culture) can influence gender in humans (Polderman *et al.*, 2018; Theisen *et al.*, 2019).

Similar diversity characterizes attraction and sexual behavior. Organisms exhibit a range of approaches to fertilization and reproductive behaviors. In some species, an egg and a sperm come together for fertilization; in others, two eggs (Booth *et al.*, 2014) or two sperm can fuse (Tinti and Scali, 1992); in still others, individual eggs or individual sperm can grow into a new organism without fertilization (Heesch *et al.*, 2021; Ryder *et al.*, 2021). Sexual behavior, if it even occurs in a species, can include "different-sex" mating and "same-sex" mating. Although originally assumed to be nonadaptive, recent studies have demonstrated the potential value of same-sex sexual behavior in organisms with social bonds (Elie *et al.*, 2011; Monk *et al.*, 2019; Vasey, 2006). Among humans in the United States, an estimated 16% of individuals aged 18–35 exhibit attractions beyond the traditionally assumed heterosexual attractions (GLAAD and Harris Poll, 2017). People use many different labels to describe their experiences of attraction (e.g., ambisexual, asexual, heteroflexible, pansexual).

In summary, the study of biology demonstrates that many different ways of being exist in nature in regard to sex, gender, and sexual behavior, and we posit that this variation can validate the experiences of students whose sex or experience of gender does not align with binary expectations of modern Western society.

Messages about Sex, Gender, and Orientation in Biology Courses

Biology courses are unique among STEM disciplines in that examples and concepts taught in core courses touch on sex, gender, and orientation. Students encounter lessons designed by their instructors on sex determination, sexual reproduction, and sexual selection early on and throughout the curriculum. Only a few studies have explored the messages about sex, gender, and orientation present in biology curricula. A study of common biology textbooks found that these books did not mention sexes beyond "male" and "female," conflated sex and gender, and linked anatomical features of the human body to specific genders rather than making space for variation (Bazzul and Sykes, 2011). A second study of anatomy and physiology textbooks used by nursing students found similar patterns (Ray King *et al.*, 2021). More generally, language in biology reinforces a focus on binary sexes. Common terms such as "sex hormones" and "sex chromosomes" (Richardson, 2013; Garcia *et al.*, 2018) reinforce notions about sex-specific physiologies (e.g., only men have XY chromosomes and facial hair), which in turn may promote binary rather than spectrum thinking (Nehm and Young, 2008; Hyde *et al.*, 2019). This language also seeps into developmental biology and neurobiology, influencing understanding of brain organization, hormones, and cell function and leading to misleading perceptions of "sexed" organs, cells, and molecules (Hyde *et al.*, 2019). In evolutionary biology, concepts of sex and gender are most prevalent in sexual selection theory, which often reinforces the idea of innate "sex roles" related to competition, choice, and parental care. In many human societies, these sex and gender roles are overwhelmingly assumed to be linked to gender stereotypic behaviors (i.e., men being promiscuous and aggressive and women being choosy and meek; Ah-King and Ahnesjö, 2013).

Taken together, these studies suggest that, rather than emphasizing the diversity of strategies and experiences

organisms have around sex, gender, and orientation, biology courses reinforce an inaccurate oversimplified story: gender essentialism. Gender essentialism is characterized by the belief that bodies can be neatly categorized as either female or male and that there is a natural essence of femaleness and maleness that dictates many aspects of life, including one's experiences, behaviors, proficiencies, and attractions (Heyman and Giles, 2006; Coleman and Hong, 2008; Rhodes and Gelman, 2009). Differences are perceived as immutable, fixed from birth (or even before), and due to innate biological features (such as chromosomes, hormones, and brain organization) rather than being influenced by environmental factors.

A Note on the Authors' Language Choices

Before we can talk further about how presentations of sex and gender in biology influence students' retention and perception of biology, we need to clarify some language. As we noted earlier, neither sex nor gender is a simple binary, and people use a wide variety of labels to distinguish their experiences of gender from binary assumptions. This language continues to evolve to capture the rich variation in this aspect of life. The growing language has forced us to make some difficult decisions about terminology to balance clarity and inclusion. We have opted to use "individuals with queer genders" to refer to our target population of students whose experiences of gender do not align with the sex assigned to them at birth. The opposite of this term is cisgender. There is also rich variation in experiences of orientation and terms to capture that variation. We are opting to use "individuals with queer orientations" to capture individuals whose orientations are not heterosexual. The term "queer," we recognize, is problematic. It is not universally subscribed to among members of these populations, and its historic use as a pejorative makes it controversial. However, we use "queer" in the strict sense of referring to genders and orientations that differ from societal expectations of the female/male binary and heterosexuality. The term aptly signifies the marginalized status of these groups and helps eliminate cumbersome and repetitive descriptions. In addition, our use of "queer" as an umbrella term aligns with the labels undergraduate students with nonheterosexual orientations and noncisgender identities chose in prior research (Mattheis *et al.*, 2020; Rankin *et al.*, 2019; Yoder and Mattheis, 2016)

Impacts of Gender Essentialist Thinking in Biology

Gender essentialist thinking in biology courses is harmful for many reasons. Recent research suggests that essentialist thinking may drive misconceptions that students hold about important topics in physiology, ecology, evolution, and genetics (Coley and Tanner, 2012). For example, undergraduate biology students frequently struggle with learning about plant reproduction (Hershey, 2005; Coley and Tanner, 2012). Plants are in many ways incompatible with gender essentialist assumptions of the sexes and reproduction: Plants may reproduce asexually through vegetative reproduction or apomixis (asexual reproduction with seeds), may have sperm- and egg-bearing structures on the same plant (e.g., as part of the same flower), and may reproduce with plants as distant as 1700 km (Moore, 1976). Gender essentialism also influences learning in evolution and genetics by reinforcing beliefs about long-term monogamous male–female pair bonding in which males and females fill gender essentialist roles, thereby missing the variety of behaviors that actually exist (Gowaty, 2012; Warkentin, 2019).

Furthermore, gender essentialist thinking creates long-term harm through decreasing students' preparedness for professional roles. In their professional lives, students will likely work with people with queer identities, particularly considering the increasing prevalence of people openly disclosing these identities (GLAAD and Harris Poll, 2017; Jones, 2021). This is particularly important in medical fields, where doctors and nurses need to be able to relate to, do no harm to, and deliver quality care to all patients. Currently, experiences of discrimination and discomfort with health professionals can reduce the willingness of people with queer genders to seek healthcare (Baldwin *et al.* 2018). It is important to note that most medical schools do not currently require education around sex and gender diversity (Shindel *et al.*, 2016), so medical schools cannot be counted on to undo the gender essentialism taught in the undergraduate curriculum.

A third potential harm from essentialism in the biology curriculum relates to gender disparities in retention across STEM. Biology classes, especially the introductory courses, are attended not just by biology majors but a range of STEM majors. Women remain underrepresented in STEM at large, and this has been related to stereotypes about intelligence and who is good at STEM (Leslie *et al.*, 2015; Storage *et al.*, 2016; Donovan *et al.*, 2019b). People whose understanding of gender is rooted in gender essentialism tend to hold stronger gender stereotypes (Heyman and Giles, 2006) that they apply to both others and themselves (Coleman and Hong, 2008). These stereotypes undermine women in STEM and have impacts on their educational performance and career persistence (Nosek *et al.*, 2009; Beasley and Fischer, 2012; Smith *et al.*, 2015; Atherton *et al.*, 2016; Mattheis *et al.*, 2020). Gender essentialism can also facilitate the underrepresentation of men in particular careers traditionally associated with feminine values, such as nursing and science teaching, where there are currently high needs (Deikman and Eagly, 2008; Croft *et al.*, 2015; Stout *et al.*, 2016). Finally, although research has not been done to directly link gender essentialism to persistence of students with queer genders, they are underrepresented in STEM as a whole (Maloy *et al.*, 2022) and most extremely in biology (Maloy and Hughes, 2020). This suggests that biology may be a particularly challenging STEM context for students with queer genders.

A fourth harm from gender essentialism in the biology curriculum, and the focus of this paper, is that it erases the lived experiences of students whose gender does not align with the sex they were assigned at birth. This leads to a hostile or, at best, unwelcoming climate for these individuals in STEM and could explain their lower persistence. Very little work has been done that specifically focuses on the experiences of students with queer genders in higher education. Most existing work either focuses specifically on students with queer orientations (Cech and Waidzunas, 2011; Hughes, 2017) or lumps queer genders and orientations together (Cooper and Brownell, 2016; Cech and Pham, 2017; Cech and Rothwell, 2018). Conflating gender and orientation masks the specific challenges students with queer genders face and the strengths they bring to overcome those challenges (Dickey *et al.*, 2016).

