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We Can Update our Own Stories: Trans*-Informed Principles for Gender-Inclusive Science Teaching.

K. Ren Rende

ABSTRACT

RENDE, K. REN. We Can Update our Own Stories: Trans*-Informed Principles for LGBTQ-Inclusive Science Teaching. (Under the direction of Dr. Carla C. Johnson).

Across the United States, Anti-LGBTQ curriculum laws are being passed in staggering numbers, impacting an estimated 25 million children. At a time where a majority of LBGTQ students report feeling unsafe at school, a significant education challenge is how to meet the needs of these students while addressing and dismantling the way the institution of science education continues to uphold systems of oppression. While there have been waves of LGBTQ-inclusive science education reform, these movements have been stymied by a lack of cohesive guidelines for practice and are generally limited in their inclusion of considerations that attend to the needs of trans* and gender creative students.

In order to address the epistemic erasure of trans* voices and perspectives in LGBTQ-inclusive science education reform, this dissertation explored the gender-inclusive teaching practices of 10 trans*-identified science teachers with the purpose of learning from their experiences creating trans*-inclusive science curriculum. Using a qualitative research design, this dissertation collected three sources of data (interviews, instructional materials samples, and reflective teaching statements) in order to answer the research questions.

Emergent in the data was the overarching theme of *trans*-informed science education pedagogy* which encompassed the central philosophies and practices employed by the teacher participants. First, participant interview data revealed that teachers' trans* experiences impacted the development of their teaching motivations, desires to be visible trans* role models, and shaped their epistemological relationships to science as well as to science teaching and learning. Second, the triangulation of teaching materials and reflective statements with interview data led

to the identification of three teaching practices including *interrogating and accessing power, resisting essentialism,* and *embracing experiential knowledge and personal epistemologies*.

Together, these philosophies and practices lay the theoretical and conceptual foundation for a set of teaching principles that can guide teachers in implementing gender-inclusive science teacher through a trans*-informed lens. These recommendations implore teachers to Teach with Continuity and Authenticity, Center Epistemic Justice, Affirm Diversity, Embrace Scientific Complexity, Emphasize Experiential Knowledge and Personal Epistemologies, and Critically Assess Provenance and Validity when selecting gender-inclusive teaching materials. The findings of this dissertation are valuable to the science education community because they amplify and center the experiential knowledge of teachers whose voices are critically absent from conversations surrounding LGBTQ-inclusive science education practice. Moreover, the principles derived from trans* teachers' experiences can be used to guide other educators in making their science classrooms more trans*-inclusive.

We Can Update our Own Stories: Trans*-Informed Principles for Gender-Inclusive Science Teaching

by
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DEDICATION

To my trans* family, near and far, and especially to W and E who are my love, support, and reason for fighting.

BIOGRAPHY

K. Ren Rende was born in Pittsburgh, Pennsylvania and raised in Morrisville, North Carolina. They attended the North Carolina State University where they earned a bachelor's degree in Plant Science. After working in environmental education for a number of years, they received their master's degree in Multimedia Journalism with a focus on Science Communication from the University of Miami in Coral Gables, Florida. Ren spent many years as a practicing journalist then transitioned into a role as a science communication educator at a natural history museum. In the Fall of 2018, they enrolled in the Learning and Teaching STEM: Science Education program at North Carolina State University. Ren will be joining the University of Nebraska at Omaha as an Assistant Professor of STEM Education in the Summer of 2022.

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The word transgender has shifted and morphed both in its meaning and purpose since its conception in the 1970s (Clarkson, 2017; Stryker et al., 2008; Vicente, 2021; Zimman, 2017). Around the 1990s, transgender supplanted the word transsexual much of the North American literature (Moleiro & Pinto, 2015). Transgender was considered to be a more inclusive term that did not rely on transmedicalism for its definition of gender expansion (Moleiro & Pinto, 2015) and honored those who chose to live as a gender/sex different from that assigned at birth without medical intervention (Kronk et al., 2022). Between 2008-2011 the term expanded to encompass any person whose gender identity and/or gender expression differed from their assigned sex at birth. Today, transgender is still used as an umbrella term for a person whose gender identity does not necessarily match their assigned sex at birth, but also describes groups of people who transcend conventional expectations of gender identity and gender expression (PFLAG, 2021). Transgender now includes a multiplicity of identities beyond those that are trans-prefixed such as nonbinary, genderqueer, gender variant, gender diverse, agender, bigender, etc. (Kronk et al., 2022).

However, there have been waves of discourse within in the trans* community, particularly by trans* people of color, who feel that the word transgender does not fully capture their full, material, and embodied experience (Vicente, 2021). For this reason, I will not use the word transgender as an umbrella term in this dissertation except when referring to its incorporation into science education literature or when quoting or summarizing other work. Instead, I will use the designation trans* to honor the capaciousness of the community as it includes not only trans-prefixed identities such as transgender, transsexual, trans* man, trans* woman, but also other identities such as agender, genderqueer, intersex, nonbinary, cross-

dresser, two-spirit, and genderfluid (Tompkins, 2014; Vicente, 2021). Described by Halberstam (2018), trans* signifies "continuously unfolding categories of being organized around, but not confined to, forms of gender variance" (p. 4). Using the asterisk rejects the "certainty of diagnosis" and "keeps at bay any sense of knowing in advance what the meaning of this or that gender variant form may be, and perhaps most importantly, it makes trans* people the authors of their own categorizations" (Halberstam, 2018, p. 4). As the authors of their own categories, some with the above-listed identities may not identify as part of the trans* umbrella (e.g., some nonbinary and/or gender non-conforming people do not identify as trans*). Though the use of this term is an attempt to be wholly inclusive, total inclusivity and representation is not possible.

CHAPTER 1

INTRODUCTION

As of May 1, 2022, at least 20 states have introduced or passed "parental rights" legislation that bans the discussion of LBGTQ topics in schools (DiMarco, 2022; Rosky, 2017; Smith, 2022). While it is tempting to assume these bills would predominantly impact English or history classes, this is a huge problem for science education. School science has long been criticized as an institution that "propagates oppression" (Bazzul & Sykes, 2011, p. 269) for students who do not conform or align to entrenched cisheterosexual norms (Kumashiro, 2000). Standards, curriculum, and textbooks, are generally rife with misconceptions and misinformation that reinforce the idea that LGBTQ individuals aberrant and abnormal (Bazzul & Sykes, 2011; Gunckel, 2009; Letts, 2001). Wholly inaccurate conceptions such as a strict, biologically determined sex/gender binary lie in direct opposition to accepted contemporary science and students' own lived experiences (American Medical Association, 2021; World Medical Association, 2015). And once-common pedagogical practices such as separating students into groups based on gender, or using the words "mother" and "father" when discussing genetics or sexual reproduction fail to be inclusive or attentive to the needs of all students (Cooper et al., 2020; Long et al., 2021). Together, the onslaught of legislative attacks coupled with historically exclusive curriculum bombard LGBTQIA+ students with messages that they are unwelcome in schooling communities (Meyer et al., 2022).

As these bills gain momentum across the country they have attracted international attention and a snappy shorthand, "Don't Say Gay." However, the thing that makes the phrase so memorable obscures the fact that these bills are also very intentionally anti-trans* (Smith, 2022). Trans* erasure has been a longstanding issue in many mainstream LGBTQ-rights movements

(Smith, 2022) and education reform has been no exception (Airton & Koecher, 2019; Kean, 2020; Witcher, 2014). Therefore, while it is crucial LGBTQ-inclusive science education studies be done on behalf of all youth, regardless of sex, gender identity, gender expression, or sexual orientation, it is imperative work also be done to specifically "attend to the most vulnerablized population of queer youth to date, those that are trans+" (Miller, 2016, p. 1).

This dissertation explored the LGBTQ-inclusive teaching practices of trans*-identified science educators with the purpose of learning from their experiences creating trans*-inclusive science curriculum. The findings of this dissertation are valuable to the science education community because they amplify and center the experiential knowledge of teachers whose voices are critically absent from conversations surrounding LGBTQ-inclusive science education practice. Moreover, the findings contribute a set of principles derived from trans* teachers' experiences that can be used to guide other educators in making their science classrooms more trans*-inclusive. This chapter includes an overview of the state of LGBTQ and gender equity reform in science education as well an exemplar that highlights limitations of current efforts. It identifies the purpose of the research and corresponding research questions, describes the significance of the study, and provides an overview of the methods used as well as a glossary of definitions and important terms.

The Current State of Gender and LGBTQ Equity in Science Education Reform

Extensive research has shown that K-12 classrooms can be sites of hostility and trauma for LGBTQIA+ students, and particularly youth who are trans* (Kosciw et al., 2020). Negative school experiences adversely affect student health and academic performance which can have long-term physical, social, and emotional impacts (Meyer et al., 2022). Consequently, there have been recent reform efforts aimed at preparing science teachers to better address LGBTQ equity

in their classrooms. In 2019, the National Science Teaching Association (NSTA, 2019) released a position statement expanding gender equity to include LGBTQ students, challenging stakeholders to ensure that "*all* students of *any* sex, gender identity and/or expression, or sexual orientation—regardless of racial or ethnic background or ability—are empowered, challenged, supported, and provided full access to become successful science learners" (paragraph 1). Following their lead, the National Association of Biology Teachers (NABT, 2021) called for school science to transcend antiquated notions of sex, gender identity, and gender expression and to ensure that outdated and refuted concepts, pedagogies, and instructional practices do not perpetuate harmful stereotypes or misconceptions. Suggestions for inclusive practices included charging teachers, teacher educators, curriculum designers, administrators, counselors, and policy makers with understanding and disrupting the ways that language, curricular materials, pedagogical choices, and their own biases uphold inequity (NABT, 2021).

Problem Statement

Despite calls for advancing of gender equity in science education, there are substantial barriers that can incumber implementation of inclusive curricula and practices. For one, high levels of public scrutiny can make it challenging for educators to engage in teaching around politicized topics (Sadler et al., 2006). Studies have shown that classroom decision-making around teaching controversy is imbued with complexity and influenced by teachers' knowledge of the topics, personal beliefs and understandings, their perceptions of the beliefs of students, parents, and communities, and the degree of support they get from their administrators (Hildebrand et al., 2008). These layers can impede teachers' ability to negotiate controversy and can often lead to instructional choices that prolong problems rather than provide solutions (Scharmann & Harris, 1992).

Secondly, though recent studies have shown teachers are generally interested and willing to implement gender-inclusive curriculum, they lack the knowledge, resources, and support to carry out these practices (Eldridge & Hodges, 2022; Kean, 2021; Meyer, 2008; E. Payne & Smith, 2014). While the statements from the NSTA and NABT challenge stakeholders to become more equitable, they offer limited recommendations for how this can be accomplished. Without comprehensive and verified guidelines, teachers run the risk of contributing to the proliferation of resources that may be inaccurate, lacking in nuance, or directly damaging to queer and trans* students (Gorski, 2008).

A Case Study Example

A recently published article in *The Science Teacher* practitioner journal very clearly demonstrates the challenges of grappling with this complex educational issue. Partially autobiographical, the essay "Transgender Perspectives in the Biology Classroom" focused on how the author's experiences with a transitioning spouse influenced her teaching, of which she gives many examples and recommendations (Hobbs, 2020). However well-intended, the article was critiqued for a number of misrepresentations via two letters to the editors (Mackenzie et al., 2020). In the first letter, Kimberly Zieselman, the director of an advocacy organization for intersex youth addressed concerns about conflations between intersex and transgender experiences and the dangers of using sex trait variations to "justify" transgender existence (Mackenzie et al., 2020). Zieselman also identified commonly made conceptual errors about intersex conditions, such as Hobbs' claim that intersex variations are resultant of "differences in sex development" (DSD, e.g., visible genital variation) which is an outdated and disfavored medical label that ignores chromosomal, hormonal, and gonadal variations, whether they are obvious or not (Mackenzie et al., 2020, p. 10). Hobbs was also criticized for calling intersex

conditions “interesting” and minimizing the invasiveness of non-consensual surgical procedures that have lifelong “physical and psychological consequences” for children who undergo them (Mackenzie et al., 2020, p. 10).

The leading authors of a second letter were two trans*-identified science teachers who founded a free, online teacher education resource, Gender-Inclusive Biology (Sam Long and Lewis Maday-Travis) along with 61 transgender, nonbinary, and intersex educators and their allies who co-signed in support. Their letter critiqued Hobbs’ article for not providing “up-to-date factual knowledge or best practices for teaching about transgender topics” (Mackenzie et al., 2020, p. 8) and listed a number of issues including how the manuscript contained inconsistent and incorrect information about language and transgender identity, suggestions for practice that were likely to harm transgender, nonbinary, and gender non-conforming students, and specious misconceptions about transgender and intersex communities without contextualizing or dismantling the misconceptions. Fearing the spread of potentially dangerous misinformation, they asked that the article be immediately withdrawn from publication and a that statement be made acknowledging the highlighted issues (Mackenzie et al., 2020). They also suggested that Hobbs work with a consultant who could provide the expertise necessary to guide revision and re-release of the article. In a powerful concluding statement, Long and Maday-Travis implored the educators of the NSTA to listen to the voices of those in the transgender and intersex communities and to “trust the expertise of marginalized groups” (Mackenzie et al., 2020, p. 10)

Hobbs and the journal field editor, Anne Haley Mackenzie, thanked the authors for their letters, which were later incorporated into the following issue, but stood by the publication of the article without revision or redaction (Mackenzie et al., 2020). They provided the rationale that criticism it is to be expected given the “emotionally sensitive” (Mackenzie et al., 2020, p. 9)

nature of the topic and that "one article cannot possible address all the aspects of something as complex as gender" (Mackenzie et al., 2020, p. 8). In her response to Long and Maday-Travis, Hobbs also addressed that she shared the article with trans* friends in her community as presented her work at the 2019 Transgender Spectrum Conference at Washington University, a private institution in St. Louis, Missouri (Mackenzie et al., 2020). However, it is unknown if any of these consulted persons had either the scientific or educator expertise to assess the materials for their appropriateness in a gender-inclusive biology classroom. In her final statement as field editor, Mackenzie went on to call the piece compelling and a vital start to a conversation around issues that the "science education community as a whole has been silent on" (Mackenzie et al., 2020, p. 8)

However, for Long and Maday-Travis, the article was less the start of a "compelling" conversation and more a missed opportunity to serve transgender and intersex communities with accuracy and authenticity (Mackenzie et al., 2020, p. 8). Troubling for me, the refusal to redact, revise, or re-submit the article under the guidance of a community expert speaks, in-part, to the notion of silence Hobbs and Mackenzie are purporting to break. It is well-documented that trans* people have been largely excluded from involvement and research conducted within and about their communities and are rarely consulted in the way studies of trans* people are designed, conducted, or disseminated (Rosenberg & Tilley, 2021). Moreover, and acutely represented in the case study example, outsider perspectives on trans* considerations can frequently be "inaccurate, lacking nuance, or directly damaging" (Rosenberg & Tilley, 2021, p. 923). In their letter, Long and Maday-Travis addressed this specifically by calling into question Hobbs' choice to leverage her ex-spouse's mid-transition suicide attempt as a plea for readers to empathize and act on behalf of trans* people (Mackenzie et al., 2020). According to their statement, "there are

more affirming and effective ways to demonstrate the need for creating gender inclusive schools" than by centering trans* issues through a lens of victimization (Mackenzie et al., 2020, p. 9). Concerned by a lack of first-person perspective that could speak to the experience of suicidal ideation, they also feared Hobbs' discussion perpetuated the common myth that all trans* peoples struggle with suicidality (Mackenzie et al., 2020).

In her response, Hobbs divulged that her now ex-spouse had submitted articles to numerous journals that took a first-person experiential account of why teaching gender-affirming content is important in the science classroom (Mackenzie et al., 2020). All of these articles were rejected, she said, due to the first-person nature of the writing (Mackenzie et al., 2020). She further situated this example as rationale for the role of allies in magnifying calls for social justice and trans* rights, perhaps overlooking the ways in which she was speaking over, rather than amplifying, trans* voices. It is unknown which publications Hobbs' ex-spouse submitted to, but this response also speaks to a perceived preference for cis perspectives of trans* considerations in academic writing. An often-seen argument is that trans* people cannot be sufficiently objective enough to make unbiased contributions to scientific literature (Barsczewski, 2020). However, trans lived experiences are a valuable sources of knowledge and are critical for the production of meaningful scholarship (Kean, 2021).

The case of the *Science Teacher* article provides a useful example for illuminating how a lack of centralized and verified guidelines for teaching trans*-inclusive science may perpetuate potentially harmful classroom practices and resources. It also clearly demonstrates the need for trans* voices and expertise within the literature. According to trans* scholars, amplifying and emphasizing trans* lived experience as a source of knowledge begins with increasing the

visibility of trans* experts as well as endorsement of trans* lived experiences as a valuable sources of knowing (Martino & Cumming-Potvin, 2018; Nicolazzo, 2017, 2021).

Purpose Statement and Research Questions

The purpose of this study was to examine the work of trans*-identified educators in order to learn from their experiences creating gender-inclusive science classrooms. Emphasizing trans* lived experience as a source of knowledge, and increasing the visibility of trans* experts in science education, is vital for the development of pedagogies and practices that best attend to the needs of the trans* community (Kean, 2021; Martino & Cumming-Potvin, 2018; Nicolazzo, 2017, 2021). By situating the experiential knowledge of trans* science educations within trans*-created frameworks for critical education, this dissertation opens up the possibilities of trans*-informed research and teaching in order to strengthen gender-inclusive science education practices. The research questions that guided this dissertation are:

1. How, and in what ways, does the lived experience of being a trans*-identified science teacher shape the development of teachers' gender-inclusive science practices?
2. How do trans* -identified science teachers incorporate gender-inclusivity into their science curriculum and instruction?