Studies in high school settings demonstrate that the experiences of students with queer genders are different from those with queer orientations: Students with queer genders

experienced greater peer victimization, felt less safe, perceived the school climate more negatively, and heard more transphobic remarks than their peers with queer orientations reported hearing homophobic remarks (Kosciw *et al.*, 2016; Hatchel and Marx, 2018). In addition, a study of more 3000 Canadian teachers found they were more likely to challenge homophobia in their classes than transphobia (Taylor *et al.*, 2016). In college, the few studies conducted specifically on students with queer genders found they experienced worse academic climate, greater exposure to discrimination, and lower sense of belonging compared with cisgender students (Dugan *et al.*, 2012; Rankin and Beemyn, 2012; Garvey and Rankin, 2015; Day *et al.*, 2018). Two studies that focused exclusively on students with queer genders in higher education found that lack of belonging and worse academic climate predicted experiences of stress (Garvey and Rankin, 2015; Budge and Goldberg, 2020). These students reported feeling invisible, being misunderstood by peers and faculty, and not experiencing affirmative gender-identity experiences in college (Budge and Goldberg, 2020). Finally, a preliminary study on the retention of students with queer genders in STEM found they had lower retention than cisgender students, particularly in biology (Maloy *et al.*, 2022).

Theoretical Framework for Understanding How Biology Content Can Impact Students with Queer Genders in Biology: Master Narrative Theory

The period of most rapid development of personal identity is during the transition from childhood to adulthood; for many individuals, this occurs, at least partially, while they are in college (Erikson, 1968; McAdams, 1993; Kroger, 2015). Master narrative theory is a framework that deciphers how messages in the cultural environment become internalized and impact the development of personal identity (McLean and Syed, 2016). Master narratives are "culturally shared stories … [that] provide guidance for how to be a 'good' member of a culture" (McLean and Syed, 2016, p. 320). As a person constructs their identity (their personal story) they use these culturally shared stories to guide their thoughts, beliefs, values, and behaviors; thus, these master narratives become internalized. For people whose lives do not fit the master narrative, often those that belong to groups marginalized by society, these narratives can create a psychological toll. In these situations, people may construct alternative narratives that differ from, and possibly resist, master narratives (McLean and Syed, 2016). An individual's personal story is influenced by how much their identities align with master or alternative narratives.

An example of a master narrative and alternative narrative that resists it can be seen in Bradford and Syed's (2019) study of trans people living in the United States. Study participants identified cisnormativity as the master narrative they commonly encounter. Cisnormativity is the narrative that cisgenders are normal and anything else is aberrant, should be ignored, or can be seen as dangerous (Bradford and Syed 2019). Through this culturally shared story, trans people are framed as outside cultural norms and even potentially dangerous to others. Bradford and Syed's (2019) participants described how trans communities resisted this master narrative by creating their own alternative narrative of transnormativity. This narrative celebrates the affirmation of transgender gender identity through medical transition and presenting as the individual's true gender. However, as with the master narrative, this alternative narrative still reinforced specific requirements for being transgender and harmed individuals who did not have access to or want to go through a medical transition or whose gender was not aligned with the binary gender categories of man or woman. Thus, while alternative narratives help address problems that exist within a master narrative, these alternatives can also have problems themselves.

It is possible, with time and effort, to change the master narratives (McLean and Syed, 2016). Such change may be more readily achievable in a narrow context—like changing the gender essentialist narratives that dominate in biology classrooms—and this may have a particularly powerful role on individual narratives if they occur as individuals are defining themselves, such as during adolescence and college (Stewart and Healy, 1989; Eisenberg and Silver, 2011).

Existing research using master narrative theory to understand the experiences of individuals with queer genders and orientations provides insight into how these queer identities are perceived in different societal contexts (Hammack and Cohler, 2009; Weststrate and McLean, 2010; Hammack and Toolis, 2014; Bradford and Syed, 2019). Researchers have found that the personal narratives of younger generations of individuals with queer orientations are more variable than those of older generations, as the restrictions of master narratives around orientation have lessened (Weststrate and McLean, 2010). However, interviews with young adults with queer genders revealed how master narratives continue to negatively influence their relationships to others and how challenging it was for others who embraced the master narrative of gender essentialism to understand the experiences of these youth (Bradford and Syed, 2019). Both studies demonstrate that youth can identify master narratives in their environments and are impacted by these narratives both in terms of how their identities develop and in their relationships to others. We found no research on individuals with queer genders that focused on narratives in a particular social context, such as a college biology class, and how those context-specific narratives influence identity development.

In the current study, we explore the master and alternative narratives students with queer genders perceived in biology courses and how these narratives influenced these students. The small number of research studies on students with queer genders in college and the lack of this research in a STEM contexts limit the ability of institutions to respond to these students' needs and support their retention. We begin to address this need by interviewing five students with queer genders about their experiences in biology courses. Small qualitative studies such as ours are important, as this type of research allows for an in-depth exploration of students' experiences (Pawley, 2019).

Specifically, our study addresses the following questions:

1. How do students with queer genders describe the narratives they encounter about sex and gender in undergraduate biology courses?
2. How do students with queer genders perceive the impacts of those narratives?
3. What strategies do students with queer genders use to counter any threatening narratives?

METHODS

Identities of Those Conducting the Study

This study was performed by a team of STEM education researchers, including an assistant professor in biology, an assistant professor in biology education, a STEM education research scientist with a background in biology, a gender and orientation educator, and an undergraduate student majoring in psychology who has a background in biology. All three faculty and scientist members of the research team have seven or more years of experience performing STEM education research and also have experience teaching undergraduate biology courses. Within our research team, queer gender, queer orientation, and cisgender identities, as well as white and Hispanic-Indigenous racial and ethnic identities are represented. Our identities provided us with a range of insider and outsider perspectives regarding orientation and gender identities; student and educator perspectives; and different racial, ethnic, and cultural perspectives. Collectively, our diversity of identities helped us to interpret students' experiences from a range of perspectives.

Context, Inclusion Criteria, Recruitment Efforts, and Participant Demographics

We recruited students with queer genders from a single Hispanic-serving institution. These students attended an urban university in the southeastern United States that draws the majority of its students from the surrounding three counties and is primarily a commuter school. The state the university is located in has few policies that protect individuals with queer genders or orientations legally; of potential relevance to our participants, there are no nondiscrimination laws nor antibullying laws protecting queer students, and transgender youth are banned from participating in sports consistent with their gender identity (Movement Advancement Project, 2021). We share this to give readers a general sense of the cultural climate for the students who participated in our study.

Students were recruited through fliers sent via STEM-specific queer organization Listservs on campus in the Spring semester of 2021. Before being selected for an interview, students completed a questionnaire that included questions on the number of biology courses taken, major, gender, orientation, and race/ethnicity. These demographics provided important context for the various ways our participants experienced narratives about sex and gender in biology classrooms. Finally, as part of this survey, students were informed about the study and could consent to participate. To be eligible for participation, students were required to have taken at least three college-level biology courses and to self-identify as having a queer gender. We used this minimum number of courses taken as an eligibility requirement to ensure that students could discuss experiences across a range of courses. This requirement also allowed us to include students who had interdisciplinary academic paths and students who changed majors to leave biology.

From the pool of students who completed the survey, we invited all eligible participants. Five of six eligible students elected to participate. To protect the privacy of our participants, we report identity information in aggregate, rather than providing profiles of each participant. Due to the low numbers of students with queer genders in STEM (Maloy *et al.*, 2022), simply knowing a student's gender and orientation identities, major, and racial and ethnic identities could make them identifiable.

Our participants had a range of queer gender identities, as well as a range of other social identities. To collect these identities, we used a queer-inclusive gender item as well as a sexual, romantic, and related identities item developed by Casper *et al.* (2022). For race/ethnicity we used survey items recommended by recent Census Bureau research (Cohn, 2022). The range of gender, racial/ethnic, and orientation identities, along with student majors of our participants, are shown in Table 1. The variation demonstrates that our participants each experienced their biology courses from a unique combination of social identities.

In addition to variation in identities, our students varied in their biology experiences. Some students described experiences they had at community colleges as well as experiences at their current institution, while some only referenced their current institution. In addition, students described a mix of online and in-person experiences. We did not specifically ask students to provide information about when they took the classes they discussed or if those classes were taught in an online or hybrid format due to COVID-19; however, the timelines students described indicated that they all had taken at least one biology class before the start of the pandemic. Additionally, students in our study explicitly discussed some situations that occurred in face-to-face classroom environments, and in some cases, they described events in the term that would have taken place virtually. However, in many cases, it was less clear if events occurred in virtual or face-to-face classroom environments.

Interview Methods

Participants were invited to a sequence of three interviews to provide space for an in-depth exploration of their experiences in biology courses. Informed by master narrative theory, the sequence of interviews sought to identify narratives about sex and gender in biology courses and connect them to impacts on students' affective experiences and sense of belonging in biology. We used a semistructured interview format in which interviewees were all asked a set of six to eight core questions with the flexibility for additional follow-up questions. The focus of the first interview was the students' experiences with biology content that was related to sex and gender and the narratives they perceived in that content. The second interview explored the students' affective responses to the content and narratives. The third interview explored how the students' experiences in biology classes influenced their overall professional identity development, sense of belonging, and relationships in biology. This third interview also included a digital card-sorting activity using the online platform Padlet so students could freely move the cards around and the interviewer could view the sorting process. Students rated (on a continuum from "strongly agree" to "strongly disagree") how much they agreed with statements about experiencing different microaggressions in biology. Multiple cards could be placed at the same location on the continuum. As they sorted the cards, students described what experiences they were drawing on to make those ratings. The microaggression statements on the cards were selected from the Daily Heterosexist Experiences Questionnaire (Balsam *et al.*, 2013). Interview protocols and details on the card-sorting activity are included as Supplemental Material.

These interviews were conducted using an online videoconferencing platform. All interviews were recorded and transcribed verbatim. The interviews ranged in length from 25 to 45 minutes. After each interview, students received a $25 gift

TABLE 1. Demographics of study participants[a]

Gender[b]	***N***
Female and/or Feminine and/or Woman; Questioning and/or figuring it out	1
Genderqueer and/or nonbinary; Transgender	1
Genderqueer and/or nonbinary	1
Questioning and/or figuring it out	1
Female and/or Feminine and/or Woman; Genderfluid; Genderqueer and/or nonbinary; Transgender	1
Race/ethnicity[c]	
Hispanic, Latino, or Spanish	3
Asian; White	1
Asian	1
Orientation[b]	
Bisexual	2
Gay; Lesbian; Queer	1
Lesbian; Queer	1
Gay; Queer	1
Major/focus	
Biological sciences	1
Biomedical engineering	1
Health services administration (pre-med track)	1
Philosophy (started as a biological sciences major)	1
Women and gender studies with a biological sciences minor	1

[a]A semicolon between words indicates that the participant chose multiple options in the category.
[b]To gather data about gender and orientation we used the survey items developed by Casper *et al*. (2022).
[c]To gather data about race/ethnicity we used survey items recommend by recent Census Bureau research (Cohn, 2022), and added the options "prefer to self-identify" and "prefer not to respond."

card for their participation. All five participants completed all three interviews.

This research was conducted under Florida International University Institutional Review Board approval (IRB-20-0500).

Data Analysis

We performed a qualitative content analysis (QCA) to analyze our data. QCA is particularly appropriate for our data, as it allows researchers to synthesize text into smaller categories, sometimes referred to as themes, related to commonalities and differences across the data that are both frequent and uncommon (Graneheim and Lundman, 2004; Elo and Kyngäs, 2008; Mayring, 2014). Specifically, we performed an abductive QCA (simultaneously inductive and deductive), in which there is not an existing literature base to develop extensive deductive codes, theory and the limited existing literature provides some information about anticipated codes. Furthermore, our abductive analysis allowed us to focus on our participants' unique lived experiences and develop codes and themes rooted specifically in those experiences, while also considering existing theory and literature. The deductive codes we started with related to gender essentialism and master narrative theory.

The QCA process follows three steps: preparation, organization, and reporting (Elo and Kyngäs, 2008). The preparation step involves planning for data analysis. In our preparation step, we defined our unit of analysis as the set of three student interviews, following Graneheim and Lundman's (2004) recommendation that the unit of analysis encompass an entire person that is part of the study. With this person-as-a-unit perspective in mind, authors A.C., N.R., and S.E. read through all transcripts initially. This helped us make sense of the data as a whole and prepare for the organizing phase, which involved coding (Elo and Kyngäs, 2008).

In our organization phase, authors A.C. and S.E. moved through an iterative process of open coding. This involved reading one participant's interviews, coding for meaning units (words and/or sentences with an overarching meaning) related to our research questions through the lens of our theoretical framework, discussing codes and coded text, and then performing the same process for the next participant's interviews (Elo and Kyngäs, 2008). After these two authors had coded all the interviews once, they discussed the codes and their meaning-making from the interviews with N.R. together, these three authors discussed the overarching themes present in the coded passages (Graneheim and Lundman, 2004). Then, A.C. and S.E. performed a second coding pass, in which both authors coded all the text for each participant a second time, this time using the set of codes agreed upon after the first coding pass. After both A.C. and S.E. had coded all three interviews for one participant, they met and discussed their codes until they reached consensus agreement in coding (Stemler, 2004). Throughout our coding process, we kept a memo log shared by all three authors involved in coding to track patterns within the data as well as exceptions to these patterns. We then collated the distilled passages within specific codes and their overarching themes and subthemes. Definitions of themes and subthemes along with exemplary quotes are provided in the Supplemental Material.

For our reporting phase, we wrote profiles for each participant to help analyze how the different codes and themes interacted throughout the experiences of each participant. This allowed us to move beyond simple descriptions of experiences

and understand linkages between our codes and themes. To help with confidentiality concerns, we then extracted these linkages from the student profiles and reported them as part of our results. To further protect student identity, and because the pronouns a student used may be context dependent, we use the singular they as a universal pronoun for all participants. Once we had written these synthesized results, we provided these results to our participants to allow them to provide feedback on the way we had interpreted their data. We revised our analysis based on this feedback as well as feedback from N.R., A.L., and L.J.

In our data-collection and analysis process, we addressed credibility, dependability, and trustworthiness in several ways that are appropriate to QCA (Graneheim and Lundman, 2004). We established credibility through recruiting participants with experiences relevant to the experience we are studying—undergraduate students with queer genders who had taken multiple biology courses and were either currently in a biology-related course of study (i.e., major, minor, or premed/PA) or had previously been a biology major. We also established credibility through keeping our meaning units (i.e., chunks of text labeled with a code) focused on the set of words or sentences coding a specific meaning and presented representative quotations from the transcribed interviews (Graneheim and Lundman, 2004). Furthermore, while there are different opinions about the appropriateness of seeking agreement across co-researchers in QCA, multiple realities exist and are dependent on subjective interpretations. We developed dependability through involving multiple researchers in the coding process and obtaining feedback from our participants on our analysis, following the methods of Graneheim and Lundman (2004) and Graneheim *et al.* (2017). Also, we had two people with queer identities and different positions in academia code each participant's interviews independently and then discuss the codes in depth (Stemler, 2004). For trustworthiness, we performed the three interviews for each participant over the course of a short 2- to 4-week period to avoid inconsistency in data collection due to change over time (Graneheim and Lundman, 2004).

RESULTS AND DISCUSSION

We identified five major themes from the student interviews: 1) two master narratives are present in biology courses (master narratives); 2) a range of harms results from these narratives (harms); 3) students employ resilience strategies (resilience); 4) biology courses are implicitly exclusive (exclusion); and 5) biology courses have unfulfilled potential to be queer-inclusive (potential). each of these themes describes a different, related facet of the experiences students with queer genders navigated in biology classrooms. We describe each of these themes and any subthemes below; specific definitions and additional example quotes are located in the Supplemental Material.

Theme 1. Master Narratives: Students Perceive Two Master Narratives in Biology Courses—Gender Essentialism and Biology as a "Neutral" Space

All of the students in our study described two different, related master narratives in biology courses: gender essentialism and biology as a "neutral" space. While their experiences with these two themes were often connected, gender essentialist narratives specifically related to discussions of sex that focused exclusively on a binary representation of sex and assumed heterosexual orientations. In contrast, experiences that enforced the idea of biology as a "neutral" space related to explicitly avoiding topics, such as transgender people, that might be perceived as related to personal beliefs or political views.