Rationale and Significance

Given the lack of attention to trans* perspectives in LGBTQ-inclusive science education, it is vital that the field turn focus towards the inimitable expertise of trans*-identified science teachers. This dissertation is of value to the science education community because it amplifies and centers experiential knowledge and perspectives that are critically absent from current gender-inclusive science education scholarship. Moreover, this study illuminates best-practices

and principles that any science teacher can employ in order to make their gender-inclusive science teaching more trans*-inclusive. Together, the results from this study contribute to new conceptualizations of practice that can aid teachers in designing resources, adapting existing lessons, and evaluating public resources for trans*-affirming perspectives.

Summary of Methodology

This dissertation followed a qualitative research design. Three sources of qualitative data were collected in order to answer the research questions. First, interviews explored the lived experience of being a trans*-identified science teacher engaged in gender-inclusive science teaching (Marshall et al., 2021). Participants also provided instructional materials that they used in gender-inclusive science teaching, along with teaching reflections for each resource. The materials and reflective statements were used to triangulate data from the interviews (Yin, 2009).

In order to distill central themes, the interview transcripts, submitted instructional materials, and reflective statements underwent several rounds of inductive and deductive coding analysis. This analysis led to the identification of various themes that were then aligned to each research question. A more thorough explanation of the rationale for research approach, participant and recruitment, methods of data collection, and data analysis, including the coding schema, are provided in Chapter Three.

Conceptual Frameworks

Two conceptual frameworks were used to guide this dissertation, Kean's (2021) critical trans framework for education and Keenan's (2017) critical trans pedagogy. Grounded in multi-disciplinary perspectives (e.g., critical race theory, tribal crit, Black feminism, queer theory, and trans* studies) and their own personal experiences, Kean's (2021) framework provided a foundation for "illuminating the structural, institutional, and epistemological means through

which transgender oppression occurs" (Kean, 2021, p. 267). The framework is guided by three principles and seeks to (1) embrace the infinitely imaginative ways that gender is individualized (2) emphasize institutional administration and enforcement of gender within educational spaces, (3) distinguish trans* people as creators of valuable knowledge, and (4) provide educational tools that are useful in advancing gender justice in educational policy and practice. In this dissertation Kean's (2021) framework provided the theoretical lens for exploring trans* oppression and epistemologies in science education.

This guiding perspective was supplemented by Keenan's (2017) critical trans pedagogy which supports the fourth goal of Kean's (2021) broader conceptual framework. Keenan's (2017) framework includes four teaching practices, *Teaching with Honesty and Authenticity, Resisting Essentialism and Embracing Complex Knowledge, Unscripting Gender, and Resisting Definition,* and aims to help teachers embrace trans* epistemologies and experiences in order to make schools safer, more welcoming places for all students. Keenan's framework was used to guide an exploration of the current literature on gender-inclusive science pedagogy and formed the foundations of an a priori coding schema that was used in the analysis of trans* teachers' gender-inclusive science curriculum and practices. Though these frameworks have been used extensively in higher education, policy, teacher education, and LGBTQ-inclusive education, neither have yet been applied to studies in science education.

Critical trans framework for Education

Drawing together frameworks from education, educational justice, and queer and trans* scholarship, Kean's (2021) critical trans framework for education comprises three principles for teaching and learning that "celebrate gender diversity and center transgender experiences" (p. 262). With an emphasis on counternarratives, these principles provide guidance for undertaking

critical analyses of gendered power in education fields. While each of the principles will provide a guiding lens for this dissertation, significant focus will be given to the third principle which explicitly addresses epistemic erasure of trans* identities and the power of trans* epistemologies in challenging dominant narratives about gender in education spaces.

Kean's (2021) first principle "*Gender Operates on Individual, Institutional, and Cultural Levels*," understands that settler colonial conceptions of immutable, binary gender have served as dominating ideologies that enforce cisheteropatriarchy and policing of gender (non)conformity. In educational contexts, these enforcements exist across the several domains including, the personal, pedagogical, curricular, social, and institutional. At the individual level there is "no archetypical means" (p 263) through which all trans* people relate to their gender (Kean, 2021). Consequently, the enforcement of binary gender erases the infinite ways that trans* people exist within and experience the world. At the institutional level, binary gender is "administered and codified" (Kean, 2021, p. 267) into laws, policies, practices, record-keeping, physical arrangements, spaces, and traditions, which can render trans* identities illegible and unrecognized (Kean, 2021). At the socio-cultural level, gender norms and conventions are dictated by White cisheteropatriarchal standards which create and concentrate power away from marginalized communities (Kean, 2021).

Kean's (2021) second principle, "*Genderism is a System of Oppression that Interacts with All Other Systems of Oppression*," addresses how historical perspectives on gender equity in education research (e.g., women in science, LGBQ-inclusive science education) are situated in explorations of sexism and *heteronormativity* (the assumption that heterosexual identity is the universal norm) which lack the nuance to trouble gender in ways that are inclusive of trans* experiences. This is evidenced throughout the literature on LGBTQ-inclusive science education

which are frequently situated within feminist and/or queer theory (Wright, 2022). As an alternative, Kean (2021) offers the framework of *genderism* which highlights the ways that gender norms act as a means of social control for all people, not just those who belong to marginalized groups. Additionally, Kean (2021) elucidates how gender-based oppression works interdependently with other systems of oppression to form distinct marginalization for particular groups based on race, ethnicity, religion, language, ability, socioeconomics, and other identity-based power structures.

The third principle of Kean's (2021) framework, "*Epistemic Injustice and the Critical Importance of Trans* Experiential Knowledge,*" will provide the majority structure that will guide the methods and analysis of dissertation. Epistemic injustice, or epistemic violence (Spivak, 1998), is the colonial effect where the knowledge held by marginalized groups is routinely silenced and dismissed in order to privilege Western epistemic practices (Dotson, 2011). Identity erasure is not only a denial of basic human rights, but creates unsafe spaces where trans* people struggle to authentically show up for fear of being misunderstood (Kean, 2021). This epistemic harm is perpetuated across education research and practice and leaves trans* individuals unseen, underappreciated, and their contributions unrealized (Kean, 2021).

As a newly conceptualized framework, Kean (2021) invites researchers to explore its usefulness in the teaching, learning, and research of gender, and to contribute additional scholarship that adds clarification and additional rigor. Kean (2021) additionally offers suggestions for how their framework could be applied to research and teaching. Suggested actions include (1) moving beyond deficit and victim-centered approaches that ignore the resilience, creativity, and strengths that allow trans* students to thrive, (2) disrupting epistemic injustices that ignore, overlook, misrepresent, or erase trans* identities and perspectives, and (3)

participating in critical trans pedagogies (Keenan, 2017) that create safe and trans*-affirming spaces.

Critical trans pedagogy

Keenan's (2017) framework for critical trans pedagogy is comprised of four teaching practices including *Teaching with Honesty and Authenticity, Resisting Essentialism and Embracing Complex Knowledge, Unscripting Gender, and Resisting Definition*. According to Keenan (2017), the first principle means doing the constant work of understanding the ways that schools reinforce social functions of gender and suppress basic needs and self-expression. The second challenges teachers to reject oversimplified conceptions of the sex/gender binary and embrace the complexity inherent in nature (Keenan, 2017). To *unscript gender* is to reject the assumption that gender has any single definition or meaning (Serano, 207) and to encourage students to make their own meanings (Keenan, 2017). Finally, critical trans pedagogy should not seek to define or teach students the essential meaning of what it is to be trans* (Keenan, 2017). Doing so creates a false universality that only serves to build new, confining social scripts about gender (Keenan, 2017).

Definition of Terms

This glossary is meant to provide a thorough, but not entirely comprehensive, understanding of the significance of the terms used in this dissertation. In creating this glossary, I recognize that providing definitions for complex terms and experiences "reduces their meaning in anti-queer ways" (Duran et al., 2020, p. 114). Readers should be aware that terms and definitions are continuously evolving and often mean different things to different people. There are also no universal definitions for these terms. It is most important that each individual is allowed to define themselves and the terms that they use to describe their identities.

This section also contains terms that are not necessarily directly related to gender and sexual identities such as racism and ableism, but I have included them due to the ways that oppression impacts multiple, intersectional identities. These definitions were gathered from LGBTQ-led initiatives, organizations, and resource centers (e.g., GLAAD, n.d.; GLSEN, 2014; Human Rights Campaign, n.d.; PFLAG, 2021; UC Davis, n.d.; United Nations Human Rights Office of the High Commissioner, n.d.). This dissertation will also use the phrases LGBTQ-inclusive, GSD-inclusive, and gender-inclusive education interchangeably in and accordance with the NSTA's (2019) expanded conception of gender equity has been expanded to encompass LGBTQ identities and gender and sexual diversity. Where appropriate additional definitions or supports will be cited throughout the manuscript.

Ability: The quality of having the means or skill to do something. Ability is not permanent, can fluctuate throughout one's life, and is another aspect of diversity in our communities. Disabilities do not necessarily limit people unless society imposes assumptions that do not account for the variation in people's abilities (UCD, n.d.)

Ableism: The pervasive system of discrimination and exclusion that oppresses people who are disabled, including differences in mental, cognitive, emotional, and/or physical abilities, through attitudes, actions, or institutional policies (UCD, n.d.).

Ally or Allyship: The action of working to end oppression through support of, and as an advocate with and for, a group other than one's own (UCD, n.d.).

Asexual: An umbrella term used to describe someone who does not experience physical and/or sexual attraction. Some describe this as having a lack of attraction toward others or as the experience of not being sexually attracted to others. The term "Ace" is a colloquial abbreviation

often used to describe someone who is asexual, in the same manner "straight" is used to represent someone who is heterosexual (Cooper et al., 2020).

Being out: Not concealing one's LGBTQ+ identity (Cooper et al., 2020).

Being outed: When someone reveals an individual's LGBTQ+ identity without their explicit consent (Cooper et al., 2020).

Bigender: Having two genders, exhibiting cultural characteristics of masculine and feminine roles (UCD, n.d.).

Bioessentialism: Short for biological essentialism. Reliance or weaponization of biology in an attempt to disprove trans* people's genders (PFLAG, 2021). Common bioessentialist arguments reduce people to their chromosomes (though there are more than 30 chromosome combinations that people have); their genitalia (though there are many natural variations; or their binary gender (though gender and sex are not binary).

Bisexual: A person who is emotionally, romantically, or sexually attracted to more than one sex, gender, or gender identity though not necessarily simultaneously, in the same way or to the same degree. Sometimes used interchangeably with pansexual (HRC, n.d.).

Cisgender: A term used to describe a person whose gender identity aligns with those typically associated with the sex assigned to them at birth. This term is often shortened to simply "cis" (GLSEN, 2014).

Cisnormativity: The assumption that cisgender identity is the norm, which plays out in interpersonal interactions and institutional privileges that further the marginalization of transgender people (GLSEN, n.d.).

Cissexism/Genderism: The pervasive system of discrimination and exclusion founded on the belief that there are, and should be, only two genders and that one's gender or most aspects of it, are inevitably tied to assigned sex. This system oppresses people whose gender and/or gender expression falls outside of cis-normative constructs. Within cissexism, cisgender people are the dominant group and trans/ gender non-conforming people are the oppressed group (UCD, n.d.).

Cross-dresser: While anyone may wear clothes associated with a different sex, the term cross-dresser is typically used to refer to men who occasionally wear clothes, makeup, and accessories culturally associated with women. This activity is a form of gender expression and not done for entertainment purposes (see *Drag*).

Drag: The theatrical performance of one or multiple genders (often including makeup, costume, dance, lip-syncing, and temporary body modifications). Performers who present in a feminine manner are called Drag Queens, while performers who present in a masculine manner are called Drag Kings (PFLAG, 2021).

Endosex: Refers to people whose sex characteristics meet medical and social norms for typically 'male' or 'female' bodies (see Intersex).

Gay: A person who is emotionally, romantically, or sexually attracted to members of the same gender. Men, women, and people who identify as non-conforming may identify with this term (HRC, n.d.).

Gender: Socially constructed cultural characteristics that denote identities, e.g., women or men (note: this is different from sex-associated terms, including "female" and "male"). Gender is also used more broadly to denote a range of identities that do not correspond to established ideas of male and female, can vary from society to society, and can change over time. (Cooper et al., 2020).

Gender and Sexual Diversity (GSD): GSD is an umbrella term that encompasses LGBTQ+ identities (Meyer, 2008).

Gender Binary: A system in which gender is constructed into two strict categories of male or female. Gender identity is expected to align with the sex/gender assigned at birth and fit traditional expectations of gender roles and expressions (UCD, n.d.).

Gender Diversity: Umbrella term used to represent the spectrum of gender identities and gender expressions (UCD, n.d.).

Gender Dysphoria: A condition in which one feels discomfort or distress because their emotional and psychological gender identity is different from their biological sex assigned at birth (Cooper et al., 2020).

Gender Expansive: An umbrella term sometimes used to describe people who expand notions of gender expression and identity beyond perceived or expected societal gender norms. Some gender-expansive individuals identify as a mix of genders, some identify more binarily as a man or a woman, and some identify as no gender (see agender). Gender-expansive people might feel that they exist among genders, as on a spectrum, or beyond the notion of the man/woman binary paradigm. Sometimes gender-expansive people use gender-neutral pronouns (see Pronouns), but

people can exist as any gender while using any pronouns. They may or may not be comfortable with their bodies as they are, regardless of how they express their gender (PFLAG, 2021).

Gender Expression: External appearance of one's gender identity (e.g., behavior, clothing, body characteristics or voice) which may or may not conform to socially defined behaviors and characteristics typically associated with being masculine and feminine (HRC, n.d.).

Gender-Fluid or Genderfluid: A person who does not identify with a single fixed gender or has a fluid or unfixed gender identity. (HRC, n.d.).

Gender Identity: One's innermost concept of self as male, female, a blend of both or neither – how individuals perceive themselves and what they call themselves. One's gender identity can be the same or different from their gender/sex assigned at birth (HRC, n.d.).

Gender Modality: A newly conceptualized term, gender modality refers to how a person's gender identity stands in relation to their gender assigned at birth. It is an open- ended category which includes being trans and being cis and welcomes the elaboration of further terms which speak to the diverse experiences people may have of the relationship between their gender identity and gender assigned at birth (Ashley, 2022).

Gender Non-Conforming (GNC): A broad term referring to people who do not behave in a way that conforms to the traditional expectations of their gender, or whose gender expression does not fit neatly into a category. While many may also identify as transgender, not all gender non-conforming people do and vice versa (HRC, n.d.).

Gender Confirmation Surgery (GCS): Refers to doctor-supervised surgical interventions and is only one small part of transition (see transitioning below). Avoid the phrase "sex change

operation." Do not refer to someone as being "pre-op" or "post-op." Not all transgender people choose to, or can afford to, undergo medical surgeries. People should avoid overemphasizing the role of surgeries in the transition process (GLAAD, n.d.).

Genderqueer: Genderqueer people typically reject notions of static categories of gender and embrace a fluidity of gender identity and often, though not always, sexual orientation. People who identify as "genderqueer" may see themselves as being both male and female, neither male nor female or as falling completely outside these categories (HRC, n.d.). People who identify as genderqueer may or may not also identify as transgender (GLSEN, 2014).

Gender Roles: The strict set of societal beliefs that dictate the so-called acceptable behaviors for people of different genders, usually binary in nature (PFLAG, 2021). Many people find these to be restrictive and harmful, as they reinforce the gender binary (see Gender Binary).

Gender Variant: A term often used by the medical community to describe individuals who dress, behave, or express themselves in a way that does not conform to dominant gender norms (see *Gender Expansive*). People outside the medical community tend to avoid this term because it suggests that these identities are abnormal, preferring terms such as gender expansive (PFLAG, 2021).

Heteronormativity: Heteronormativity is the assumption that heterosexual identity is the norm, which plays out in interpersonal interactions and institutional privileges that further the marginalization of lesbian, gay, bisexual, asexual, and queer people (GLSEN, n.d.).

Heterosexism: The assumption that all people are or should be heterosexual. Heterosexism excludes the needs, concerns, and life experiences of lesbian, gay, bisexual and queer people while it gives advantages to heterosexual people (OHCHR, n.d.).

Heterosexual: Refers to a person who is emotionally, romantically, and/or physically attracted to a person of a different gender. Also referred to as *straight* (PFLAG, 2021).

Homophobia: The fear and hatred of or discomfort with people who are attracted to members of the same sex (HRC, n.d.).

Homosexual: A person who is emotionally and/or physically attracted to some members of the same gender. Many people prefer the terms "lesbian" or "gay", instead (GLSEN, 2014).

Hormone Blockers (also referred to as Puberty Blockers): Medical treatment which allows young trans* and gender-expansive people to prevent the potentially negative outcomes of going through a puberty that does not match their gender identity (PFLAG, 2021).

Hormone Replacement Therapy (HRT): Treatment which allows trans* and gender-expansive people to medically transition or feel more at home in their bodies (see Gender-Affirming Surgery and Transitioning).. Many intersex people take HRT to balance the naturally occurring levels of estrogen and testosterone in their bodies. Benefits of such therapy can include improved mental and physical wellness, and reduced anxiety and dysphoria, for those who experience it (PFLAG, 2021).