Gender Essentialism. The master narrative of gender essentialism manifested in two primary ways in the classroom when topics related to sex and gender were discussed, such as sex chromosomes, gametes, plant reproduction, animal reproduction, and sex determination. First, students described the absence of any discussion around variation that exists in biology outside the gender essentialist pathway: There were no discussions of sexes beyond the binary, there rarely were discussions of gender roles beyond traditional gender roles, and there were no discussions of gender and its relationship to sex during class or in out-of-class assignments. For example, Student 1 shared this about discussions of animal diversity:

> We just focus on how the male species appeals to the female species by flapping their feathers. Very heteronormative … like, if you identify as male then it's your job to go after the woman. It's your job to like this, and this, and that…

This discussion, which limited who males should be attracted to and how they should behave, reinforced ideas of gender as binary and the naturalness of traditional gender roles. Student 1 found the same limited perspectives in out-of-class assignments:

> I would definitely say that the narrative is very binary. The way the professor translates information, it's very binary. The worksheets, the application projects: really binary. Just like on a scale of one to ten, ten being super clear and super cool, they'll probably fall around three.

A second way the gender essentialism master narrative manifested was that biology professors demonstrated explicit support of the notion that there are only males and females. Students 1, 2, and 3 all described instances of hearing explicit messages from biology professors upholding binary conceptions of sex and gender. For example, Student 2 shared:

> [My biology professor] would share her opinions on it and it made me want to stay silent…. She disagreed with the fact that people change their gender identity. She thinks whatever you were born, you should stay and that's who you are don't try to change it.

Student 3's professor also explicitly upheld the sex binary as an immutable biological fact: "My professor said there are only two [sexes] and that's according to biology and it'll never change." Another way instructors supported the binary was through the design of activities that reinforce it. Student 1 experienced such an activity. They were in a biology class where "the professor [said,] 'Let's divide into groups … just like all the boys go over here and the girls over here'… and there isn't a category for me." This instructor assumed every student fit into one of two categories, and this activity demonstrated that belief by leaving no room for students who did not identify as "boy" or "girl."

Attempted Neutrality. The second master narrative that students identified was related to what many authors refer to as the "neutrality" of STEM (Cech and Sherick, 2015; Hughes, 2017; Miller and Downey, 2020; Leyva *et al.*, 2022). Here we refer to this as "attempted neutrality" to explicitly bring attention to the problem with the perception of biology as neutral. Attempted neutrality in STEM includes classroom values of meritocracy, color-blindness (and its counterpart of gender neutrality), and the valuing technical abilities over social abilities. These values mean that discussions of identity and the impact of science on social inequalities are often seen as off topic and not welcome. In turn, this impacts students' ability to engage as their full selves in the classroom, because the values of the class and the content do not create a safe space for them to do so (reviewed in Leyva *et al.*, 2022). Thus, attempted neutrality in the classroom does not equal harmlessness. There are multiple studies documenting the harm of this attempted neutrality narrative for students with queer genders and/or orientations as well as BIPOC (Black, Indigenous, and people of color) students (Johnson, 2007; Cech and Waidzunas, 2011; Dyer *et al.*, 2019; Gibney, 2019). In our study, we found that this attempted neutrality led to the potentially inadvertent norming of binary sex and genders and the view that identities and personal perspectives were off topic.

Instructor silence around sexes and genders beyond binary man and woman was a common manifestation of the narrative of attempted neutrality. Students perceived that their instructors considered these sexes and genders to be controversial or too political. This motivation for silence was exemplified by Student 4's perception of instructor choices around what to talk about: "[Biology professors] they're really neutral, they just choose not to speak about [sex and gender beyond the binary]. They think it's touchy and they want to be politically correct." Student 5 shared their perception of why this silence occurs:

> There was a concerted effort to simply just stay away from [conversations about gender and sex outside the binary], to be safe. It was intentional in the fact that they [the instructor] didn't want to offend or hurt anybody but they would simply stay away, just drop the topic, but they wouldn't necessarily go either/or in terms of invalidating it or in terms of making a point to reaffirm it.

Student 1 had a similar experience. Another student asked about how the content related to being transgender, and the instructor "was like, we're not gonna talk about that in this class." Some of the students in our study believed this avoidance of queer sexes and genders was motivated by instructors trying to not offend any students. Student 3 discussed how this avoidance impacted them, because it led to a lack of clarity about how safe it would be to reveal their gender identity to their professors: "[Students] definitely have to guess. It's not very clear or apparent what [biology professors'] opinions are."

The attempted neutrality narrative was not just enforced by instructors, but also by students in the class. Student 4 shared their experience during discussions with classmates: "Identities were not things that came up, that just wasn't a part of the conversation…. It would feel like you are forcing an issue … like you would be stepping out of line or doing something unusual." Even among classmates, the culture was to not talk about personal identities.

It is important to note that although both master narratives we describe are unique, the narratives can intertwine to limit content representing diverse sexes, genders, and gender roles in biology courses. Existing research with STEM instructors has found that they may avoid topics that they perceive as too political in their classrooms (Cech and Sherick, 2015). Because gender essentialism is a master narrative in our larger culture, the only "apolitical" genders are man and woman. Therefore, when instructors limit themselves to an "apolitical" curriculum in an attempt to be neutral, they cannot mention sexes or genders beyond the binary. Thus, the attempted neutrality narrative limits discussion in the biology classroom to only the "safe" narrative of gender essentialism.

In summary, both master narratives act to limit content representing diverse sexes, genders, and gender roles in biology courses. Students with queer genders did experience some counternarratives, which we discuss in *Theme 4*, but these are rare compared with the overwhelming messages of gender essentialism and biology as neutral.

Theme 2. Harms: The Master Narratives in Biology Courses Harmed Students with Queer Genders across a Range of Dimensions

The harm students with queer genders experienced from both master narratives can be classified into three subthemes: harms to 1) sense of belonging, 2) interest in biology content and the discipline, and 3) professional preparation—all of which are key dimensions in models for persistence in biology career pathways (Lent *et al.*, 1994; Tinto, 1975). The specific harms students experienced seemed to vary by master narrative, although the source of some harms could not be untangled.

Sense of Belonging. Students' sense of belonging in biology was negatively impacted by curriculum reinforcing binary sex and gender (gender essentialism master narrative) and uncertainty about what instructors and peers believed about genders beyond man and woman (neutrality narrative). Students described a range of experiences that cumulatively harmed their sense of belonging, including feelings of exclusion, cognitive dissonance, lack of identity safety, and reduced ability to form relationships with instructors and peers.

Exclusion was the experience of feeling unwelcome or different in biology courses because of a student's queer gender. Exclusion manifested for Student 4 when the professor discussed topics that reified sex and gender as a binary; this feeling of exclusion was furthered by their peers' apparent agreement with the gender essentialist narratives being taught in class.

> The moment that [sex and gender topics] come up in class, I look around and people are in agreement with it.… If the professor said [the color] is red, it's red. They're not looking to challenge these ideas. They're not looking into the exception; they're not asking these questions…. It makes me extremely uncomfortable around my peers. I'm not close with my peers in my science classes as much as I am close with my peers [in other classes].

Exclusion also occurred through the design of course activities, such as the activity in which Student 1's class was split into teams of boys or girls, and Student 1 did not have a team to go

to (discussed in *Theme 1*). Student 1 also experienced a second course activity, a course survey, as exclusionary due to its design:

> You fill out contact information forms … and there's gender identity, and it goes woman, man, other. Why would you "other" someone? Like really like other? So I'm an other.… That's just … really dehumanizes people. In that sense, and I've experienced that in a lot of classes in science classes and we have to do like you know questionnaires or so fill in forms or whatnot.

Surveys often use "other" as a gender option to include genders beyond man and woman. Yet to Student 1, that choice felt exclusionary.

Reinforcement of binary sex also led to experiences of cognitive dissonance, or mental discomfort due to navigating conflicting beliefs. Student 3 discussed how the cognitive dissonance between their experience of gender and what their biology instructor taught them about sex as a binary during a discussion of cell division made them feel discomfort in class:

> I felt a little bit overwhelmed and kind of confused because … what he was saying and what I was feeling were very contradictory … [and] it kind of stuck with me, obviously. I usually trust whatever my professors say; I don't even, like, look too into it. But … he was so adamant … and I was like: I don't know if I agree. I didn't know how else to verify I was correct, because the professor [was] telling me this like I should … trust him. But I just didn't. I didn't feel right about it.