Intersectionality: Coined by Kimberlé Williams Crenshaw (1989), this term refers to the overlap of social categorizations or identities such as race and ethnicity, gender, disability, geography,

and class which exist in an individual or group of people that can contribute to discrimination or disadvantage (PFLAG, 2021).

Intersex: Intersex people are born with a variety of differences in their sex traits and reproductive anatomy. There is a wide variety of difference among intersex variations, including differences in genitalia, chromosomes, gonads, internal sex organs, hormone production, hormone response, and/or secondary sex traits (HRC, n.d.).

Lesbian: A woman who is emotionally, romantically, or sexually attracted to other women. Women and those who identify as non-conforming may identify with this term (HRC, n.d.).

LGBT: Abbreviation for Lesbian, Gay, Bisexual, and Transgender. An umbrella term that is often used to refer to the community as a whole (HRC, n.d.).

LGBTQ: An acronym for Lesbian, Gay, Bisexual, Transgender, and Queer or Questioning. An umbrella term that is often used to refer to the community as a whole (HRC, n.d.).

LGBTQIA: This acronym includes Intersex and Asexual communities along with Lesbian, Gay, Bisexual, Transgender, and Queer or Questioning (HRC, n.d.). Occasionally the 'A' has been understood to mean ally though this not unanimous and is often contested (Tinkler, 2020).

LGBTQ+ (or LGBTQIA+): The 'plus' is used to signify all of the gender identities and sexual orientations that are not specifically covered by the other initials (UCD, n.d.).

Lived Experience: To value the personal experiences of individuals as much as quantitative data. For example, believing narratives of discrimination against LGBTQ+ people persisting even if

they counter larger narratives of acceptance. The concept of lived experience as a criterion on meaning was coined by Patricia Hill Collins (PFLAG, 2021).

Misgendering: Attributing a gender to someone that is incorrect/does not align with their gender identity (UCD, n.d.).

Monolith: Refers to a large single upright block of stone, formally, and a group or organization with unified and unchanging attributes, informally. In context, the term monolith is used to show that "[group of people] are not a monolith." It means that members of a group have varying experiences, and the voice of one member of the group should not be taken as a representation of the experiences of all members of that group (PFLAG, 2021).

Nonbinary or Non-binary: An adjective describing a person who does not identify exclusively as a man or a woman. Nonbinary people may identify as being both a man and a woman, somewhere in between, or as falling completely outside these categories. While many also identify as transgender, not all non-binary people do. Non-binary can also be used as an umbrella term encompassing identities such as agender, bigender, genderqueer or gender-fluid (HRC, n.d.).

Oppression: exists when one social group, whether knowingly or unconsciously, exploits another social group for its own benefit (UCD, n.d.).

> *Individual Level:* a person's beliefs or behaviors that consciously or subconsciously work to perpetuate actions and attitudes of oppression (See internalized oppression)
>
> *Institutional Level:* Institutions such as family, government, industry, education, and religion have policies and procedures that can promote systems of oppression.

Societal/Cultural Level: community norms that perpetuate implicit and explicit values that bind institutions and individuals; social norms on what is valued, accepted, or desirable give the individual and institutional levels the justification for systemic oppression.

Pronouns: Linguistic tools used to refer to someone in the third person. Examples are they/them/theirs, ze/hir/hirs, she/her/hers, he/him/his. In English and some other languages, pronouns have been tied to gender and are a common site of misgendering (UCD, n.d.).

Queer: Umbrella term used to refer to any person whose sexual orientation, gender identity, and/or gender expression does not conform to dominant societal norms (GLSEN, 2016). Historically, queer as an umbrella term was most frequently used to describe individuals with diverse orientations. This term was previously used as a slur but has been reclaimed by many parts of the LGBTQ movement (HRC, n.d.).

Questioning: A term used to describe people who are in the process of exploring their sexual orientation or gender identity.

Race: A social construct that divides people into distinct groups based on characteristics such as physical appearance, ancestral heritage, cultural affiliation, cultural history, ethnic classification, based on the social, economic, and political context of a society at a given period of time (UCD, n.d.).

Racism: The systematic subordination of people from marginalized racial groups based on their physical appearance, ethnic or ancestral history, or cultural affiliation. Racism is considered a deeply pervasive, systemic issue perpetuated by members of the privileged racial group holding

dominant social power over others. Discrimination, prejudice, or xenophobia may be more accurate terms for describing individual acts of oppression. While these individual acts likely stem from systemic racism, at the individual level the power dynamics that enable racism are not at play in the same way (UCD, n.d.).

Reclaimed Words: As language evolves, some individuals and communities choose to identify with terms that had previously been used as slurs against them. The words are "reclaimed" and given new meaning, often imbued with a sense of pride and resilience. Examples include, "queer," and "transsexual," among others. It's important to remember that identity is unique to each individual; not all members of a community readily accept the use of reclaimed words, as they may still find them offensive and hurtful (GLSEN, 2014).

Sex: Refers to a set of biological attributes in humans and animals including genitalia, gonads, hormone levels, hormone receptors, chromosomes, and genes. May be called "*biological sex,"* "*physical sex*," or "*anatomical sex*" to differentiate from the act of sex. Note: The terms *biological sex* and *natal sex* have often been weaponized against the trans* community by those who consider sex to be immutable (e.g., once you are assigned a sex, you will always be a member of that sex).

Sex assigned at birth: The assignment or classification of people as male, female, intersex, or another sex typically based on visual identification of genitalia, but occasionally by sex chromosomes, hormones, expression of hormones, and gonads (TSER, 2015). Also referred to as *assigned sex* (APA, 2020).

Sexual Orientation (or Sexuality): Emotional, romantic, or sexual attraction to other people (HRC, n.d.). Sexual orientation is independent of one's gender identity (APA, 2020).

Straight or Heterosexual: A person who is emotionally and/or physically attracted to some members of another gender (GLSEN, 2014).

Transgender: A term describing a person's gender identity that does not necessarily match their assigned sex at birth. Transgender people may or may not decide to alter their bodies hormonally and/or surgically to match their gender identity. This word is also used as an umbrella term to describe groups of people who transcend conventional expectations of gender identity or expression—such groups include, but are not limited to, people who identify as transsexual, genderqueer, gender variant, gender diverse, and androgynous. (PFLAG, 2021). Being transgender does not imply any specific sexual orientation. Therefore, transgender people may identify as straight, gay, lesbian, bisexual, etc. (HRC, n.d.).

Transmedicalism: Also known as truscum, transmedicalists are people, both trans* and cisgender, who believe gender dysphoria and the desire to medically transition are criteria to being legitimately trans* (PFLAG, 2021).

Transitioning: A series of processes that some transgender people may undergo in order to live more fully as their true gender. This typically includes social transition, such as changing name and pronouns, medical transition, which may include hormone therapy or gender affirming surgeries, and legal transition, which may include changing legal name and sex on government identity documents. Transgender people may choose to undergo some, all or none of these processes (HRC, n.d.).

Transphobia: Animosity, discrimination, hatred, or dislike of trans* and gender-expansive people that often manifests itself in the form of prejudice and bias (PFLAG, 2021).

Transsexual: An older term that originated in the medical and psychological communities. Still preferred by some people who have permanently changed - or seek to change - their bodies through medical interventions, including but not limited to hormones and/or surgeries. Unlike transgender, transsexual is not an umbrella term. Many transgender people do not identify as transsexual. It is best to ask which term a person prefers. If preferred, use as an adjective: transsexual woman or transsexual man (GLAAD, n.d.).

Two-Spirit: A term used within some American Indian (AI) and Alaska Native (AN) communities to refer to a person who identifies as having both a male and a female essence or spirit. Non-indigenous people should not use this term (NPAIHB, n.d.).

Organization of Dissertation

This dissertation is organized into a five-chapter dissertation structure. Chapter One contains background information that situates the problem explored in this dissertation, a problem statement, a section describing the research purpose and questions, an overview of the methodology, a description of the conceptual frameworks used to guide the study, and a definition of terms. Chapter Two lays out an in-depth exploration of the extant science education literature with regards to trans* representation and epistemologies. Chapter Three describes the methods of the study including the rationale for the research approach, descriptions of participants and participant recruitment, methods of data collection and analysis, and a statement on positionality, validity, and reliability. Chapter Four contains the findings of the study as well as some contextual discussion of the identified themes. Chapter Five addresses conclusions, implications, and recommendations drawn from the findings.

CHAPTER 2

LITERATURE REVIEW

In this chapter I present a review of the literature that informed this dissertation. First, I discuss current research on school climate for queer and trans* youth as well as the impacts of LGBTQ-inclusive and trans*-affirming curriculum. Next, I briefly attend to the history of LGBTQ-inclusive curriculum in science education before exploring gaps in the extant science education literature with regards to trans* representation and epistemologies. Finally, I explore the alignment of two recently developed frameworks for gender-inclusive science education with Keenan's (2017) framework for critical trans pedagogy.

School Climate for LGBTQ+ Youth

The percentage of adults identifying as Lesbian, Gay, Bisexual, Transgender, Queer and Questioning (LGBTQ) in 2021 was 5.6%, up from 4.5% from their previous update in 2017 (Jones, 2021). While this number may not seem high, there is an upward trend of increasing number of young people identifying as gender expansive. According to the Trevor Project's 2021 National Survey on LGBTQ Youth Mental Health, as many as one in three LGBTQ youth (ages 13-24) in the U.S. identify as transgender and/or nonbinary (The Trevor Project, 2021). Understanding a changing demographic of students also means examining their experiences in school-based settings. Since 1999, the Gay, Lesbian, and Straight Education Network (GLSEN) has been conducting the biennial National School Climate Survey in order to document the effects of hostile school climates on LGBTQ students' educational outcomes and well-being (Kosciw et al., 2020). In addition to documenting student experiences, the survey also covers the availability and utility of resources and supports that may "offset the negative effects of a hostile school climate and promote a positive learning experience" (Kosciw et al., 2020, p. 1).

According to the report, hostile environments are the norm, with LBGTQ students reporting feeling unsafe at school because of their sexual orientation, gender expression, or gender identity (Kosciw et al., 2020). As a result of hearing anti-LGBTQ language and experiencing victimization and discrimination students reported avoiding school activities (71.8%) and functions (77.6%), feeling unsafe in bathrooms (42%) and locker rooms (43.7%), missing one day of school, or more, in a month (32.7%), or even changing schools entirely (17.1%) due to feeling unsafe or uncomfortable (Kosciw et al., 2020). Respondents to the GLSEN survey also generally indicated a lack of teacher support in their institutions. Less than 50% of the students sampled said they could identify more than ten supportive teachers in their school (Kosciw et al., 2020).

Negative school experiences have been shown to significantly impact LGBTQ students' academic performance, sense of belonging, and psychological well-being (Snapp et al., 2015). Students who experienced hostile school climates were less likely to feel comfortable expressing their sexual orientation and gender, had lower GPAs and attendance records, had lower self-esteem, and were less likely to report wanting to go to college (Kosciw et al., 2020). While the research shows that many LGBTQ students share similar experiences, these students also represent a diverse population, and these experiences can vary based on their personal demographics.

Gender Identity and Expression

Hostile school climates were also felt more acutely by transgender and nonbinary students than by their cisgender peers. Transgender students, including students who identified as transgender and male, transgender and female, transgender and nonbinary or genderqueer, or only as transgender, were more likely to feel unsafe and to experience victimization and

discrimination on the basis of their gender expression and gender identity (Kosciw et al., 2020). Within the report, an analysis of gender-related discrimination over time showed that while schools may be coming more accepting of transgender students' identity expression by honoring preferred clothing and chosen names and pronouns, they remain largely unchanged in restrictions on gendered and gender-segregated spaces and facilities such as bathrooms or locker rooms (Kosciw et al., 2020).

Nonbinary students—students who identified as nonbinary, bigender, agender, genderfluid, and nonbinary students also identified as male or female, but not cisgender or transgender—were less likely to feel unsafe compared to their transgender peers with regards to gender expression but were more likely than their transgender peers to feel unsafe based on their sexual orientation (Kosciw et al., 2020). Compared to cisgender LGBTQ students, nonbinary students were more likely to feel unsafe based on sexual orientation, gender expression, and gender identity; to avoid gendered and gender-segregated spaces; to report missing school for safety reasons; to experience in-school discipline; and to experience gender-related discrimination such as not being referred to by their chosen names and pronouns and being restricted from accessing locker rooms that align with their gender identity.

Race and Ethnicity

Students with multiple marginalized identities, including LGBTQ youth of color, experience identity-based victimization across intersecting systems of oppression (Crenshaw, 1989). For example, the transphobia that a Black, transgender student may experience also impacts the racism they experience and vice versa. According to the GLSEN report, all LGBTQ students of color experienced similar levels of victimization based on race/ethnicity with Black students being the most likely to feel unsafe (Kosciw et al., 2020). Many LGBTQ students of

color experienced victimization based on both their race/ethnicity and their queer identities. Native and Indigenous youth were overall more likely than other racial/ethnic groups to experience anti-LGBTQ victimization and discrimination (Kosciw et al., 2020). White students were less likely than all others to feel unsafe or experience victimization on the basis of race/ethnicity (Kosciw et al., 2020).

Impacts of LGBTQ+ Inclusive Curriculum

The GLSEN survey also documented the availability, utility, and impacts of LGBTQ inclusive resources and practices on student outcomes. Students who attended schools with LGTBQ-inclusive curriculum (e.g. positive representations of LGBTQ in course materials, LGBTQ-inclusive sex education, and access to LGBTQ-related information online and in school libraries), supportive educators (e.g., teachers who are openly supportive or put up Safe Space stickers or posters in their classrooms), inclusive school policies (e.g., anti-bullying policies and guidelines to support transgender and nonbinary students), and LGBTQ-related school resources (e.g. Gay-Straight Alliances/Gender and Sexuality Alliances) performed academically better and had greater overall feelings of safety and belonging than those whose schools did not offer these supports (Kosciw et al., 2020).

Despite its benefits, integration of inclusive curriculum varies widely by state and district. Currently, while some states require mandatory LBGTQ+ inclusive curriculum (Prescott, 2021) others have explicit anti-LGBTQ curriculum laws that prohibit or limit the discussion of diverse genders and sexualities (Rosky, 2017). Where inclusive curriculum, integration also varies widely across disciplines (Kosciw et al., 2020; Snapp et al., 2015). In one study, Snapp et al. (2015) found that students were least likely to indicate the presence of LGBTQ-inclusive curriculum in their mathematics/science courses (16%) compared to English/social studies (27%)

and sexuality education/health (40%). Similarly, according to the 2019 GLSEN survey, 66.8% of LGBTQ students surveyed reported that their science classes do not include any representations of LGBTQ-related topics in the curriculum (Kosciw et al., 2020). When representations were present, they were less likely to be positively framed (10.6%) as opposed to social studies (60%) or language arts classes (38%).

In a content analysis of eight biology textbooks, Snyder and Broadway (2004) found that when LGBTQ issues were present they were typically in reference to negative presentation of homosexuality as it related to the AIDS epidemic and drug use. Other textbook and curriculum analyses have explored the hidden normative curriculum in biology texts, which privilege heterosexual, cisgender, and endosex identities in descriptions of "normal" sexual behavior, biological sex, and gender roles (e.g., Ah-King, 2013; Bazzul & Sykes, 2011; Letts, 2001; Snyder & Broadway, 2004). Overall, the GLSEN survey reported that only 19.4% percent of students reported positive representations of LGBTQ topics, history, and individuals in any of their courses (Kosciw et al., 2020).

LGBTQ-Inclusive Curriculum in Science Education

There have been several waves of research theorizing best practices for approaching LGBTQ-inclusive science education reform (e.g., Fifield & Letts, 2014; Gunckel, 2009; Letts, 2001; Letts & Fifield, 2020; Wright, 2022). However, there is still a general lack of consensus from education communities on what constitutes an inclusive science curriculum (Wright, 2022). The existing literature contains an enormous diversity of thought with regards to the objects and beneficiaries of LGBTQ-inclusive education, the conceptual foundations of inclusive efforts, as well as differing perspectives on the desired outcomes and related practices associated with those goals (Airton & Koecher, 2019). As is the case with LGBTQ representation in school

classrooms, science education research has continued to lag behind other disciplines in understanding and conceptualizing what it means to be inclusive and for whom (Wright, 2022).

A New "Discourse of Invisibility"

In 1996, the National Research Council (NRC) proposed the *National Science Education Standards* (NSES) as part of a massive push towards science education reform. Included in the Standards was the principle of 'science for all Americans' and the insistence that equity "should pervade all aspects of science education (NRC, 1996, p. 16) and support all students "regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science" (NRC, 1996, p. 2). Though an admirable goal, the notion of Science for All also prompted criticism in how the principle lacked an explanation or rationale for why equity was given such a prominent position in reform protocols. In their critical review, Rodriguez (1997) described how the NSES promoted a 'discourse of invisibility' by failing to name the names of marginalized populations or to call out systems of oppression. Building off this critique, queer theory scholars keyed in on the lack of any explicit mention of "masculinity, femininity, sexuality, or minoritized sexual identities" agreeing with Rodriguez that any omission promoted a "biased, uncritical, and partial view of science education and science education reform" (Letts, 2001, p. 268). Over the last 20 years, scholarship has since been engaged in exploring how science and science education uphold and perpetuate oppressive systems for gender and sexual minorities, but the treatment and representations of those within these groups continues to be unbalanced, non-specific, or altogether absent.