Student 3's quote particularly exemplifies the potential harm that gender essentialist narratives can cause for students who are questioning and who do not have other readily available ways of learning about queer identities: The student did not know how to resolve the conflict between what they thought and felt and the "expert knowledge" of the professor.

While explicitly exclusionary views expressed by instructors and peers were harmful, students also discussed the stress created by not knowing what people thought. Students assumed they were not safe while staying continually alert for cues about what others believed about queer gender identities. All participants mentioned this lack of identity safety, the experience of not being sure whether one's queer gender will be accepted in the biology community. Student 5 described this uncertainty:

> If you don't see the safe zone sticker, if [professors] don't initiate the conversation, can we really share who we are with them? …Cis-het students have it so much easier because … they don't have that barrier of having to … come out to [their] Professor. Are they going to accept me? They don't have to do that.

Student 2 further described conflicts and fears related to the lack of identity safety:

> My gender… it hasn't really been something that I express like you can't see it. But I'm really scared about that if I ever do end up being able to express myself the way I want to express myself. I'm scared of being in STEM and expressing myself … I just feel like I won't be respected at all.

The experiences of exclusion, cognitive dissonance, and lack of identity safety affected students' perceptions of their ability to form relationships with their instructors and peers. For Student 3, cognitive dissonance impacted their trust of the instructor. For Student 4, exclusion was explicitly related to not feeling able to connect with their peers. Student 4 further clarified this experience of exclusion on relationships in biology:

> [Exclusion] makes me feel less connected at a human level with my peers and my professors. I'm not in the position to create very connecting relationships. I'm there to get the job done and then get out, you know? I feel like I'm not included in the community. They didn't make a space [for me].

Overall, a sense of alienation from their peers and instructors was evident in all of our student interviews. Content and discussions that focused on sex as a binary, which was incongruent with students' own experiences, left students feeling excluded. This exclusion also led to cognitive dissonance for the student who did not have readily available sources they could rely on beyond their biology classroom to provide them with information about queer sexes and genders. Furthermore, neutrality narratives meant that cisgender peers and faculty were rarely explicitly inclusive, leading students to a general feeling of being uncertain about their safety and unable to be their authentic selves with biology professors and students.

Interest. Master narratives in biology also influenced students' interest in the discipline—both their interest to continue in the major as well as their more specific interest in the content. Student 4, who started college as a biology major, described how her lack of belonging and the lack of content on her identities in biology reduced her interest in pursuing biology.

> I feel like there's just like … a lack of piqued interest because they always talk about [sex as a binary]. It would have been interesting if they [added] a little spice…. I think that, looking back, I can say that I felt less accepted and more invisible. I had to hide my identity more, so in that sense [biology] didn't have the extra "oomf" effects my [new major's] classes did that meant [I] want to keep going and learning and sticking to it … If they did say more about gender and did teach more about the spectrum, then I would have been more likely to stay…. I think I could confidently say that, but also who knows.

Student 5's quote exemplifies how content that went beyond the binary—hermaphroditic (i.e., monecious) plants—increased their interest:

> The one that I always think about is talking about all the hermaphroditic plants…. These variances, um, can be found in in all of nature in all animals … I found that really interesting that I guess the way in which it's described as like maybe just a human phenomenon, or some a select subgroup of people want to do their own thing and think their own thoughts and this is so weird when it's ubiquitous in nature. However, students in our study rarely, if ever, described having experiences like this in their biology classes.

Importantly, students in our study believed that the reduced interest due to binary representation of sex was experienced by

all students, not just students with queer genders. As Student 1 explained, students have learned the traditional biology perspective over and over again, but if instructors threw in some new element, "that would have made a huge difference, and I think it would be a wonderful learning experience, not just for LGBTQ students who are sitting in the classroom but for other students to be like wow this is new information."

Career Preparation. A third category of harms that students described were harms related to their preparation for their and their peers' future careers. Career preparation harms included two personal harms specific to students with queer genders: harms to students' performance and access to resources and opportunities. Additionally, the career preparation of all students was harmed through the missed opportunity to educate all students about the diversity of sexes, genders, and orientations that exists within biological organisms.

In terms of personal harms, students described how binary-focused content and their lack of identity safety prevented them from participating in some class activities. For example, Student 1 described how they lost class points because they refused to select a binary gender during a class activity, which directly and negatively impacted their grade: "I'm just not going to answer the clicker questions…because I don't feel like [the question] applies to me. I lost some points, but I was like I was, I was very adamant on not answering." Student 5 also described how their experiences in biology courses made tasks related to performance in biology more challenging:

> [Lack of representation in biology content] is a constant, consistent demoralizing feeling that just adds on to everything else that you have to deal with as a student in bio…. Basically, it's just the compounding layer of having to think about this on top of the regular things you would have to think about as a student.

As students, our participants looked to their instructors for letters of recommendation, research experiences, and advice to aid them in their pursuit of their careers. However, lack of identity safety impeded the relationship building necessary to access these resources and opportunities. For example, Student 1 felt like they had less access to letters of recommendation and research opportunities.

> [Lack of identity safety] gives me a hard time building personal relationship with [instructors] and then that prevents me from getting letter of recommendation so I can pursue future, you know, academic endeavors and I think that's a barrier for a lot of LGBTQ students.

Finally, students with queer genders also recognized how biology classes were missing an opportunity to educate students about diverse sexes and genders. This impacted them and their cisgender peers. Student 1 directly called out the importance of integrating queer identities and the diversity that exists within biology into the curriculum for the knowledge of all students in the class.

> You're teaching a class of people who are going to be scientists, people going to be researchers, people who're gone to be healthcare providers. It brings a huge effect … to a lot of other people's lives, and I would expect with them to be aware [of] that. I felt like that was such a good opportunity. To go over… and to reconstruct what gender and sex is in society, but I guess the professor just didn't, wasn't really aware of that.

Exemplifying Student 1's point about the importance of curriculum in educating all students about the spectrum of genders and sexes, the lack of education in biology classes impacted Student 3's personal understanding of gender: "I was like, what is the difference between sex and gender? What is gender? What is sex? I don't know. I never learned that. They never told me what gender was."

Thus, the students in our study experienced a range of harms that limited their ability to be successful in biology and that limited their peers' ability to learn vital information about sex and gender. These harms not only limited students' success in specific classes, but also had larger negative impacts on their interest in and career preparation for careers in biology.

Theme 3. Resilience: Along with the Harms They Experienced, Students Also Demonstrated Resilience

Students had many different resilience strategies to help them address the many potential harms present. These strategies included lowering expectations of biology content, focusing on personal goals, connecting with people they knew were safe, searching out alternative sources of information, and thinking critically.

The resilience strategy of lowered expectations describes how students simply did not expect their biology classes to be inclusive, such as Student 4's explanation:

> I don't think I felt any type of way when I didn't see [my biology courses being] very inclusive. If I had seen it, I would have been happy, but when I didn't see it … I wasn't sad about it. I didn't expect it. It was … biology being consistent with the rest of the world.

Because they were not expecting an inclusive environment due to the master narrative of gender essentialism being prevalent throughout their sociocultural context (described in more detail in *Theme 4* below), the exclusion of their identities and the neutrality narrative felt less harmful.

A second strategy was focusing on personal goals, such as career goals or goals to create change once they are in positions of power in biology. This is exemplified by Student 1:

> I let it motivate me to work harder to so that I can reform healthcare, reform curriculum, reform the way healthcare is taught, reform the way biology is taught. Because, It's one thing to be a member of the LGBT community but it's another thing to shape the community.

These personal goals may bolster students against the erasure they experience through gender essentialism and the neutrality narrative.

The third strategy was identifying and connecting with fellow biology students whom they had seen in gender studies classes or in queer spaces. For example, Student 2 shared:

> There have been people who have been in my women's and gender studies classes who then I see in my biology class and I feel seen by them. They're awesome; I love them. Everybody else I just kind of keep my distance.

Student one found similar types of connections when they became involved in a queer mentoring program on campus and was paired with a science faculty member who had a queer identity. This strategy of resilience addressed both master narratives. It allowed the student to counter the impact of the neutrality narrative, because they were able to identify people with positive views of their gender identities through information gathered from other contexts. It also countered the harms of gender essentialism, because it created a space in biology, through relationships, where more inclusive conceptions of sex and gender are prevalent.