"Who" Counts in LGBTQ-Inclusive Science Education

Within education, trans* considerations have largely been positioned as a component of LGBTQ+ issues. While signaling inclusivity, this has the potential for exclusivity, with the

acronym serving as a falsely unifying force (Knisely & Paiz, 2021). Using an applied linguistics approach, Knisley and Paiz (2021) recently explored how LGBTQ issues are presented in a multidisciplinary selection of curricula, textbooks, research, and pedagogy. They found that LGBTQ issues are typically framed holistically and with respect to the larger community, but that the content and examples found within are generally exclusive to gay and lesbian perspectives (Knisely & Paiz, 2021). When trans* considerations are conflated, or fail to be included, with other perspectives it can perpetuate invisibility and hinder the creation of more critical and equitable pedagogies (Knisely & Paiz, 2021).

Other scholars have written extensively about how the epistemic erasure of trans* identities, lived experiences, and material realities has severe consequences within the domain of education and educational research (Kean, 2021). The illegibility of trans* epistemologies has been identified as a particularly problematic aspect of teacher education programs as they leave teachers unprepared to address gender diversity or support trans* students (Athanases & Larrabee, 2003; Gorski et al., 2013; Macgillivray & Jennings, 2008; Meyer & Leonardi, 2018; Payne & Smith, 2014; Wright, 2022). In their review of 35 years of GSD- (gender and sexual diversity) inclusive teacher education (GSDTE) research, Airton and Koecher (2019) explored how 'gender and sexual diversity' are constructed as the "objects with which the field concerns itself" (p. 199). Since GSDTE's beginnings in the 1980's, scholarly works have predominantly focused on gay, lesbian, and queer students and teachers as the objects of consideration (Airton & Koecher, 2019). Though discussions of trans* individuals and experiences have been historically present in the GSDTE literature, they are notably underrepresented with only nine of 158 publications explicitly addressing either, with most being concentrated within the last seven years (Airton & Koecher, 2019).

The more recent "cleaving" (Airton & Koecher, 2019, p. 200) of trans* interests away from a historical focus on non-heterosexual identities is also present in academic science education literature. In the earlier years of LGBTQ-inclusive science education research (approximately 1995-2004), studies tended to be conceptual or theoretical critiques of the heteronormative nature of science education (e.g., Fifield & Swain, 2002; Letts, 1995, 1999, 2001) or, more specifically, normative representations of human sexuality in school science (e.g., Good et al., 2000; Reiss, 1998; Scholer, 2002; Smith & Drake, 2001). However, broader challenges to conceptual notions of sex and gender were also present. Though limited in scope, Letts (1995) uses the example of gender affirming surgery to challenge Western cultural discourse that emphasizes sex dichotomy over sex diversity. He asks, "Does anatomy determine sex? Do genetics? Who decides?" (Letts, 1995, p. 7). Though the article does show its age (e.g., using the phrases "sex-change" and "transsexual surgery"), it is the only publication from that time that explicitly explored sex conventionality from a transgender perspective. While other articles did address binary sex, they tended to focus most specifically on implications for intersex individuals and communities.

Articles from 2009-2014 advanced the use of queer analysis and critique to drive investigations and disruptions of heteronormativity in school science. Focusing less on individual identities, these articles often focused on gender and sexual diversity more broadly (Ah-King, 2013; Bazzul & Sykes, 2011; Broadway, 2011; Fifield & Letts, 2014; Gunckel, 2009; Lemke, 2011; Lundin, 2014; Milne, 2011). An article by Bazzul & Sykes (2011) was one of the first and only articles to concretely identify locations of and challenges to heteronormative school science in ways that specifically attend to transgender experiences. As with the earlier wave of research, sex diversity was most frequently positioned adjacent to discussions of intersex experiences.

A significant number of studies published between 2018-2021 were part of a textbook publication, STEM of Desire: Queer Theories and Science Education (Letts & Fifield, 2019), that further explored integrations of queer critique into various STEM disciplines. A few of these studies situated discussions of transness within a broadly queer approach but were not explicitly or directly trans*. Understandably, it could be said that a lack of trans* inclusion is due to the temporal nature of social movements. Though trans* people have always existed, momentum around trans* rights and visibility in education is relatively new compared to gay and lesbian rights which are more longstanding (Airton & Koecher, 2019).

Queer Theory and Trans Tensions*

Another contributing factor to the lack of nuanced trans* representations may be the varied conceptual and theoretical underpinnings that have guided scholarly research. In science education, trans* experiences and identities have most often been conceptually and theoretically connected to queerness. Extending beyond inclusion in the LGBTQ+ acronym, the word *queer* was near universally represented in the 42 articles examined for this literature review. Twenty-one of these studies explicitly contained some variation of the word queer (e.g., queered, queering) in the title of the manuscript and it was within these manuscripts that explicit references to trans* topics most often occurred

The word "queer" is inherently difficult to conceptualize by design, and thus most scholars avoid directly defining it in their research and teaching (Kean, 2020). Consequently, the high degree of variability in applications of queer within the literature is reflected in the varied representations of trans* as a constituent or counterpart. This phenomenon was recently explored in a review of trans* representation in teacher education programs (Kean, 2020). In a content analysis of syllabi, and through interviews with teacher education professors, Kean (2020) found

that the word queer was most often used (1) as identity label, (2) to refer to embodiment or expression, (3) to serve as an analytical or theoretical approach, or (4) as a political stance (Kean, 2020). Examining the science education literature using this structure, I also found notable similarities, and differences.

Queer as an Identity. In contemporary society, queer is most frequently understood as an adjective for describing sexual identity (Kumashiro, 2002), or more specifically "non-normative and/or non-hetero sexual identity" (Kean, 2020, p. 61). However, and in more recent history, queer has also been extended to describe any person with a non-normative gender identity, gender expression, sex, or sexuality (GLSEN, 2021). It should be noted that many trans* theorists and scholars have cautioned against the use of queer as an umbrella term that includes trans* identities (Martino & Cumming-Potvin, 2018; Namaste, 2000; Prosser, 1998; Salamon, 2010; Stryker, 2004). Many trans* people may feel uncomfortable using queer to describe themselves as they find fulfillment identifying within traditionally normative categories gender or orientation (Kean, 2021).

In their review of teacher education syllabi, Kean (2020) described that queer as an identity label was most frequently positioned in relationship to terms that reference or describe sexuality or sexual orientation such as heteronormativity, heterosexism, homophobia, and same- or opposite-sex relationships. Less frequently, queer was associated with terms that reference gender identity such as transphobia, cisnormativity, access to gender- and sex-segregated spaces, or pronoun/name changes (Kean, 2020).

By contrast, nearly all of the studies surveyed for this dissertation explicated the relationship between queerness and heteronormativity, but only a few selectively focused these discussions around sexual orientation (e.g., Ah-King, 2013; Good et al., 2000; Reiss, 1998;

Scholer, 2002b; Smith & Drake, 2001). Most included a more expansive conception of queer identity that challenged binary sex/gender categorizations as well as sexuality. This is a distinctly different trend than was found by Kean (202) suggesting may be a disciplinary effect as science, and particularly biology, are more concerned with sex and classification than other education fields.

In an effort to center gender creativity along with sexual diversity, some researchers discussed heteronormativity as it is related to cisgenderism, the "cultural and systemic ideology that denies, denigrates, or pathologizes self-identified gender identities that do not align with assigned gender at birth as well as resulting behavior, expression, and community" (Lennon & Mistler, 2014, p. 63). In their article describing fourteen recommendations for GSD-inclusive biology courses, Cooper et al. (2020) include disrupting cisnormativity and cissexism along with heteronormativity as a conceptual focus for LGBTQ-inclusive science education. Cisnormativity is the assumption that all people are cisgender and have gender identities that align with their sex assigned at birth (Cooper et al., 2020). It should be noted that the 26 authors that contributed to this paper include biology education students, faculty, and professionals who represent the identify as lesbian, gay, bisexual, transgender, queer, agender, and asexual, or as an LGBTQ+ ally (Cooper et al., 2020).

Queer as an Embodiment or an Expression. According to Kean (2020) queer as an embodied experience refers to looking or visually embodying being queer, including dressing, presenting, or behaving in ways that signal gender non-conformity. This theme was also represented in the science education literature. An essay by Knaier (2019) explored gender conventionality and gendered language in the "All Standards, All Students" appendix, and accompanying case studies of the updated Next Generation Science Standards (NGSS Lead

States, 2013). Knaier's (2019) findings described several case studies that made gendered assumptions about girls and boys having innately dissimilar science interests. In their essay Knaier (2019) poses the questions, "What is the difference between a "girl" interest and a "boy" interest? … Are these interests relevant only to gender-conforming girls?" (p. 212). Here Knaier (2019) challenges assumed gendered roles in the NGSS and interrogates what happens to students who do not conform to those roles. Another place in the essay Knaier (2019) writes that instead of assuming and reinforcing gendered-behavior that teachers "need to offer support to gender non-conforming students (e.g., girls who present masculine traits, boys who present feminine traits, and trans students)" (p. 213).

Though a small reference, this quote is important to address because of the way it erases trans* students who do identify and present in gender-conforming ways. It is typical language to include transgender, nonbinary, and gender non-conforming people together in one clustered phrase, but that does not mean that they are interchangeable. Broadly, *gender non-conforming* refers to people who have a *gender expression* that does not conform to traditional gender norms. While gender non-conformity does fall under the trans or trans* umbrella, it does not necessarily work the other way. There are many trans* people whose gender identity is outwardly expressed in ways that align with and conform quite intentionally to many traditional norms. Many trans* people might find being called gender non-conforming invalidating.

There is also an important distinction between queer bodies and embodiment and trans* bodies and embodiment (Kean, 2020). The intention of queer embodiment is to bristle against conventional norms of sexuality and/or gender expression, but not necessarily bodily materiality (Kean, 2020). By contrast, trans* scholarship acknowledges that embodiment can exist as a marriage between the self and flesh (Merleau-Ponty, 1964). For some trans* people, gender is

deeply tied to their bodies, and sex, and for others there is a looser connection between the two (Kean, 2020). Consequently, when queer perspectives of embodiment are used make sense of a trans* experiences it can limit or minimize the authority from which a trans* person is able to speak about their own understanding of their gender identity and personhood (Martino & Cumming-Potvin, 2018; Rodemeyer, 2017).

Under the tradition of trans* studies, and particularly Black transfeminism, other intersecting identities such as race, class, and ability are also essential to the embodiment of gender (Martino & Cumming-Potvin, 2018). According to simpkins' (2016) "dynamic materiality" identities, identifications, and subjectivities arise from material embodiment and are produced anew within changing contexts of marginalization and privilege, meaning that some bodies are able to move through society more easily than others. As identified in Kean's (2021) critical trans framework for education, genderism is a system of oppression that interacts with other systems of oppression. Under settler colonialism, bodies become societally organized into rigid and prescriptive categories which renders certain bodies as valuable and others as abnormal, inferior, and disposable (Keenan, 2017).

While they may have the same parentage, trans* studies has its "own trajectory and has the potential to address emerging problems in the critical study of gender and sexuality, identity, embodiment, and desire in ways that gay, lesbian, and queer studies have not always successfully managed" (Stryker, 2004, p. 214). The focus on subjectivity in trans* studies also extends compatibly to disability and intersex studies which similarly investigate embodiment outside normativity, but are not well-suited to queer embodiment frameworks that focus on sexual identity (Baril, 2015). Learning how to center the material experience of trans* embodiment can give teachers "valuable perspective on structural gender oppression and the specific barriers that

trans* bodies face within school contexts" (Kean, 2020; p. 62) such as the use of bathrooms, locker rooms, and other gender/sex segregated spaces.

Queer as an Analytic Approach. Queerness and transness can also extend beyond body, identity, or expression and exist in relation to epistemologies, methodologies, theories, and pedagogical perspectives (Duran et al., 2020). Queer analysis is grounded in and informed by queer theory which focuses on disrupting normative processes and problematizing anything (e.g., categories, identities) that appear to be fixed or stable (Britzman, 1995; Sumara & Davis, 1999). In the case of the science education literature, queer theory, and subsequently queer pedagogy, has reigned as the dominant theoretical perspectives with which studies have been concerned (Wright, 2022). In addition to interrupting the way science and science education are "explicitly heterosexualized" (Sumara & Davis, 1999, p. 316), queer theory is useful in critiquing normalized ways of knowing, being, and doing (Gunckel, 2009).

In their foundational article on queering science for all, Gunckel (2009) states that queering science education means "exploding binary gender and sexuality constructions, collapsing heteronormativity, and opening spaces within science education for the marginalized identities" (p. 69) by "exposing the social codes, forces, and institutional powers that interact to shape the ideas of what is normative or deviant at any particular moment" (Snyder & Broadway, 2004, p. 631). Here queer theory excels in disrupting the ways that stereotypes can reinforce harmful hierarchies for students with LGBTQ identities. However, by its theoretical nature of assuming binary dichotomies, queer applications to trans* experiences "may still promote gender role stereotyping by seeming to accept gender categories, even as it attempts to queer, i.e., destabilize them" (Nagoshi et al., 2018, p. 74). Born of feminist and sexuality studies, queer theory has been critiqued for failing to account for "the difference and specificity of trans*"

(Keegan, 2020, p. 385). Where queer theory is premised on critique and the need to examine the social stability of normativity through disruption of categories, trans* theory embraces non-normative understandings of gender and embodiment calling for a reimagining and reinhabiting of longstanding, though not necessarily always-conformed-to, gender norms (Mayo & Blackburn, 2020).

As a pedagogical approach, any person can participate in "queering" or engage in a topic "queerly" without having to necessarily identify as queer themselves (Kean, 2020). For example, queer pedagogy in the science classroom is often grounded within inquiry approaches (Wright, 2022). However rather than encouraging students to inquire into natural phenomenon, queer pedagogy asks students to inquire into the domain of science in order to "identify assumptions about what is considered normal, and by whom" (Gunckel, 2009, p. 70). Thus, through inquiry, queering education becomes as much about claiming all that has been previously unseen and unknown as it is about claiming equal rights (Gunckel, 2009).

As an alternative approach to queering education, trans* education scholars have proposed an aligned, but distinctly different, method for transing education. Drawing substantially from queer theory, Miller's (2016) pedagogy of refusal conceives that in the same way *to queer* is to question, *to trans** is to " cut across or go between, to go over or beyond or away from" (p. 2) ideas, concepts, and knowledges. Just as being trans* refuses definition (Kean, 2021; Keenan, 2017), a pedagogy of refusal encourages learners to refuse to accept essentialized constructions of ideas, gender, bodies, and identities (Miller, 2016). To refuse is to honor the way that trans* bodies become agentive and construct new ways of being through (a)gender self-determination (Miller, 2016). The (a) in front of gender infers that gender as a construct can be refused or shift infinitely over space and time. Though trans-pedagogy has not been explicitly

connected to science education, the processes inherent in transing aligns compatibly with our understanding of the nature of science which acknowledges that knowledge is tentative, creative, subjective, and socially embedded (Khishfe et al., 2017).

Queer as a Political Stance. Queer politics is a subversive and anti-assimilationist stance that requires all marginalized people to come together in a collective coalition to fight against all dominant norms and hegemonic systems of oppression (Jagose, 1996). Historically, queer politics was a reactionary counter to identity politics (e.g., gay and lesbian studies) which relied on the assumption that people with shared identities have shared goals or motivations (Kean, 2020). Queer politics, on the other hand, insist that shared identity can lead to a "exclusion and false universality" (Kean, 2020, p. 8). For example, though Caitlyn Jenner is a transgender woman, her conservative politics typically do not align with pro-trans* perspectives.

In their essay calling for a [re]consideration of queer theories in science education, Fifield and Letts (2014) explore the uneasy relationship between science education practices that are grounded in identity politics and those that use queer theory to interrogate the fundamental nature of science and education. In science education, identity politics are focused on ontologies of being(s) and involve increasing representation of voices that have been historically stereotyped, silenced, or pathologized in curriculum (Fifield & Letts, 2014). In the classroom this could include referencing the accomplishments of gay and lesbian scientists or discussing examples of non-heterosexuality in the animal kingdom. However, these often assimilationist actions can have the unintended outcome of feeding into the binaries of others-versus-the-norm (Carlson, 1998). This has implications for education in particular which is highly concerned with identity-based reform (Knaier, 2019). How can the field be concerned with supporting students

with marginalized identities, without naming them as experiencing identity-specific forms of oppression? (Rodriguez, 1997).

Trans* Perspectives in Studies of LGBTQ Teacher Experiences

As described in previous sections, trans* representations have been scant in the overall literature on LGBTQ-inclusive teacher education. Similarly, a lack of attention to trans* individuals is also apparent in studies focused on the experiences of LGBTQ teachers in K-12 classrooms (Suárez, 2021). In general, the limited works that do exist tended to focus on how K-12 educators navigate discrimination and transphobia in workplace environments (Suárez, 2021). Though these studies shed light on teachers' experiences, they tend not to focus on pedagogy or practice. Thus far, there have only been handful of manuscripts that have explored the connections between K-12 trans* teachers' epistemologies, experiences, and pedagogy. Using storylines as a poststructural method of inquiry, Wells (2018) documented that trans*-identified teachers possess unique insights into the ways that gender is performed, regulated, and understood in classrooms (Wells, 2018). However, this study focused mainly on teachers' experiences with transition, and did not offer many examples of impacts on pedagogies, classroom management, and engagement with students.

Self-studies of trans* educators' practices have led to the formation of various pedagogical frameworks, three of which have already been mentioned in this dissertation (e.g., Kean's (2021) critical trans framework for education, Keenan's (2017) critical trans pedagogy, and Miller's (2016) pedagogy of refusal). In general, each of these frameworks attends to a set of common goals including (1) inviting students to examine the ways that gender systems oppress all people in society, (2) preventing harm to trans* students, and (3) embracing trans* knowledge and experience. Notably, these frameworks are also not specific to discipline and can be used as overarching guidelines across classrooms and disciplines. It is likely that this dissertation is the

first of its kind to collectively explore the relationships between trans*-identified K-12 teachers' experiences, epistemologies, and pedagogical practices. It is almost certainly the only one to have explored these phenomenon in science education.

Because of its focus on pedagogical techniques (e.g., *teaching with honesty and authenticity, resisting essentialism and embracing complex knowledge, unscripting gender, and resisting definition)*, and broad disciplinary application, Keenan's (2017) framework is useful as an analytical and organizational tool for situating LGBTQ-inclusive practices within trans* epistemological perspectives. In the next section, I will use Keenan's (2017) framework of critical trans pedagogy to guide an exploration of two recently developed frameworks for gender-inclusive science education. The goal of this portion of the review is not to discount nor disparage the work done by others, but rather to add further academic rigor by focusing specifically on alignment of these frameworks to the theoretical and conceptual underpinnings associated with trans*-inclusive pedagogy.

Applying Critical Trans Pedagogies to Gender-Inclusive Science Education Frameworks

Within the last year, two publications have sought to address the need for comprehensive, verified guidelines for teaching about gender and sexual diversity in science education. Most recently, Wright (2022) conducted a systematic literature review and identified six core themes that undergird research on GSD-inclusive science education (see table 1). Drawn largely from theoretical and conceptual considerations, Wright (2022) contends that the themes constitute the foundational capacities that STEM educators need to build an understanding of in order to effectively integrate GSD-inclusive science education into STEM classrooms. According to Wright (2022) the ultimate goal of identifying these capacities was to provide an operationalized

definition of GSD-inclusive science teaching that enables institutionalization of GSD-inclusivity within teacher education programs.

Table 1

Wright's (2022) Six Core Capacities for GSD-Inclusive Science Teaching

Capacity	Definition
Heteronormativity	(Hetero)normativity refers to the curricular and pedagogical ways that STEM education reinforces gender binaries, constructs categories, and enforces normalization.
Social Justice	Social justice includes an awareness of the oppressive experiences of LGBTQ students and the curricular and student support resources for inclusion and representation.
Epistemic Knowledge of Science and Inquiry	Epistemic knowledge of science and inquiry includes embracing multiple ways of knowing, interrogating the authoritative character of academic knowledge, and creating sociocultural learning experiences.
Identity	Identity refers to the ways that STEM is not neutral or detached from identity development, moving past biologically deterministic views, and acknowledging the role of intersectionality.
Embodiment	Embodiment refers to facilitating embodied pedagogies that embrace students' sense of curiosity and wonder. It includes an understanding of the role that bodies and lived experiences have in knowledge production.
GSD Terminology	GSD terminology refers to the specific vocabulary related to sex, gender, and sexual orientation necessary for STEM educators to avoid binary language and move towards more inclusive vocabulary.

Note. Modified with permission from Wright, G. W. I. (2022). Queering science teacher education: Exploring changes in pre-service science teachers' attitudes and beliefs about gender and sexual diversity inclusive science teaching [Doctoral dissertation, NC State University]. Electronic Theses and Dissertation (ETD).

Second is the Gender-Inclusive Biology framework (Long et al., 2021) which was developed by the same trans*-identified secondary science teachers who developed Gender Inclusive Biology and critiqued the essay, "Transgender Perspectives in the Biology Classroom" (Hobbs, 2020). Published in *The Science Teacher* practitioner journal, Long et al. (2021) offer real-world strategies for teaching about gender, sex, and sexuality in biology classrooms. Long et al., (2021) purport that these attributes are not strictly reserved for biology education and "can be

used to guide any lesson to be inclusive of diverse gender, sex, or sexuality" (see Table 2). This framework is unique and may be the first science-specific framework for gender-inclusive education written by practicing teachers who also identify as trans*. The publication of this framework represents a key step in amplifying expertise of trans* educators and honoring the epistemological knowledge these educators bring to the teaching of gender and sexual diversity.

Table 2

Long et al.'s (2021) Principles for Gender-Inclusive Biology Education

Attribute	Definition
Authenticity	Provide accurate content and language that acknowledges both gender diversity and scientific precision. For example, "ovaries produce eggs" in meiosis, not "women produce eggs." Ask: Is the content accurate or oversimplified?
Continuity	Consistently include gender, where applicable, as one of many lenses for analysis. Begin with a diversity lens instead of teaching an oversimplification that is later changed for exceptions. Ask: Do we have a consistently inclusive lens or a special token lesson?
Affirmation	Highlight and celebrate the naturally occurring diversity of human and nonhuman species. Frame diverse phenomena, such as chromosomal intersex traits, with interested curiosity. Do not sensationalize or pathologize these variations. Ask: Do we normalize or stigmatize variation?
Anti-Oppression	Encourage students to identify and analyze the patterns that inform society's status quo. Help students recognize recurring injustices such as intersex genital mutilation, court-ordered sterilization and chemical castration of transgender and gay individuals, and sex verification in sports. Ask: Do we empower or marginalize groups?
Student Agency	Provide students choices and habitually incorporate a student feedback cycle. Students engage more when they explore their own questions and make decisions, especially in learning about gender, sex, and sexuality. Ask: Do we invite the sharing of student experience?

Note. Reproduced with permission from Long, S., Steller, L., & Suh, R. (2021) Gender-inclusive biology: A framework in action—Practical strategies for teaching about gender, sex, and sexuality in biology. *The Science Teacher, 89(*1), 27–33.

Teaching with Honesty and Authenticity

According to Keenan (2017) *teaching with honesty and authenticity* refers to using consistent, everyday interactions to directly trouble the ways schools reinforce social functions of gender and suppress self-expression. Rather than one-and-done approaches such as single day

trainings or only asking students to share their pronouns the first day of class, Keenan (2017) implores teachers to take up critical trans pedagogy as a constant practice of interrogating and responding to gender oppression. In their framework for Gender-Inclusive Biology education, Long et al. (2021) also advise that *continuity* is necessary for the long-term disruption of the negative messages about gender diversity that students are continuously receiving from the media and their families, peers, and schools. According to the Long et al. (2021), continuity is best achieved by consistently using gender as a frame of analysis throughout the entirety of a curriculum. This requires proactive planning and reviewing lessons and activities for consistent messaging, language, and terminology (Long et al., 2021).

Wright (2022) also explored the tensions between continuous and discrete GSD interventions in science education as they related to the capacity of *social justice*. Within the literature social justice approaches to integrating GSD-inclusivity were generally able to be categorized into two methods. The "add lgbt and stir" (Letts, 2002, p. 119) approach posits that the best way to disrupt social injustices is to explicitly expose oppressive climates and attitudes and to increase inclusion and representation of LGBTQ people, and their contributions, through curriculum, instruction, and teaching practice (Bazzul & Sykes, 2011). Recommendations included having LGBTQ guest speakers, watching films that include LGBTQ scientists, intentionally including positive representations of LGBTQ people in teaching materials, or having a dedicated portion of the curriculum to address the contributions of LGBTQ researchers to scientific enterprise (Cooper et al., 2020; Dzurick, 2018). The add and stir approach has numerous benefits including ease and immediacy of integration, however, these initiatives can often run the risk of being perceived as additional or tokenistic if not coupled with critical analysis or regular anti-oppressive practice (Mercer-Mapstone et al., 2021). Long et al. (2021)

also caution against tokenistic practices such as “one-time very special” (p. 30) lessons about gender and sexual diversity as these can contribute to a feeling of otherness and can create a lack of trust between LGBTQ students and their teachers (Gutzwa, 2021).

In contrast, ‘queer’ approaches were aimed at expanding inclusivity beyond representation and included explicit advancements towards addressing systemic inequities. According to Wright (2022), queer approaches to social justice generally focused on increasing the literacy and agency of students to participate more fully in questioning the constructs that have legitimized discrimination on the basis of sex, gender, and sexual orientation. In summarizing these perspectives Wright (2022) notes how the approaches themselves are intertwined within the literature with each offering strengths and weaknesses in terms of implementation and the tangibility and longevity of impacts.

Resisting Essentialism and Embracing Complex Knowledge

Keenan’s (2017) second principle asserts that educators need pedagogies that refuse the ways “strict, institutionalized, and categorial definitions” (p. 548) have created oversimplified scripts of sex and gender which contribute to systemic gender-based oppression. This is a particularly relevant point to science education which deals first-hand with scientifical knowledge constructed through genderist colonialist enterprise. Biological essentialism, the belief that all organisms have innate, immutable characteristics that give rise to specific differences between groups, provides much of the underlying scaffolding that has historically shaped the natural sciences. The conception of the sex binary, essential gender, masculinity, and femininity are themselves a part of a bioessentialist colonial agenda that sought to establish whiteness as superior by “scientifically” demonstrating that only white people had racially

evolved enough to display a clear distinction between sexual groups (DuBois & Shattuck-Heidorn, 2021).

Though disproven and heavily criticized as being biologically inaccurate (Smiler & Gelman, 2008), essentialist thinking continues to persist in everyday reasoning and perpetuates intolerant attitudes, prejudices, and biases about race, gender, sexual orientation, illness, and ability (Gericke et al., 2017; Glazier et al., 2021; Heine et al., 2019). Those who perceive others through the lens of essentialism are more likely to endorse social hierarchies (Mandalaywala et al., 2018) and be accepting of discriminatory practices (Skewes et al., 2018) and are less likely to support the rights of those with marginalized identities (Tee & Hegarty, 2006) or invest in efforts that promote social change (Wilton et al., 2019).

Resisting Essentialism by Identifying Normativity. Identifying and disrupting normative conceptions of gender and sexual diversity is typically listed as the overarching goal within a majority of the literature on GSD-inclusive science education (Wright, 2022). In their systematic review, Wright (2021) recognized *heteronormativity* as one of the critical capacities that science teachers must familiarize themselves with in order to engage in GSD-inclusive science teaching. This theme refers explicitly to the ways textbooks, standards, curriculum and pedagogy enforce normalization by reinforcing the idea of fixed or essential categories. Examples identified in the literature included textbook passages that framed sexuality as exclusively reproductive, pedagogical practices that neglect alternative family structures when talking about parentage, or curriculum that presents strictly dichotomous notions of gender and sex (Wright, 2022). As mentioned earlier in this paper, nearly all of the extant literature on GSD-inclusive science education is grounded in the goal of disrupting heteronormativity in classrooms and practice.

While disruption of heteronormativity maps neatly onto science as a discipline, focusing solely on heteronormative reproductions of gender may be limiting of trans* epistemologies. In their suggested application for the critical trans framework, Kean (2021) encourages teachers to ensure they are also attending to genderism, and not just heteronormativity or sexism, when they discuss oppressive systems related to gender and/or sexuality. Indication that a resource, lesson, or curriculum might not be trans*-affirming include conceptions of gender that only include cisgender men and women, or discussing sexuality, homophobia, and heterosexism, but not gender identity, transphobia, or cisgenderism/cissexism (Kean, 2021; p. 276).

Resisting Essentialism by Interrogating Authoritative Epistemologies. Within the science education literature other scholars have additionally suggested disrupting essentialism through questioning of the institution and epistemologies of science. In their theme of *Anti-Oppression*, Long et al. (2021) draw attention to the human endeavor of science. Specifically, creating a gender-inclusive biology curriculum requires identification of where science and oppression intersect to impact marginalized gender groups (Long et al., 2021). Engaging students in anti-oppressive inquiry practice includes helping them to understand that science involves "describing and explaining phenomena, not prescribing what *should* happen in systems" (Long et al., 2021; p. 31). Similarly, Wright (2022) describes that pre-service science teachers also need to possess an understanding of *epistemic knowledge of science and inquiry*. As represented by (2019), research exploring *epistemic knowledge of science* through *inquiry* has focused on the responsibilities of researchers and educators to embrace multiple ways of knowing and interrogate the authority of scientific knowledge through inquiry-based sociocultural learning experiences. Inquiry in and of itself constitutes a queer pedagogy as it "requires teachers and

students to inquire into science…to identify assumptions about what is considered normal, and by whom" (Gunckel, 2009, p. 70).

Aligned with the theme of resisting essentialism, Long et al.'s (2021) *affirmation* component also encourages teachers to question whether or not naturally occurring human diversity is embraced or sensationalized and pathologized. In the United States, the medical model of gender that arose in the early 20th century described trans* people as flawed individuals with mental illness rooted in mind-body incongruity (Keenan, 2017). However, gender creativity has been present throughout history and an held to high esteem in many indigenous cultures across the globe (Feinberg, 1992; Keenan, 2017). Rather being a flaw within individuals, trans* activist Leslie Feinberg (1992) argued that society is flawed for rigidly enforcing essentialism. Long et al.'s (2021) suggestions for practice included critiquing scientific models and learning how scientific knowledge "affects their identities and communities" (p. 30). Understanding *the identity* was also described by Wright (2021) in their six capacities for gender-inclusive science teacher education. According to Wright (2021) teachers need to be prepared to identify the ways that essentialist and deterministic views have shaped the way society views and values gender and sexual identities.

Resisting Essentialism by Embracing Scientific Complexity. The principal attribute in Long et al.'s (2021) framework for Gender-Inclusive Biology encourages teachers to embrace *authenticity* and "provide accurate content and language that acknowledges both gender diversity and scientific precision" (p. 28). To do this, materials, resources, and curriculum should be evaluated for whether the content presented, and terminology used, is accurate or oversimplified (Long et al., 2021). Oversimplification can easily occur when discussing sex, particularly when gendered terms are used describe biological processes in human and non-human organisms.

Examples of phrasing found in textbooks might be “male hormones” or “the mother cares for her offspring.” Instead, Long et al. (2021) encourage teachers to focus on the functional activity or role of organs and hormones as well as patterns and probability in nature when teaching about sex.

In December 2021, *Science* magazine published an article by three trans*-identified scientists that also addressed the importance of using accurate scientific language when discussing sex diversity in biology (Miyagi et al., 2021). Recognizing the “context-dependent and multidimensional nature of sex” (Miyagi et al., 2021, p. 1568) the authors call attention to the misappropriation of gendered terms and insist on precise language that focuses on the biological variables of sex. Examples included referring to specific chromosomes (e.g., x or y) rather than saying male or female chromosomes, identifying biological mechanisms rather than gendered outcomes (e.g., the T*df* gene leads to testicular development, not male development), or discussing bodily processes in gender-neutral ways (e.g., menstruating people instead of menstruating women). Long et al. (2021) also encourage emphasizing the biology of sex as context-dependent and multi-variate saying that terms like “male” and “female” need to be formally defined continuously across various contexts. For example, in genetics “male” and female” might be used to describe chromosomal variation while in an evolutionary context they might refer to gamete size (Long et al., 2021).

Unscripting Gender

If teachers wish to *unscript gender* they must reject the assumption that gender has any single definition (Serano, 2007) and recognize that the “meaning” of gender is bound to individual experience and inextricably linked to other normative systems of sorting such a race, class, and ability (Kean, 2021; Keenan, 2017). *Unscripting gender* in the classroom is to refuse

the way society has defined gender, and instead allow creativity and self-determination on behalf of the individual. As pedagogy of refusal (Miller, 2016), *unscripting gender* positions educators as dialogic partners who encourage students to make their own meanings of the varied contemporary language around gender for themselves (Keenan, 2017). By allowing students the agency to construct their own knowledge, they can develop the "language and practice necessary for a less violent organization of our bodies in the world" (Keenan, 2017).

In their framework, Long et al., (2021) also emphasize the importance of *student agency* in shifting towards a gender-inclusive teaching model. Encouraging students to ask questions, develop their own language, and giving them a protected space to voice concerns can create safer conditions for them to engage in material that may be deeply personal (Long et al., 2021). Challenging the rigidity of standardization, Keenan (2017) also encourages teachers to create avenues for all students to safely explore their own truths and embodied experiences with gender "as they understand it" (p. 552) and not as curriculum defines. One suggested practice is developing opportunities for experiential inquiry where students are encouraged to answer questions about the world through engaging with it directly (Keenan, 2017).

In Wright's (2022) review, the capacity of *embodiment* similarly attended to the need for teachers to foster students' embodied senses of curiosity for understanding and exploring lived perspectives of sex, gender, and sexuality (e.g., Adsit-Morris & Gough, 2017; Fifield & Swain, 2002; Gilbert & Gray, 2019; Gunckel, 2009; Santavicca et al., 2019). In their work on wonder in the science classroom, Gilbert and Gray (2019) sought to queer school-based science education through a critique of the rules, practices, and activities of science. According to the authors, school science has historically over-focused on cognition and lacked attention to the emotive and embodied parts of the learning process (e.g., awe and wonder). Consequently, this has caused a

crisis of interest (Tytler, 2007) which starves children of meaningful engagement with science in favor of memorization and recall of scientific 'truths'' and facts (Bazzul & Sykes, 2011)).