The final strategies students used focused on exploring alternative sources of information and developing critical thinking to parse through the conflicting messages students encountered. Students described seeking more inclusive information about sex and gender online, through platforms like YouTube, TikTok, and Khan Academy, and in university courses outside science classrooms, such as philosophy or gender studies. For some, this research helped them develop critical-thinking skills. Student 3 shared their experience:

> I didn't feel right about [my professor's presentation of sex]. I was like I don't know if I agree, and so I decided to think about that, and simmer on it and research more … and I decided since then, that I would keep their opinions out at a distance and make my own.

Thus, students parsed the data that were presented in class and that they found on their own to decide what to believe about sex and gender.

Overall, students employed multiple strategies that helped them stay engaged with biology and navigate the harms they experienced.

Theme 4: Exclusion: Biology Courses Are Implicitly Exclusive

Universally, students in our study discussed that explicit inclusion was vital to create environments where they felt welcome. Students with queer genders in biology classrooms are part of a larger social context at the university and in the city and state where the university is situated. This context impacts the expectations and social norms that students bring with them into biology classrooms. Students in this study were embedded in a larger community that they did not feel was understanding of their queer genders and, thus, did not feel welcome in their larger social context. Because of this, explicit signals that their queer identities were welcome in their classes were key to feel like they belonged. This rarely happened in biology classes because of the master narrative of neutrality.

Student 2 described the pressures and challenges of expectations related to gender in the larger social context:

> The society around you expect[s] you to be one way…. And even if you don't want to do it, you have to do it. Like, I don't really care about putting makeup on and all that other shit but it's kind of seen as something that I have to do, especially my culture, you know gotta dress up nice and all that other stuff. I just have to, you know, keep my mouth closed because nobody really agrees with me but yeah a lot of expectations come with my being female … If I do state my opinion, which I have in the past, … it becomes a debate and it becomes like the judgment is put on you if you disagree with frickin' societal standards. It doesn't make sense in my brain. I don't want to confuse myself, so I don't want to tell myself that I'm in the middle or things like that, because at the end of the day, like, I'm honestly lost.

During the interview, Student 2 also discussed how these societal expectations do not stop upon entering a biology classroom.

Students developed defenses in response to this larger context that they also used in biology classrooms. For example, Student 4 shared how they watch what they say and do in biology classes "because I'm just programmed to do that with everybody…. I don't want to be super queer or something in an area I don't feel [is] a safe area."

Experiencing a lack of acceptance and safety outside the classroom impacted what some students need inside the classroom to feel like they belong or are safe. Several of the students described how—without explicit signals of safety—they did not assume a space was safe; instead, they often assumed the opposite. Student 1 explained succinctly: "If you're not setting a clear line, you're building more ambiguity and it in turn reinforces heteronormativity and cisgenderism." Student 1 also described how this ambiguity related to their experiences of safety in the classroom:

> I think subconsciously in almost every biology class that I'm taking the first instinct is to hide.… I wait until someone takes the initiative or you know something is mentioned [in class] regarding my identity, then I feel a little bit seen … but waiting doesn't mean that it will happen because a lot of times it doesn't.

Similarly, Student 3 shared that without explicitly being given a reason to feel like they belong, they felt disconnected in their biology classes: "I don't really feel like I have a reason to belong. I'm kind of floating around. There is no link. I don't belong, I don't not belong."

In biology courses, the master narrative of neutrality meant that it was rare for someone to explicitly indicate that the course was a space where queer genders or orientations were welcome (examples of when they did occur can be found in *Theme 5*). However, students did receive this explicit signaling in some of their humanities classes and felt welcome there. For example, Student 3 described a humanities professor who made them feel welcome in class by generally bringing up the student's identity in class and saying she supported it. This was important, because "it was very clear where [the instructor] stood," and the student "developed a relationship with this professor, which was nice and it's a little hard to do in biology classes," where they "definitely had to guess. It's not very clear or apparent what [instructors] opinions are." Other students discussed how the content in these classes that directly related to their identities made them feel accepted. Student 4 described this experience:

> In the [humanities] classroom it's more of an open space. I think more accepting of everybody. They make it a space to be very safe and inviting and open for conversation. So, gender identity sorts of topics, the spectrum, are not invisible. I think they even encourage you. They don't ignore it, they don't want to bypass the topic, they want to establish that first.

This experience of feeling encouraged to bring their identities into the classroom had a beneficial impact on their sense of belonging: "I feel more welcome to just be myself around these people." It also enhanced their interest in course content: "It makes me more excited to actually do the work and learn about this subject. I find myself really enjoying the classes and being excited to go to them." Further, it positively affected their approach to learning: "It just opens up the air to being … more about developing more than just learning."

In summary, because of their larger social contexts, students in this study did not assume biology courses were places they would be welcomed. Instead, they assumed that the biology classes were not safe spaces, and they looked for explicit signals of inclusion from instructors before they felt safe. The master narrative of neutrality in biology courses meant they did not receive this signaling. This omission was not a general college problem, but specific to biology and STEM. Students did receive explicit signaling of their inclusion in at least some of their humanities classes.

Theme 5. Potential: Students Describe Counternarratives and the Potential Power of Biology to Validate Queer Orientations and Genders

The students in our study were aware of some of the diversity of sex, gender, and orientation that exists biologically, and this knowledge bolstered their sense of belonging in biology. However, this material was largely excluded from their biology courses, so the potential for these courses to further increase their sense of belonging was not realized. All but one of the students were explicit about their dissatisfaction with the limited representation in course content of the biological diversity in sex, gender, and orientation. Student 4 succinctly described the contrast between their own experience and what they wanted to exist in biology courses:

> I want there to be a space open that's not necessarily only in the binary. I want people to know that there's other things beside the binary and like we should discuss these things in biology. It should be taught … inclusive. That's something I didn't experience.

Similarly, Student 3 said, "I think a good start would be just to throw it out there to make it known that …[queer] people exist, they're normal."

Queer-Inclusive Content in Current Biology Courses. In contrast to the experiences of Students 3 and 4, Students 1, 2, and 5 did experience some content in their biology courses that challenged the master narrative of gender essentialism. These examples included plants that produce both eggs and sperm, lions with same-sex sexual behavior, lizards and fish that change sex over their life spans, and chromosome combinations beyond XX and XY. Instructors did not seem to intentionally hold these examples up to counter gender essentialism, but some of the students used them to bolster personal alternative narratives. For example, Student 5 described how they found the discussion of hermaphroditic plants interesting, particularly because sex and gender beyond the binary are often framed as only a human thing.

> My professor … was talking about hermaphroditic plants, so it was really interesting because it's something I never knew of and seeing how [queer sex and gender topics] that often seem just human are really just like ubiquitous in all of nature, even within plants … seeing the reality of hermaphroditic species in plants is really interesting. Because you see that sexual and gender variance, um, well sex, even within plants, who are so like the opposite of us.

However, Student 5 later pointed out that their instructor did not make this connection between plants and humans, so the example did not reach its true potential to validate queer identities. The student found the connection, but the instructor did not seem to.

> In any of these topics that have to do with sex or gender or even sexuality, I don't think they necessarily have to stay away from [sex and gender topics beyond the binary]. I think often, like, it would not be discussed the fact that … trans people exist, like, they would talk about hermaphroditic species and plants, but then or in other animals, but they wouldn't also talk about, like, we as people … There are examples within people and whatever somehow connecting on the topics, I think that would have improved my experience, and you know essentially ... [their] efforts have been neutral, [which] kind of hindered [me] a lot.

Hence, the small amount of inclusive material was beneficial for Student 5, and they used it to create a counternarrative. However, that counternarrative was not necessarily available to other students in Student 5's class who might not be seeking meaningful connections between their gender identity and biology.

Similarly, Student 1 discussed how their biology textbook brought in topics beyond the binary that the professor could have used to create a powerful and inclusive narrative in the classroom. Instead, the professor ignored them.

> Small subsections [about diverse animal sexuality] were mentioned in [the] textbook as exceptions … except biology has a lot of exceptions, you know. They make a huge difference, they make a completely other conversation. It is their adaptability. Lions just don't interact with other lions [referencing same-sex sexual behavior in lions from the textbook] because they're bored. There's a reason why they do certain things for survival, it's tied to their biology and it's just not a choice or decision. It's something that they're born with like how we humans are too…. We should have talked more about the exceptions, just as much as we talk about the main narrative. [There were] so many missed opportunities…. Yes, I wish the professors would have come up with more inclusive and diverse narratives to translate the textbook materials into the classroom. That would have made a huge difference, and I think it would be a wonderful learning experience, not

> just for LGBTQ students who are sitting in the classroom but for other students to be like wow this is new information, you know.