Criticizing the field of science education, and science itself, for demanding certainty, Gilbert and Gray (2019), and others, argue in favor of pedagogical vulnerability and embracing the discomfort of the unknowable through wonderment. Delicately distinct from curiosity, which is a drive to investigate or study, wonder is an aesthetic emotion involved in contemplation, questioning, and appreciating (Hadzigeorgiou, 2012). Queering science through pedagogical approaches grounded in wonder opens up the possibility for appreciating (1) the ways in which science is and will always be incomplete, (2) the multiple connections between scientific concepts, and (3) the beauty of scientific phenomena and the natural world (Hadzigeorgiou, 2012). To wonder queerly is to recognize how science 'facts' are "embodied, evolving, and given contested meanings by authors, teachers, and students, whose bodies of knowledge shape and are reshaped by cultural norms" (Fifield & Swain, 2002, p. 177) and to move towards a nurturing of fascination for the indeterminable complexities of the natural world (Gunckel, 2019).

Taking a slightly different approach, Gunckel (2019) also described queering science education as "asking the questions that science does not dare to ask" (p. 149). Likening queer theory to a microscope or telescope, Gunckel (2019) describes the theory as a powerful illuminator, bringing into view questions about prior knowledge, assumptions, explanations, and theories about what counts as scientific knowledge and who can participate in its constructions. Focusing, again, on embodied cognition, Gunckel (2019) also adopted Britzman's (1995) conception of the pleasure of knowledge-seeking as a sexuality which unchains the construct from the acts of sex and positions it as the driver of "human's insatiable quest for knowledge and

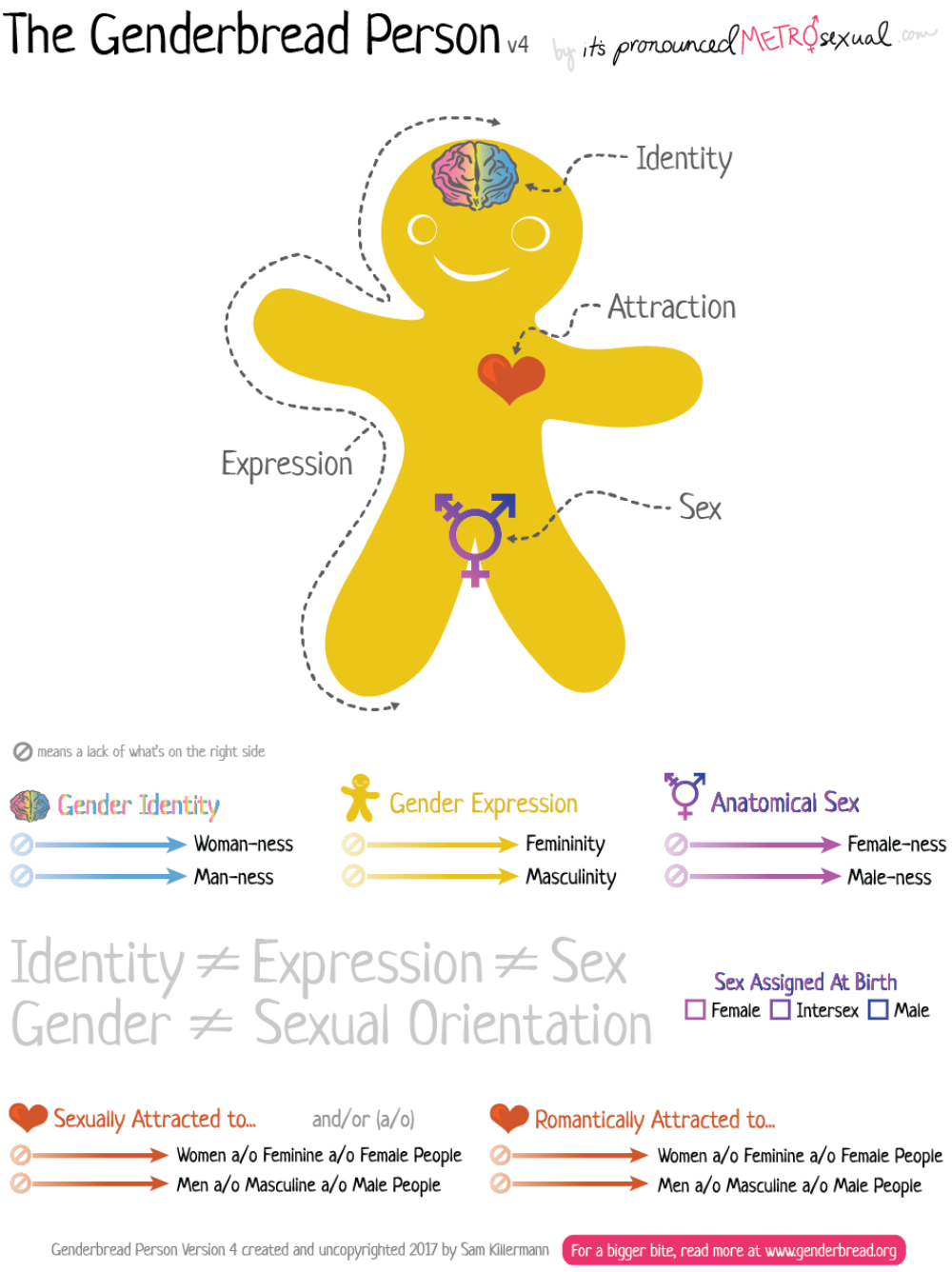
understanding" (p. 151). In this spirit, Gunckel (2019) calls for science education to embrace the mind and body as inseparable and find more ways to incorporate the bodily pleasures of learning in its practice.

Resisting Definition

In the final piece of the framework for critical trans pedagogy, Keenan's (2017) warns teachers about trying to teach students the essential meaning of what it is to be trans*. By definition, the word transgender was conceived to embrace the incredible complexity and multiplicity of gender and sex (Keenan, 2017). There is no universal experience of being trans*, and any attempt to define or categorize transness only serves to create new scripts that contribute to the policing of bodies and identities (Keenan, 2017).

Figure 1

The Genderbread Person



Note. Killermann, Sam, "The Genderbread Person" (2016). ESED 5234 - Master List. 52. https://digitalcommons.georgiasouthern.edu/esed5234-master/52

There are several examples of popular education resources that fall into the trap of redefinition. A frequently cited example is the Genderbread Person (Figure 1) which explains that sex, gender, and orientation are categorically separate and distinct from one another and exist in different locations within the body (e.g., gender is in your mind, sex is the physical characteristics of the body, and sexual and romantic attraction lie in the heart). While it is important to not conflate gender and sex when describing biological processes, it is also inaccurate to consider them completely separate and distinct concepts (Fausto-Sterling, 2017). The idea that sex is biological, and that gender is a social construct, oversimplifies the fact that sex is also a socially constructed premise that divides human beings into artificially rigid categories of sexual differentiation, and consequently, gender (Fausto-Sterling, 2017). When gender and sex are separated as existing in the mind versus in the body, it can reinforce bioessentialist rhetoric that being trans* is a mental disorder and that though a person can mentally change gender, they cannot physically change their sex. This is also something that is perpetuated with narratives such as "born this way" and "born in the wrong body" which are largely rooted in the pathologization of gender dysphoria and medical regulation of trans* bodies (Bettcher, 2014).

This does not mean that science or biology are not important when it comes to learning about sex, rather that conceptions and definitions are always limited by the social, geographic, historical, and cultural positions of our bodies in the world (Keenan, 2017). Consequently, it is important to be wary of "terms-and-definitions-based materials" (Keenan, 2017, p. 547) that only serve to replace old gender scripts with new ones. In summary, Keenan (2017) recommends that teacher engage in the continued practice of interrogating their own internalized scripts about

bodies, critically examine curricular materials for the presence of scripts, and support students in analyzing their own scripts and imagining a future that is liberated from scripted categories,

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

The ultimate goal of this dissertation was to identify best practices for teaching gender-inclusive science that are grounded in the inimitable expertise of trans*-identified science teachers. In this chapter, I present the data collection and analysis methods that were employed in order to answer the research questions: (1) How, and in what ways, does the lived experience of being a trans*-identified science teacher shape the development of teachers' gender-inclusive science practices? and (2) How do trans* -identified science teachers incorporate gender-diversity into their science curriculum and instruction. The following sections will describe the rationale for each research design, the research contexts and samples, data collection methods, and data analyses.

Rationale for Research Approach

This study followed a qualitative research design and utilized in-depth, semi-structured interviews and content analysis of instructional materials in order to answer the research questions (Marshall et al., 2021). Through interpretive models of qualitative research, focus is given to ascertaining how participants make sense of their personal and social worlds (Marshall et al., 2021; Smith & Shinebourne, 2012). Interpretive methods also allow for analytical analysis that honors the lived experience of the researcher as an interpretational lens (Alase, 2017). This is vital in a study where the researcher is conducting an investigation with in-community participants who also have shared life experience (Alase, 2017). From an epistemological perspective, qualitative approaches grounded in explorations of personal experience emphasize the importance of personal, subjective knowledge in cutting across normative assumptions and ways of knowing (Salamon, 2014). Consequently, interpretive qualitative research is uniquely

positioned to address the epistemological limitations of the current gender-inclusive science education literature, increase the visibility of trans* experts, and endorse trans* lived experiences as a valuable sources of knowledge (Martino & Cumming-Potvin, 2018; Nicolazzo, 2017, 2021).

Participants and Participant Recruitment

There is a wealth of professional and community organizing taking place in queer and trans* educator circles (Keenan, 2020). Many of these efforts have oriented towards providing professional development, teaching materials, and teaching methods that support the development of anti-oppressive and gender-inclusive science education and curriculum. Because this inquiry was focused on the experiences of a relatively homogeneous group of participants, purposeful sampling was conducted from amongst these organizations as they are generally comprised trans*-identified individuals who are intentionally engaged in trans* scholarship and practice. Because many of these groups are restricted to teachers and scholars with non-cisgender identities who may be targeted by anti-trans actors, I have chosen not to name the organizations in this manuscript in order to protect anonymity of the individual members.

Flyers that contained a link to a confidential recruitment form were distributed across the private email listservs associated with the above organizations. In addition to the link, the flyer referred to the nature of the study and the study requirements. Because many in the trans* community feel justifiably apprehensive about participating in studies led by cisgender researchers (Barsczewski, 2020), the form also identified the study as being trans*-led. The form was used to collect consent information as well as to screen participants for required criteria. This study required participants to self-identify as trans*, or specifically, not cisgender. Participants were also required to be teaching science as a full-time, grade 6-12, educator at a K-12 institution and purposefully integrating gender-inclusive science education curriculum and

teaching into their practice. Participants were not bound to any specific discipline/s of science education as inclusive practice can extend beyond content areas and include pedagogy, classroom management, and institutional efforts.

In total, ten trans*-identified teachers participated in the study, exceeding minimum suggested requirements (6-8 individuals) for an inquiry of this kind (Alase, 2017; Dare et al., 2018). Because qualitative research requires extensive time and energy components, participants were offered stipends of $275 for participating in data collection, which took approximately two months to complete. Table 3 includes participant's pseudonyms and their salient social identities as they related to the study (modeled after Gutzwa, 2021).

Table 3

Participant Backgrounds, Demographics and School Information

Name	***Gender Descriptors***	***Pronouns***	***Race / Ethnicity***	***Years Teaching***	***Grades Teaching***	***Teaching Discipline***	***School Information***	***School Locality***	***Geographic Region***	***Other Identities***
Harper	Femme genderqueer person	She/they	White	11-15	9-12	AP Bio, Earth/Space Science	Public School	Suburban	East North Central	Queer, first-gen college student, disabled
Jenna	Woman, trans woman, trans feminine, nonbinary, trans, transgender, transsexual	She/they	White	11-15	6, 8, 11	Biology, Chemistry, Earth and Environmental Science	Religious Private School	Urban	Middle Atlantic	Queer, lesbian, disabled
Ken	Trans masculine, trans guy	He/him	White	1-2	8	Biology, Anatomy	Public Charter School	Urban	East North Central	Working class, gay, disabled, first-gen college student
Kylie	Trans woman	She/her	White	6-10	7-8	Life science, Earth science, Physical sciences	Public School	Suburban	South Atlantic	Queer, working/middle class, bi-pan, lesbian
Liam	Trans man	He/him	Asian American	6-10	7-12	Biology, Anatomy	Public School	Urban	Mountain	First-gen Chinese-American-Canadian
Martin	Trans guy	He/him	White	16-20	9-12	Biology, Environmental Science, Anatomy	Public School	Urban	Middle Atlantic	Queer, gay, disabled
Parker	Trans, nonbinary	They/them	White	6-10	6-7	General Science, STEAM	Secular Private School	Suburban	Middle Atlantic	Queer, asexual, religious
Sparrow	Transgender man, trans masculine	He/him	Asian American	1-2	9-10	Biology	Public Magnet School	Urban	South Atlantic	Queer, first-gen Chinese-American, liberal

Table 3 (continued).

Steven	Trans, nonbinary	They/them	White	3-5	9, 11	Chemistry, Physical Science	Public School	Rural	Middle Atlantic	Queer
R. J.	Nonbinary, genderqueer	They/them	White	20+ years	9-12	Chemistry, Biology, Physics, Environmental Science	Secular Private School	Urban	Middle Atlantic	Queer, Jewish, disabled

Methods of Data Collection

Three sources of qualitative data (interviews, instructional materials samples, and reflective teaching statements) were collected in order to answer the research questions guiding this dissertation. The interviews included in-depth inquiries that explored the lived experience of being a trans*-identified science teacher engaged in gender-inclusive science teaching (Marshall et al., 2021). As a second data source, participants provided instructional materials that they had used to teach gender-inclusive science. Finally, participants were asked to draft reflective teaching statements that described the purpose and implementation of each instructional material submitted. The instructional materials and reflective statements were used to triangulate data from the interviews (Yin, 2009).

Qualitative Interviews

Three serial, in-depth interviews were conducted with each of the study participants (Seidman, 2006). These interviews took place approximately 7-10 days apart for each participant. Based on recommendations from Bevan (2014), the first interview was focused on assessing and contextualizing themes of interest. These interviews narratively explored the development of, and relationships between, teachers' trans*, science, teaching, and other salient identities. The second interview focused on apprehending teachers' current experiences (Bevan, 2014), specifically the day-to-day practice of gender-inclusive science teaching. The third interview further clarified the information obtained in the prior interviews (Bevan, 2014). In the third interview, teachers were encouraged to explore contextualization of their experiences within larger institutional and social systems.

Each interview followed Seidman's (2006) recommendation for interpretive research and included a semi-structured protocol with open-ended questions (Appendix A). Having a semi-

structured interview protocol allowed for engagement in dialogue that was defined by a purpose but allowed the participants to direct the conversation around their own experiences and perspectives. It also allowed the researcher to cover identical topics with each participant. Care was taken to not rely too heavily on the pre-written questions as a guide in order to keep the interview flexible to the experiences of the teachers (Bevan, 2014). During the interviews I implemented in enhanced member reflection, frequently repeating or confirming the interpretation and intent of the participants' statements using phrases such as "I am hearing you say…" or "can you confirm what you meant when you said…" (Chase, 2017). I also engaged in memoing during and after the interviews and recorded my ideas, thoughts, and reflections about the content and quality of the interviews to use in later analysis (Glaser, 1987).

With permission, participant interviews were electronically recorded by the researcher using NC State's secure Zoom platform. Interviews were limited to 50-70 minutes in length which will allowed participants to deliver rich descriptions of their experiences and provided ample time for probing further and asking additional clarifying questions (Adams, 2015). This length also limited researcher and participant fatigue (Adams, 2015). The audio files from each recording were transcribed for analysis. After anonymizing the transcripts, the original audio files were destroyed.

Content Analysis

This study also included a content analysis of instructional materials related to the teaching of gender-inclusive science. Using protected Google forms, teachers were encouraged to submit materials that were either positive or negative representations of gender-inclusive science teaching or practice. The researcher provided guidelines for elements that might constitute a positive versus negative resource (e.g., accuracy of concepts, presence of

misinformation, biases, trans* inclusivity, need for editing or modification), but ultimately teachers were given the flexibility to define positive versus negative materials according to their own interpretations (see Appendices, B and C).

Participants were encouraged to submit many different types of materials including lesson plans; activity and reading guides; pedagogical frameworks; graphics, diagrams, and models; videos; readings, scientific papers; news articles; or any other resource used in implementing gender-inclusive science education practices. Teachers were also asked to answer reflective questions related to the provenance, accuracy, and validity of the submitted material (Appendix B). If a material had been used in the classroom, teachers were asked to reflect on the effectiveness of the resource, any challenges they encountered in deploying it, and if they plan to use, adapt, or discard the resource in the future. For negative representations, teachers also answered a series of questions related to provenance, validity, and potential for negative impacts to students' learning and safety (Appendix C). The return rate of instructional materials was approximately 50%. Four individual participants submitted a total of 9 negative representations while six individual participants submitted a total of 18 positive resources.

Data Analysis

In order to distill the central themes of the study, the interview transcripts, submitted instructional materials, and reflective statements underwent several rounds of inductive and deductive coding analysis. According to Fereday and Muir-Cochrane (2006) a hybrid approach to coding and thematic development adds rigor and allows for more comprehensive identification the overarching themes present in the data. Two a priori code books were created during the deductive coding process. The first codebook was developed based on the theoretical frameworks that guided this study (Table 4). The coding categories included the third component

of Kean's (2021) critical trans framework for education (*experiential knowledge, and epistemic (in)justice*) and, relatedly, Keenan's four principles for critical trans pedagogy (*teaching with honesty and authenticity, resisting essentialism and embracing complex knowledge, unscripting gender, and resisting definition*). These codes guided exploration of Research Question One.

Table 4

Codebook One: Theoretical Perspectives

Codebook 1a: Kean's Framework for Critical Trans Education	
Capacity	*Definition*
Experiential Knowledge	Refers to knowledge gained through lived experience. May or may not refer to the trans* lived experience.
Epistemic (In)justice	Refers to issues of injustice related to knowledge (in) or acting against epistemic erasure or injustice (justice).
Codebook 1b: Keenan's Critical Trans Pedagogy	
Capacity	*Definition*
Teaching with Honesty and Authenticity	Refers to understanding the ways that schools reinforce social functions of gender and suppress basic needs and self-expression. Can also refer to engaging with one's own intelligible or unintelligible gender identity in school spaces.
Resisting Essentialism and Embracing Complex Knowledge	Resist reliance on oversimplified conceptions of the sex/gender binary and embrace the complexity and diversity inherent in nature.
Unscripting Gender	Reject the assumption that gender has any single definition or meaning and recognize that the "meaning" of gender is bound to individual experience and inextricably linked to other normative systems of sorting such a race, class, and ability
Resisting Definition	Individuals should not seek to define or teach the essential meaning of what it is to be trans*. Instead, encourage the multiplicity of lived experience and infinite capacity for self-determination.

A second codebook (see Table 5) was developed from the principles Long et al.'s (2021) frameworks for GSD/gender-inclusive science education (*authenticity, continuity, affirmation, anti-oppression, and student agency*) as well as the six capacities from Wright's (2022) literature

review (*heteronormativity, social justice*, *epistemic knowledge of science and inquiry, the identity, embodiment,* and *GSD inclusive terminology*). These codes, along with the codes from the first codebook, guided analysis of triangulated data used to answer Research Question Two.

The codes from the two schemas were checked for reliability by a second coder, a PhD student who had significant research experience and content knowledge related to LGBTQ-inclusive science education. To prepare for the calculation of intercoder agreement, I drew together a spreadsheet that contained examples of instructional materials that had already been triangulated with the reflective statements and relevant quotes from the interviews (if a teacher had mentioned the submitted resource during their interview). Together the two coders applied the schema to 40% of the examples and established an adequate reliability of 94% agreement (Miles & Huberman, 1994). The interview transcripts were coded using Atlas.ti, and the remaining materials and reflection statements were coded by hand using Microsoft Excel.

Table 5

Codebook Two: Conceptual Practices

Codebook 2a: Based on the Gender-Inclusive Biology Framework (Long et al., 2021)	
Attribute	*Definition*
Authenticity	Provide accurate content and language that acknowledges both gender diversity and scientific precision. For example, "ovaries produce eggs" in meiosis, not "women produce eggs." Ask: Is the content accurate or oversimplified?
Continuity	Consistently include gender, where applicable, as one of many lenses for analysis. Begin with a diversity lens instead of teaching an oversimplification that is later changed for exceptions. Ask: Do we have a consistently inclusive lens or a special token lesson?
Affirmation	Highlight and celebrate the naturally occurring diversity of human and nonhuman species. Frame diverse phenomena, such as chromosomal intersex traits, with interested curiosity. Do not sensationalize or pathologize these variations. Ask: Do we normalize or stigmatize variation?
Anti-Oppression	Encourage students to identify and analyze the patterns that inform society's status quo. Help students recognize recurring injustices such as intersex genital mutilation, court-ordered sterilization and chemical castration of transgender and gay individuals, and sex verification in sports. Ask: Do we empower or marginalize groups?
Student Agency	Provide students choices and habitually incorporate a student feedback cycle. Students engage more when they explore their own questions and make decisions, especially in learning about gender, sex, and sexuality. Ask: Do we invite the sharing of student experience?
Codebook 2b: Based Wright's (2022) Core Capacities for GSD-Inclusive Science Teaching	
Capacity	*Definition*
Heteronormativity	(Hetero)normativity refers to the curricular and pedagogical ways that STEM education reinforces gender binaries, constructs categories, and enforces normalization.
Social Justice	Social justice includes an awareness of the oppressive experiences of LGBTQ students and the curricular and student support resources for inclusion and representation.
Epistemic Knowledge of Science and Inquiry	Epistemic knowledge of science and inquiry includes embracing multiple ways of knowing, interrogating the authoritative character of academic knowledge, and creating sociocultural learning experiences.

Table 5 (continued).

Identity	Identity refers to the ways that STEM is not neutral or detached from identity development, moving past biologically deterministic views, and acknowledging the role of intersectionality.
Embodiment	Embodiment refers to facilitating embodied pedagogies that embrace students' sense of curiosity and wonder. It includes an understanding of the role that bodies and lived experiences have in knowledge production.
GSD Terminology	GSD terminology refers to the specific vocabulary related to sex, gender, and sexual orientation necessary for STEM educators to avoid binary language and move towards more inclusive vocabulary.

Though the preliminary codes guided the analysis of the data, coding was not exclusively confined to the predetermined codes (Fereday & Muir-Cochrane, 2006). Inductive codes were assigned to newly emergent themes that presented during analysis (Alase, 2017; Fereday & Muir-Cochrane, 2006). The coded statements were then further clustered into overarching patterns that were then aligned to the research questions. For example, in the first round of analysis with Codebook 1, the following passage was flagged as *teaching with honesty and authenticity* and *epistemic (in)justice* due to focus on how the participant worked to mitigate the ways that schools reinforce binary gender, suppress self-expression, and erase trans* identities. From this analysis, the sub-themes of *role models* and *visibility* emerged.

> Most of it was for the authenticity and also because if there are nonbinary or trans students in my class, I want them to see that we exist as adults [*role model* code]. That's really important, that visibility is important…[*visibility* code]…Being the person that I never had growing up who can also relate to certain students in a way that they're not able to relate to other teachers [*role model* code]. - Parker

The themes were then coalesced into an overarching pattern which described the thematic relationship, in this case, Trans* Representation/Role Models in K-12 Settings.

For Research Question Two, the same coding strategy was applied. First, I went through the interview transcripts and isolated any explicit discussions of pedagogical practice. Where applicable, individual's interview excerpts were triangulated with their instructional material submissions and corresponding reflective statements. The data was then coded according to Codebooks 1 & 2. Coding of this passage revealed alignment to several of the a priori codes.

> I do think that my trans identity [and my] science credentials has meant that I feel a lot more comfortable questioning stuff [*experiential knowledge*, *epistemic (in)justice* codes] and helping my students question stuff and making tiny moments of criticality [*anti-*

> *oppression* code]. We raise people's capacity to think about power in that way which helps them to push back against systems of oppression [*anti-oppression* code].

Thus, to home in on any overarching pattern, the excerpt was inductively analyzed to tease out pedagogical practice suggested by the participant, in this case, *Interrogating and Accessing Power*. For a full schematic of the relationships between emergent overarching themes and collapsed a priori and emergent codes see Table 6.

Table 6

Emergent Overarching Themes And Encapsulated A Priori And Emergent Codes

Research Question One: Experiences, Goals, and Philosophies	
Theme: Emergent Experience	*Encapsulated Codes*
Trans* Representation/Role Models in K-12 settings	Epistemic (In)justice (Kean, 2021), Teaching with Honesty and Authenticity (Keenan, 2017), Role Models (emergent), Visibility (emergent)
Trans* Epistemic Erasure in the Scientific Domain	Experiential Knowledge, Epistemic (In)justice (Kean, 2021), Resisting Essentialism and Embracing Complex Knowledge (Keenan, 2017)
Trans* Identity and the Nature of Science as Tentative, Creative, and Subjective	Nature of Science (emergent), Experiential Knowledge (Kean, 2021), Epistemic (In)justice (Kean, 2021), Unscripting Gender, Resisting Definition (Keenan, 2017)
Research Question Two: Gender-Inclusive Teaching Practices	
Theme: Emergent Practice	*Encapsulated Codes*
Interrogating and Accessing Power	Experiential Knowledge, Epistemic (In)justice (Kean, 2021), Resisting Essentialism (Keenan, 2017), Epistemic Knowledge of Science and Inquiry, Heteronormativity, Social Justice (Wright, 2022), Anti-Oppression (Long et al., 2021).
Resisting Essentialism: Affirming Diversity	Experiential Knowledge, Epistemic (In)justice (Kean, 2021), Affirmation (Long et al, 2021), Identity, Social Justice (Wright, 2022)
Resisting Essentialism: Embracing Complex Knowledge	Experiential Knowledge (Kean, 2021), Resisting Essentialism and Embracing Complex Knowledge, Unscripting Gender (Keenan, 2017), Anti-Oppression, Authenticity, Student Agency (Long et al., 2021), GSD Terminology, Identity, Social Justice (Wright, 2022)
Embracing Experiential Knowledge and Trans Epistemologies	Experiential Knowledge, Epistemic (In)justice (Kean, 2021), Unscripting Gender, Resisting Definition (Keenan, 2017), Student Agency (Long et al., 2021), Embodiment, Epistemic Nature of Science and Inquiry (Wright, 2022)

Researcher Bias and Positionality

My dedication to disrupting the epistemic erasure of queer, and especially trans* perspectives, in science and science education is undoubtedly connected to my own identity as a bisexual, non-binary, and transmasculine science educator. I came out as bisexual when I was a freshman at a rural/suburban, middle-class high school. Though there were two other out students at the time, and the climate was reasonably accepting, my coming out was treated with fascination and fetishization. As a femme-presenting person, I had many of the (unfortunate) experiences that bisexual women and femmes often endure, including being perceived as overly sexual or "not able to make up my mind," and was treated as a threat by other students who were worried that I would make undesired advances at them or their partners. As a result, I repressed a core part of my identity, finding safety, but also erasure, through straight-passing relationships. At the time there was no positive representation of bisexuality in K-12 spaces and the majority of popular media, if it even addressed bisexuality at all, reinforced and perpetuated the stereotypes that contributed to my negative in-school experiences.

It wasn't until coming back to NC State as a graduate student that I began advocating for the empowerment of LGBTQ students in STEM education. I joined the GLBT Center (which did not even exist when I was an undergrad) as a core member of the Out in STEM program. It was here, in my adulthood, that I began to find myself again as bisexual and realized that I was also non-binary. It has been four years since I began my transition, though I only felt empowered enough to come out to my colleagues and peers mid-way through my doctoral program as the exponentially increasing legislative attacks on trans* rights became too oppressive to my life to ignore. Though I had joined my program desiring to work in LGBTQ-inclusive education, I did not feel empowered or supported enough to truly do so until then.

The institution of schooling is not a culturally or politically neutral space, nor is the domain of science education. And while there have been attempts to address these issues, the field still struggles with honoring and accommodating trans* people and their perspectives. I acknowledge that having knowledge of these limitations, coupled with my desire for trans* epistemic justice, influenced my decision to pursue this research and certainly informed the methodological choices employed in the study. However, it is likely that my trans* identity and educator background afforded me a semblance of trustworthiness to a group who is understandably apprehensive of research conducted about their communities. The established trust of speaking with an in-community researcher with shared experience may in-turn have created an environment where participants felt more comfortable sharing information they may have withheld in other circumstances. During the interviews, my own knowledge of trans* history, experience, and epistemologies helped me to ascertain nuance that might have been overlooked by a cisgender researcher. Thus, in lieu of implementing an impossibly rigid set of rules for extracting myself from the data collection and analysis, I engaged in numerous techniques that helped me to remain reflexive (e.g., memoing), and honor the intentions and interpretations of the participants themselves (e.g., member reflection).

Chapter Summary

The interpretive qualitative design used in this dissertation guided the exploration of two research questions: (1) How, and in what ways, does the lived experience of being a trans*-identified science teacher shape the development of teachers' gender-inclusive science practices? (2) How do trans* -identified science teachers incorporate gender-inclusivity into their science curriculum and instruction? Three sources of qualitative data were collected. In-depth qualitative interviews explored the lived experience of being a trans*-identified science teacher, while

instructional materials and reflective teaching statements homed in on the specific pedagogical practices employed in gender-inclusive science teaching. The interview transcripts, submitted instructional materials, and reflective statements underwent several rounds of inductive and deductive coding analysis. This analysis led to the identification of the central theme of interest as well as various sub-themes that were aligned to each research question. These findings will be presented in Chapter Four.

CHAPTER 4

FINDINGS

This dissertation explored the lived experience of trans*-identified science teachers' engagement in gender-inclusive science teaching through in-depth interviews and a content analysis of instructional materials. While the experiences of individuals are contextual and unique, analysis of the data uncovered several commonalities which were identified as the central theme of *trans*-informed science education pedagogy*. Presented by research question, the theme is described from two perspectives.

- For Research Question One (RQ1), qualitative data from the interviews were analyzed to identify how, and in what ways, trans* lived experience shaped the development of teachers' gender-inclusive science practices. The findings presented in this section are focused on how being trans* impacted the formation of participants' teaching motivations, goals, and philosophies.
- For Research Question Two (RQ2), instructional materials and reflective teaching statements were triangulated with the interview data to specifically describe how teachers incorporated gender-inclusivity into their science curriculum and instruction.

RQ 1 – Lived Experience and the Development of Gender-Inclusive Science Pedagogies

Participant interview data revealed that teachers' trans* experiences impacted the development of their teaching goals and philosophies in a variety of ways. First, experiences with epistemic erasure influenced participants motivation to become educators. Participants also explored the benefits and challenges of being an out and visible trans* teacher. Finally,

participants reported that being trans* fundamentally shaped their epistemological relationships to science as well as to science teaching and learning.

Erased Identities: The Challenges and Benefits of Being a Role Model

One of the primary emergent patterns in participant narratives (n = 8) was how growing up without trans* representation in their K-12 classrooms influenced their desires to be out and visible teacher-role models [*role models, visibility* emergent codes]. These themes typically manifested adjacent to the code for *epistemic (in)justice* (Kean, 2021) as well as *teaching with honesty and authenticity* (Keenan, 2017) which referred to the ways that showing up reliably, and with authenticity, as a trans*-inclusive teacher can directly trouble the ways schools suppress gender self-expression, self-determination, and trans* identities and experiences.

Though all participants described the connections between lack of trans* representation and their desires to be out in the classroom, the interviews were nuanced according to individual factors. For those participants who had come to understand their trans* identities during childhood, school was an isolating experience that left them feeling othered and unseen. Teachers who realized their transness as adults, recalled that had there been positive, visible trans* role models around when they were young, they might have transitioned sooner. Regardless of their transition trajectories, the participants unanimously agreed about the importance of being the queer and trans* representation they themselves were not afforded. Many of the participants (n = 4) also reflected on how the desire to be a role model also meant assuming the risks that come with visibility (e.g., transphobia and discrimination). These risks were perceived as much more significant by trans feminine participants.

R. J. In their interview, R. J., a high school science teacher with over 20 years' experience, reflected on their wish to make the world a better place for LGBTQ youth. They

described how growing up without representations of nonconformity directly influenced the development of their activist and teacher identities. Despite living in a large, metropolitan city, R. J. was in school during a time where most queer and trans* people kept their identities private.

> I was in high school from 1987 to 1991. I don't think any kids were out as gay, let alone as trans. There was one art teacher that we knew was gay. I don't know how we knew, and we suspected one or two other teachers were gay, but nobody was out [*visibility* code].

In their struggles for representation, R. J. and their high school friends found themselves drawn to subversive culture and into social, political, and environmental activism.

> I made friends from all around [the area], and we had our own little click of kids who rejected everything else. I've always been interested in science. I was really active in the environmental and animal rights club. That was my clique. Besides hating on everything. We also were politically active. We hated mainstream everything. We hated popular culture. We hated whatever else everybody was doing. It was antithetical to our idealism and our passion for activism and making the world a better place.

While working in environmental activism through college, R. J. started to consider a career in teaching that would allow them to follow their passions for activism and social justice.

> I felt like I had this rationalization, that [teaching] is the fastest way to get a degree and start doing something. I think I had always done some teaching. It always was what I was interested in doing. I loved science, and I decided I wanted to go into high school teaching to help support queer and trans youth. I didn't have that, and it was a real motivating factor [*teaching with honesty and authenticity*, *role model* codes].

Most importantly, they recalled wanted to bring visibility to trans* experience and helps students to see that there are myriad ways of being in the world that don't necessarily have to align with the status quo.

> I don't want to necessarily say [I wanted to be a] role model, just another person in their school community, who's just another teacher to show them that there's different ways of being in the world and that they can be themselves whenever they decide they're able to do that [*teaching with honesty and authenticity, visibility* codes].

For R. J., their visibility was as much about creating safe and supportive classrooms for queer and trans* students as it was to exemplify alternative avenues for self-determination and self-expression.

Parker. Parker, a 6th-year middle school science teacher, also touched on themes of resilience and self-determination throughout their interview. While exploring their coming out story, Parker homed in on how uncomfortable they felt growing up nonbinary with no trans* representation. Though they knew at six, that they were "not a girl," having a loving, but sheltered and religious family meant that Parker felt very pressured to conform to their parents' expectations for "how I would grow up and who I would be."