Textbook readings, as described, and out-of-class assignments were the primary means students noticed instructors bringing in potential alternative narratives. Student 2 described inclusive messaging around sexuality that was in one homework assignment:

> We're learning about genetics and DNA … [in a homework video] they were talking about … race and sexuality and how things need to be changed, what are you doing to change people's perceptions … and I was, like, okay. I see you [instructor]… you didn't speak about it in class … but he did assign that to us so that was nice.

In these instances, students noticed content that did challenge the master narrative of gender essentialism. Even though the small bits of inclusive content were beneficial for the students who experienced them, most of the students were not satisfied with the amount of inclusive content present in their courses. Interestingly, these counternarratives for gender essentialism could be seen as reinforcing the master narrative of biology as neutral, because none of these counternarratives were considered valuable enough to be emphasized in class. Instead, if they were included they were presented as rare exceptions and usually relegated to an out-of-class assignment.

Cautions. While most of the students wanted more queer identity–related content, caution and careful scaffolding may be important to make students feel safe to engage with this content. This is illustrated by an incident described by Student 2. Student 2 was placed in an uncomfortable situation when a fellow student asked their instructor if being gay was genetic during a discussion of Mendelian genetics and Punnett squares. This question made them feel uncomfortable, because they felt like sexual orientation was being distilled into a simple dichotomy, and the teaching assistant did not use the situation as an opportunity to discuss the complexity of polygenic traits. Student 2 did not feel that the question had merit because of the way the genetics of orientation had been used to undermine their own identity in the past. If one reduces genetics to only Punnett squares, then one can argue you cannot have a queer orientation if none of your relatives do:

> It's kind of something that people use as an excuse. They're like "oh she's gay because her cousin's gay." Especially in the Hispanic culture, they all think it's genetic which doesn't make any freakin' sense. It really doesn't. My mom she's very religious…. She was like there's nobody in our family who's gay so you're just confused. I'm really not. But yeah, that's why it made me uncomfortable because I guess my own experiences with that being used as an excuse.

This situation exemplifies not only the importance of scaffolding content but also how biology, in this case genetics, can be simplified to the point of creating harm. The translation of genes to phenotypes was being taught through the lens of Mendelian genetics. Although easy to understand, this framework is known to reinforce misconceptions of essentialism (see work in genetic essentialism: Donovan *et al.*, 2020) and does not capture how most phenotypes come to be. Most phenotypes, and especially complex behavioral phenotypes such as sexual behaviors, are polygenic and involve complex combinations of gene by environment interactions (Bailey *et al.*, 2016; Boyle *et al.*, 2017; Hales, 2020; Sanders *et al.*, 2017). Yet students were not presented with this model that would allow them to more accurately explore how orientation could be biological. Under the rules they had been taught about genetics, it makes sense that Student 2 did not understand how orientation could have a genetic basis.

This example illustrates some key elements to address as curricula on sex and gender are developed. It is important for instructors to understand the larger cultural contexts of their students and to provide students the tools they need to understand the real biological complexity that results in spectra. This means avoiding oversimplifying topics so students are not misled to think being gay is a simple genetic "on/off" switch.

The Power of Instructors to Create Change. All students, whether they did or did not experience content in their classes that challenged gender essentialism, discussed the authority that instructors have when they teach. Thus, instructors lend validity to what is taught within the classroom and implicitly invalidate ideas that run counter to what is taught. Because of this power, some of the students also saw the potential for instructors to help validate queer identities by teaching content that counters the master narratives of neutrality and gender essentialism. However, to do this, instructors needed to go beyond anything the students in our study experienced; simply adding this gender-inclusive content in as a reading or a homework assignment that is not discussed in class was not enough.

Given the power that instructors wield, all students thought it would be transformative to have instructors with gender identities similar to their own. Going beyond the power of representation, which has been well documented in previous research (Cooper *et al.*, 2019; Linley *et al.*, 2016; Sarna *et al.*, 2021), Student 5 explicitly articulated the power that queer instructors could have in the classroom, as they can use both the authority of their degree and teaching position, as well as the authority of their lived experience, to validate queer identities from multiple perspectives: "They speak with the authority of their degree … as a scientist. But also, they add into that their personal experiences, their lived experiences to further … prove whatever, um, is already being proven by the literature." However, the power dynamics that queer instructors experience, including the potential for hostility and exclusion by supervisors, peers, and students, add levels of complexity to their ability to be out in their classrooms (Russ *et al.*, 2002; Freeman, 2018; Cooper *et al.*, 2019; Gibney, 2019; Cech and Waidzunas, 2021).

CONCLUSIONS

The master narratives of gender essentialism and science as neutral were clearly prevalent in the experiences of the students with queer genders who participated in our study. This exclusionary framing of biology created a range of harm for our participants, one of whom left biology to become a humanities major. However, students also demonstrated resilience strategies, including seeking out information to create alternative biological narratives and being motivated by their desire to

change how biology is taught. The validation they found in these alternative narratives that highlight the diversity of sex, gender, and orientation in the biological world demonstrates the currently unrealized promise of a more gender-inclusive biology curriculum.

While our data are all from a small set of students at a single university, the existing literature on the climate of STEM and biology for those with queer genders or orientations indicates that the experiences of these students are likely common (Cech and Waidzunas, 2011, 2021; Cech and Rothwell, 2018; Freeman, 2018; Gibney, 2019). This small but growing body of literature has repeatedly found an unwelcoming climate in which queer genders and orientations were, at best, considered irrelevant. This irrelevance of identity in these studies aligns with the neutrality narrative our participants observed in biology classes. In this broader literature, an unwelcoming climate leads to devaluing the work of queer scientists, and this drives queer scientists to consider and make plans to leave STEM (Dyer *et al.*, 2019; Gibney, 2019; Cech and Waidzunas, 2021). Our paper contributes to this literature by providing additional evidence of the specific narratives that drive the unwelcoming climate, by identifying pathways through which students are resilient to this climate, and by introducing ways that instructors can create more welcoming classrooms.

Another finding in the literature is that students with queer orientations gravitate away from STEM and toward humanities majors (Hughes, 2018). The way our students contrasted the uncomfortable climate in their STEM classes with the welcoming one in some of their humanities and other non-STEM classes may help explain this pattern of leaving STEM. As described in *Theme 2*, Student 4—our student who left biology for a humanities major—discussed the extra "oomph" their humanities classes had because their identity was explicitly welcomed and discussed as part of the course content. It is also possible that the resilience strategy of searching beyond biology and STEM classes for queer gender and orientation content may contribute to the increased likelihood of queer people considering leaving STEM. As students seek information about their identities in other classes, they may leave STEM because they find their non-STEM classes much more welcoming. As Student 5 discussed in the career preparation section of *Theme 2*, they found biology to be continually demoralizing and the challenges of navigating their queer gender made persisting in biology more challenging. In their experience, humanities classes, in contrast, welcomed their queer gender.

Further Research and Limitations

The contexts in which students are situated may influence how much or the types of explicit signaling needed to help students feel included in biology classes. Context can be considered across multiple levels, including families, organizations, cities, and cultures. All of the students in our study discussed that they felt their queer genders were not welcome in their city of residence. While the goal of qualitative research is not generalizability, further studies that include a larger number of students from a range of contexts will be helpful for compiling a broader perspective of what may need to change in biology classrooms to create more welcoming environments for students with queer genders.

Beyond explicit signals of inclusion, there is also a need for research on how to create effective inclusive biology curriculum. The students in our study provided insights on what was noticeable to them both positively and negatively, but there is a lack of broader research on how to successfully dismantle gender essentialism through the biology curriculum. Extensive work on race and genetic essentialism has demonstrated the power of even a single biology class session to transform students' conceptions of race and genetic essentialism (Donovan *et al.*, 2019a). The focus of these curriculum changes was biology concept based: emphasizing polygenic traits (rather than simple Mendelian ones) as well as the variation in populations.

Finally, we need to understand what is upholding the master narratives of neutrality and gender essentialism from the instructor perspective. This will impact the tools and strategies needed to make biology more inclusive for students with queer genders. If it is lack of knowledge, awareness, or confidence facilitating discussions around this content, then educating people on the current science around sex and gender and developing curricula and facilitation guides that instructors could use in their classes will be promising steps. However, another challenging barrier could be STEM or institutional cultures. Queer-inclusive curricula may have the biggest impact in areas that are more queer-exclusive; however, instructors in these areas, particularly if they are queer themselves, face bigger challenges and risks if they teach more inclusively. While the legal climate in the United States has changed in some positive ways for those with queer identities, the actual climate for those with queer identities has become more hostile. In particular, acceptance of and support for queer people has declined among younger people, despite this demographic having the largest population of those with queer identities (GLAAD, 2019).

A Need for Action

Biology is the study of the vast diversity in how organisms live and is one of the few STEM disciplines in which sex (and possibly gender) are explicitly taught. The experiences of the students in our study, combined with their desire for more inclusive content, emphasize the importance of reconsidering how we teach the biology of sex, gender, and orientation. Even the counterexample in our cautionary section exemplifies the need for change: If queer-inclusive content is left out of the curriculum students may still bring it up. That can create situations in which instructors or teaching assistants are unprepared to respond, which could lead to particularly harmful outcomes.

The way biology is currently taught, students are largely, if not wholly, on their own to learn about the biology of sex and orientations beyond the gender essentialist narrative. Avoiding these topics and not teaching the tools students need to understand the biological complexities of sex and gender creates a harmful hole in the knowledge of all students. This gap in learning harms not only queer students but also cisgender and heterosexual students who go into medical and other fields where they are likely to work with individuals with queer genders and orientations. By avoiding these topics we are not teaching the most up-to-date, accurate science, nor are we preparing students with career competencies they need to be successful.

Because there are so many examples to choose from when teaching biology content, instructors have the power to make biology more or less inclusive. It may be lower awareness, knowledge, or comfort, rather than an explicit choice, that is

upholding master narratives of gender essentialism and neutrality in biology classes. Faculty in STEM disciplines do not often examine human dimensions in their research and so may be less aware of the developments that have advanced other disciplines' understandings of sex, gender, and orientation (Bilimoria and Stewart, 2009). In addition, having a queer orientation or gender is often perceived as irrelevant to STEM disciplines (neutrality narrative). Therefore, climate for individuals with these genders and orientations is not perceived as something that needs to be addressed (Gibney, 2019). Similarly, studies on biology content have found that it is an instructor's choices or their level of knowledge that maintains a predominantly "classic" view of sexual selection in biology classes and ignores changes within the discipline that promote more inclusive narratives (Fuselier *et al.*, 2016). Thus, raising instructor awareness is an important first step to make biology more inclusive for student with queer genders, to represent science more accurately in the classroom, and to better prepare all students to interact professionally with clients, patients, and colleagues of queer genders.

Clearly, instructor professional development is one important step for creating meaningful change at the content level. LGBTQ+ Safe Space trainings are a starting place, but it is important to go beyond them. To change the climate of biology classrooms for students with queer genders and orientations, we will need to change the content we teach to match a more current understanding of the biology of sex, gender, and orientation. We must also engage in conversations about science as a process and the influence of society on scientific progress. This may also mean providing guidance to instructors on how to facilitate productive dialogue during these conversations. Many of these changes are considered best practices in STEM teaching and align with one of the core guiding documents in undergraduate biology education: *Vision and Change* (American Association for the Advancement of Science, 2011).

Creating change in the classroom can feel overwhelming at times, but the students in this study had several concrete suggestions for their vision of a more inclusive biology classroom (Table 2). These suggestions range in complexity. In addition, we have listed some existing resources for making the biology curriculum more inclusive.

Students in our study wanted to see the diversity in biology represented in the biology curriculum. This would involve changing the biology content taught to better align with more current science on sex. Several collectives are currently working on creating more gender-inclusive biology curricula and share examples of how this can be done (Table 2). At the college level, Biodiversify and the Better Biology Network are developing and sharing such recommendations. For example, Biodiversify recommends that when instructors teach about sexual dimorphism or sex determination they should start by teaching the diversity of patterns in these traits in nature (Zemenick *et al.*, 2022). This simple change diversifies the stories being represented in biology classrooms and creates a more inclusive space. Gender Inclusive Biology is a group of K–12 science teachers who have developed guides to many topics in biology, including gender-inclusive pedigree charts and teaching about current events such as sex verification of athletes (Long *et al.*, 2021). These efforts are a strong start, and there is continued need for more curricular development and research on effective strategies to break down gender essentialism through the curriculum.

When creating change, there are no golden rules, and each class and student is different. Listening to students and fostering a learning culture that gives students space to express their experiences and perspectives is a crucial first step in building a more inclusive classroom. Even while embracing individual variation, there are some clear pathways forward from our study. All of the students wanted their biology instructors to explicitly create a more inclusive environment—something some of their humanities instructors were already doing, and something that is also good pedagogy (Dewsbury and Brame, 2019). Simply teaching the biological diversity in sex and orientation in the biological world will be a strong step toward creating an inclusive environment, because the science acknowledges and validates queer orientations and genders.

Students also suggested that when sex comes up in class, instructors should define and differentiate sex and gender

TABLE 2. Summary of student recommendations for creating more inclusive biology courses

Recommendation	Suggestions
Include the diversity within biology in the content taught	• Explicitly define and differentiate "sex" and "gender" • Include a range of examples, not just gender essentialist ones • Discuss inclusive examples as normal, not exceptions • Include inclusive readings and content throughout the course
Create an inclusive environment	• Create space for pronouns • Build classroom norms around difficult dialogue and respect • Be explicitly inclusive rather than staying "neutral"
Instructor personal education	• Learn about the diversity that exists within biology • Seek out resources to help you teach this diversity • Complete LGBTQ+ Safe Space training • Learn how to facilitate difficult conversations in class • If they exist, connect to diversity initiatives on campus for resources and support

A sample of available resources on making biology more gender inclusive:
Gender Inclusive Biology (K–12; adapting existing biology teaching to grow a gender-inclusive curriculum): www.genderinclusivebiology.com
Project Biodiversify (undergraduate; tools to diversify and humanize biology): https://projectbiodiversify.org
Better Biology Network (undergraduate; collaborative of gender studies, biology, and biology education researchers to make biology more gender inclusive): https://osf.io/43hwu/

and clarify which will be focused on in class. They were also interested in seeing instructors validate human genders and sexes beyond man and woman, as is consistent with current biological knowledge (even if the lesson then goes on to focus mostly on men and women). Another simple solution is creating opportunities to share pronouns in class. In our study, one student described instructors' approaches to pronouns as a key piece of information they use to determine whether an instructor is safe (however, the other four students did not mention it, which illustrates how the importance of things can vary). An instructor could implement this by sharing their own pronouns on the first day of class and giving students the option to share theirs if they are comfortable. This could involve passing out a note card and asking students to share different types of information (e.g., career goal, what they want out of the class, anything they want the instructor to know about them), including pronouns and if they use a different name than is on the course roster. Making the sharing optional for students is important, as this practice can impact students in different ways (from fulfilling a vital need to feeling harmful and exclusionary; Inclusive Ecology Section, Ecological Society of America, 2019).

There are beginning to be resources to support instructors who want to take on these suggestions for making their courses less neutral. For example, the Inclusive Ecology Section of the Ecological Society of America created a succinct guide about why and how to include one's pronouns in science contexts (Inclusive Ecology Section, Ecological Society of America, 2019), and the Society for the Advancement of Biology Education's LGBTQ+ special interest group (Cooper *et al.*, 2020) has provided suggestions for a more LGBTQ-inclusive biology. There are also an increasing number of guides for creating norms around difficult dialogue and respect that instructors can use (e.g. AWARE L.A; www.awarela.org).

Changes to the content and narratives in biology courses suggested above can be done incrementally, and even the smallest changes may create meaningful differences for students with queer genders. The impact of feeling seen can be transformative. In Student 1's words:

> [Having spaces and people that feel safe] made me feel that like I am worth taking up space, [that] the seat that I have at college is worth it, that I deserve a seat at the table…. It makes it feel like my life is not just existing, I'm actually living it. And to know that I'm not alone. In that sense it empowers me to live … it empowers me to just be me and be able to be successful being me.

ACKNOWLEDGMENTS

We thank our participants for sharing their experiences and time with us as well as Rebecca Atadero, Yoon Ha Choi, Monique Ross, and Josef Uyeda for their thoughtful feedback on early drafts of this article.

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