> School, in general, was just a little bit awkward. I was just a little bit awkward because it felt like a mismatch. I had told my parents really young who I thought I was, and they were like, "Well, no," but I still had those feelings. I grew up with a lot of confusion, I think. Then I wound up just having to push it all down in order to just function.

Later, in their interview Parker drew direct connections between feeling invisible as a trans* youth and their desire for visibility as an out trans* adult. When asked if they were out to their students, Parker described how sharing their nonbinary identity with students at the beginning of the school year was an intentional choice directly related to their desire to stay authentic to themselves as a trans* person.

> Most of it was for the authenticity [*teaching with honesty and authenticity* code] and also because if there are nonbinary or trans students in my class, I want them to see that we exist as adults [*role model* code]. That's really important, that visibility is important,

> especially with all the stuff that tends to happen in terms of legislation and things [*visibility* code]. Like, a trans adult existing can thrive. That's a big part of it. Being the person that I never had growing up, being a really great teacher who can also relate to certain students in a way that they're not able to relate to other teachers. Showing kids that you can do what you love and exist at as an adult as a queer person [*role model, visibility* codes].

For Parker, it was immensely important that they be an example of a trans* success story for their students in spite of all the negative messaging they were receiving from recent social and political controversy.

Sparrow. Like Parker, Sparrow, a first-year teacher, confided that sharing his trans* identity with students early in the year provided an opportunity to establish a community of trust in his classroom, particularly for students who may be exploring their own identities.

> I think the most impactful part in teaching comes from just connecting with the students, definitely. I've mentioned before, I've had students come to me with questions about gender just because they themselves are questioning it. Making those connections has been really crucial just because they know I'm very open about my identity [*role model* code], so they know that they can come to me, and I won't judge them I won't make them feel stupid thinking about those kinds of things [*teaching with honesty and authenticity* code].

Sparrow mentioned several times in his interview that he wanted to create spaces where students could show up as their authentic selves without fear of judgment. According to his recollection, being out and open about being trans* "helps because I have students who feel that they can be very safe in acting how they naturally want to act and they're happy that they can act that way in my classroom without being judged" [*teaching with honesty and authenticity* code].

Kylie. Despite its benefits, being a visible trans* role model also felt risky for some of the participants. This was a particularly poignant experience for the trans women who

participated in the study. Kylie was one of four participants who transitioned while working as a science teacher. During her interview, Kylie described how she wrestled with what transitioning on the job would mean for her.

> I spent a lot of that year figuring myself out while still entirely closeted at work. About three years ago around this time, I was Googling, can you be trans and teach because it felt like it was one of those things that would be more stressful given the just sheer amount of homophobia and transphobia you see at a middle school [*visibility* code].

Unfortunately, Kylie's fears were realized, and the visibility associated with transition became a source of scrutiny for Kylie's students and administrators. Though she had generally positive experiences at her institution before coming out as a trans woman, Kylie ended up resigning from that teaching job due to a lack of support.

> I was all of four months full-time out and I showed up, and I wasn't really able to be stealth[1]. I wasn't entirely trying to. [The administration] felt they weren't really able to support me being fully out and proud, but they were like, "Yes, we'll try and show respect to you," and to their credit, the staff did. I just had lots of really horrible shit happen to me that year and it impacted my performance, and they weren't really supportive on that. They just put me under a microscope and picked me to pieces. I resigned and job hunted again and then I ended up at the school I'm in right now and teaching the year of the pandemic 2020, 2021 that went great. Virtual school you don't have to deal with the bullshit.

[1] Stealth refers to trans* people who tend to be socially recognized (or pass) as their gender identity without difficulty and do not openly identify themselves as being trans* (Pfeffer, 2016).

Though Kylie felt a greater sense of safety and security in her new, majority-virtual teaching position, she described a lingering internal conflict around her experiences with visibility. On one hand she perceived that being an out and visible trans* person was part of her duty to LBTQ students. On the other hand, visibility came at a significant personal cost. In her recollection of her experiences, she lamented on how she felt like she shouldered a lot of responsibility to represent her schools' LGBTQ community even though there were no system-wide measures in place that allowed her to do that safely.

> The idea of teaching and being stealth strikes me as incongruous. It bothers me that I end up in [that situation], but on the other hand, it feels like it's a unique opportunity and it feels like not taking it feels like a waste….At the same time, it's cost me a lot of grief…and we'll just leave it at grief. I don't know. In another field, I wouldn't mind being stealth because being visible isn't necessarily something that helps people, but in education, I feel like it really does help people [*teaching with honesty and authenticity, visibility* codes].

> I got to do that. Help people. I had a bunch of trans kids come out to me and a bunch of other queer kids seem to be really happy that there's somebody who's visibly like them in the building [*teaching with honesty and authenticity, visibility* codes]. The administration is good, it celebrates these folks, they're not all bad. They want to celebrate these folks. But that's not enough. We have to be safe.

Kylie ultimately left education after the conclusion of the study and is now working in industry as a research scientist.

Jenna. The other trans woman in the study, Jenna, also described difficulties with having to change jobs regularly due to rampant transmisogyny. Like Kylie, she directly attributed her negative experiences to an administration that would "talk the talk but couldn't walk the walk."

In her time as a teacher, this hypocrisy made it challenging for Jenna to be able to engage authentically with her students.

> We live in a society that-- Some days I will say it actively hates us, it wants to wipe us out and whatever, and some days…I feel that that's a little too far. I'll say most of the time. I think it's a risk to be out as a trans teacher. It's a positive one generally. I think it's a privilege to be safe enough to be out as a trans teacher. I also think it's a privilege to have the ability to pass and not be out. That is one [privilege] that I don't think I really have. [*visibility* code].
>
> Having just come from like a division meeting, a professional development session on identity and whatever, where they're all talking about "you bring your whole self to the classroom, blah, blah, blah, blah, blah, blah." As someone who certainly signs cover letters and applies to jobs, with saying, "I'm looking for a job where I can do that?" I think that my long list of identities is the lens through which I do all of my teaching. [*teaching with honesty and authenticity, visibility* codes]
>
> They're telling us at the PD "we want you to bring your whole self and want you to feel safe and blah, blah, blah," you know, my first response was to feel grumpy. I was like, "I never bring my whole self and I never feel safe." I will go, "I am safe enough. I know that the more of myself I'm embracing the better it is for kids. I would like to think that's not a complicated one, but I also know that if I bring my whole self, somebody is going to get upset by it in lots and lots of ways. [*teaching with honesty and authenticity, visibility* codes]
>
> My colleagues around me are like, "Jenna we are always so proud and impressed by the ways that you speak up and advocate for yourself and advocate for kids and talk all the time." I'm like, "I don't feel that way. I feel like I keep my mouth shut 95% of the time, and you're so impressed by the 5% of the time when I speak up [*teaching with honesty and authenticity, visibility* codes].

Here Jenna is referring to the ways that trans women are heavily scrutinized for their behavior and gender presentation and are often falsely accused by the anti-trans establishment as being predatory towards children. For Jenna, working in a school was a constant balance of being feminine, without being too feminine, and feeling like she had to subdue her personality and perspectives for fear of retaliation.

Martin. Fear of discrimination or disciplinary action for being trans* was a very real concern for Martin who did not feel he had the freedom to talk about his identity the same way that a cisgender colleague might. This fear spurred from an experience Martin had as a new teacher in a rural high school in the southeastern United States back in the early 2000s. Though his trans* identity was only known to his principal, a colleague at Martin's school discovered that he was trans* and brought it to the attention of another staff member.

> There's an old [redacted] article about myself and my partner from like-- Even though the [redacted] doesn't exist anymore, the article's still there. The [staff member] literally printed it out and walked it around the building and was showing other teachers and other staff people and students and telling them that I was "really a girl".

According to Martin, the colleague continued to spread gossip and fearmongering about whether or not students were safe having a trans* person as a teacher. Though the experience was upsetting, Martin described that the administration was ultimately on his side. He partially attributed their support to his being stealth, since they had gotten to "know him as a person," before learning he was trans*, and had seen that he was an "effective and solid teacher."

In his current school in the northeast, Martin is now out to most students and faculty and is enjoying being able to talk openly about his identity. However, he reflected that he still finds it challenging to show up authentically in the classroom saying, "I'm having to unlearn all of these old habits and answer questions differently than I would have years ago. It's a process of learning

how to be more authentic, which is a relief, but it's stressful" [*teaching with honesty and authenticity* code]. Despite his negative experiences, Martin agreed with the other participants that risks of being visible were outweighed by the positive impacts to queer and trans* students.

Epistemic (In)justice in the Scientific Domain: Self-Preservation and Teaching Motivation

> I guess the way that you teach science is dependent on how you learned it and what you think of it. -Liam

Aligned with the third principle of Kean's (2021) critical trans framework for education, the interrelated codes of trans* *experiential knowledge* and *epistemic (in)justice* emerged adjacent to a cluster of quotes that keyed in on the relationship between teachers' trans*, science, and teaching epistemologies. All participants described a love and affinity for science that was developed in early childhood, and many described family encouragement towards science and STEM disciplines. Ultimately, eight of the ten participants pursued a degree in a science before deciding on a teaching career. Though the participants were drawn to science as a discipline, a majority (n = 7) detailed how engaging in science as a trans* person often meant having firsthand experience of the epistemic erasure of trans* knowledge and identities within the scientific domain, most notably within school science and/or healthcare spaces. For some, these experiences directly influenced teaching motivations and philosophies.

Steven. In their interviews, a few of the teachers described the connections between one's growing self-awareness as a trans* person and a developing understanding of the way that science and society have historically excluded and erased trans* identities and perspectives. Steven, an early-career chemistry and physical science teacher, described how coming to terms with his nonbinary identity fundamentally exposed the incongruence between his own lived experiences and the binary, hegemonic norms of Western science and society.

> Chemistry is a science based on binary categorization in a lot of ways. But there are so many exceptions. [My trans identity] definitely helped me see the way categories do and don't work. I think it's definitely helped me see the way categorization is integral to the way society tries to function. I suppose without my queer identity, without my trans identity, especially, I wouldn't have made that realization. [*epistemic (in)justice, experiential knowledge* codes]

Sparrow. First-year teacher Sparrow also emphasized his frustration with the historical, scientific, and social biases that he has had to endure as a trans* person. When asked about his relationship to science, Sparrow said,

> I think this is one of the more obvious points that trans people have just been erased by science, it feels like most of the time, studies like yours are basically non-existent because that kind of stuff hasn't really been done until very recently. I think the other thing is of the media has also helped feed into, maybe, what's the word, the othering of trans identities as well. [*epistemic (in)justice* code]

> Science has that mass culture backing as well that just pretends trans people don't exist or label transness as-- At some point, transness was labeled as a mental disorder, which we've moved away from it, but a lot of the medicine or the medical field is still really hard to work with. I think in general, there's obviously a lot that can still improve. I can see spots in science where it is improving, but I think we're a long way from any sort of really inclusive science [*epistemic (in)justice* code].

Parker. In their interview, Parker extrapolated on how epistemic injustice in science and medicine had cascading impacts in their K-12 classrooms. Growing up, school was often a deeply isolating and uncomfortable place for Parker, not only because of their suppressed trans identity, but because they are asexual. Asexuality is a sexual identity that continues to be erased even within LGBTQ communities (Gupta, 2017). When asked about when in school they felt the most disparaged, Parker recalled,

> Sex Ed, health classes. That would be one thing. Then in history, or in English, I never learned or read about people who felt like me, so I thought my experience was really weird. I'm asexual. When you get to that age, when you're talking about health and Sex Ed, I didn't feel any of these things that I was supposed to be feeling. It just led to some more, "Maybe there is something wrong with me," or "Maybe I am broken," which is a very common narrative for asexuals.

Parker went on to describe that they experienced extreme discomfort due to the negative framing around queer identities in their curriculum. In their interview they reflected that "[t]he only queer inclusion was talking about AIDS and how horrible AIDS was. It was just a lot of negative things about being queer and it was very binary in general."

Liam. Teachers also described that developing awareness around the discordance between science and lived experience often meant having to reconcile their previous science knowledge with their own personal epistemologies. This often culminated in seeking out resources and communities that included more trans* representation. Like Parker, Liam, who began transitioning in ninth grade, described high school biology as "a narrative that didn't include trans people or a spectrum of gender or sex." Like many trans* youth, he had to build his own knowledge about transition and began seeking information from scientific journals and online trans* communities.

> When I started transitioning in high school, it was 2007. I was finding resources mostly on the internet. There were plenty of online communities. LiveJournal was the main one. There were people that were building resource websites that would have information about every aspect of medical and social transition that you might want to do. That was helpful. The value of having those resources was that I could pretty much see a roadmap of what things I could do in the future and what to plan for and how it might go and hear from a lot of people who were at different parts of their transition and ask questions sometimes. Though, I don't think I ever asked any questions that I-- think I really only

asked questions I already knew the answer to because I had done so much reading and researching. [*experiential knowledge* code]

Having accurate, conceptual knowledge of sex and gender was crucial for Liam's identity development as a trans* science person, as well as for his health and safety in pursuing medical and social transition. Increasing his scientific knowledge of trans* bodies and trans* medical care was also an act of self-preservation that made enduring the epistemic erasure of trans* representations in his science classes more tolerable. According to his interview, this experience directly influenced his science teaching motivations.

> Well, when I was in high school and college, I was a student that had a confident science background. I think what motivated me to learn more about those [concepts] was my own self-interest. I thought it would be important if I was going to be a trans person and know the science I should know. Really, I should be exhaustively knowledgeable anytime sex and gender would come up in science. To me, you could read everything you needed to read and learn everything you needed to learn… and if something comes up you could in the back of your head, just remind yourself, "There's something here that is not accurate to me, but that's okay because I understand it, and that's fine. I'm the only one that needs to understand it because it's just me," but that was a time in the 2000s when I think it was not expected that you would teach about gender identity in any subject. I felt no need to bring that up and bring attention to myself. [*epistemic (in)justice, experiential knowledge* codes]

> Then when I was on the teacher's side, there were more and more cues that [addressing trans* epistemic erasure] does need attention. That the way that you're teaching about gender could harm some students or maybe even all students, if they're learning something or generalized them, that promotes essentialist attitudes about people. [*epistemic (in)justice* code]

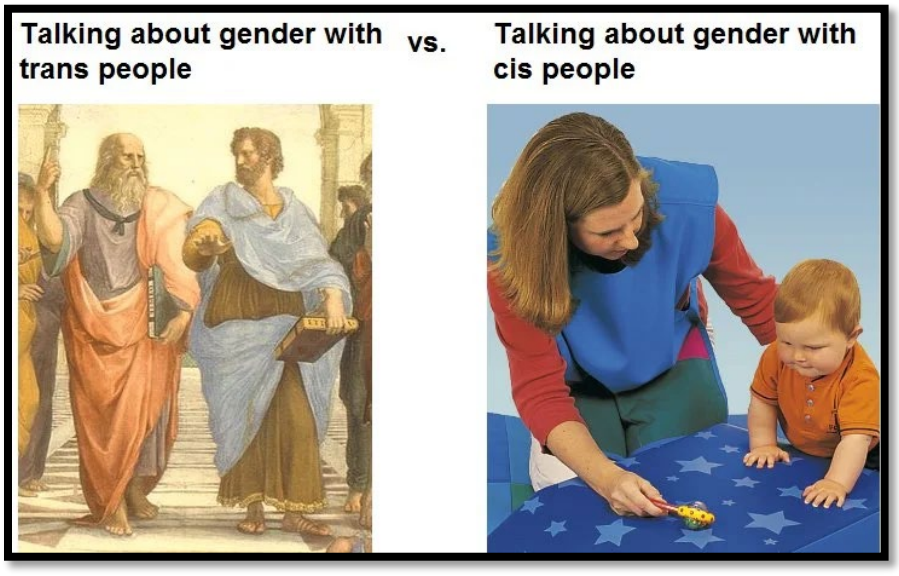
Though he opted to “lay-low” as a student. Liam believed that his feelings of needing to build his scientific knowledge of sex and gender was fundamental to his future decision to engage in gender-inclusive science practices as a teacher.

Ken. In his interview, Ken, a middle school science coach and professor of human anatomy at a local university, also made the explicit connection between his own experiences with epistemic erasure, the need for trans* epistemologies in science and medicine, and the development of his teaching identity.

> I know plenty of [trans] folks who wouldn't have gotten to where they are without some of that shared community knowledge. Let's face it, the [medical] professionals, often, especially in rural areas, don't know what they're doing, and we [as trans people] are the ones that have to do the teaching. The meme that immediately comes to mind is the one trans people talking to other trans people about gender (see Figure 2). You've got two Greek scholarly-looking people and a trans person talking to a cis person, and it's a parent talking to a child dealing with shapes. [*experiential knowledge* code]

Figure 2

“Trans People Talking to Other Trans People About Gender”



Note. A popular meme depicting the perceived incongruence trans* people experience when talking about gender with cisgender people versus other trans* people. Provenance unknown, likely attributed to an unknown Reddit user.

> I don't know that all of us are born teachers, but we get shoved into that position plenty. That was part of why I started teaching in a more inclusive manner, because I have had enough problematic interactions with medical workers. At the university I decided we need better anatomy and physiology education for pre-med students, if nothing else, for self-preservation. As I was working on that, it was like, okay, no, we need to take a step back, and everybody needs better biology education, which is why I wanted to work in middle schools. We're going to make real progress and not just stop gaps. [*epistemic (in)justice, experiential knowledge* codes]

A notable similarity between Liam and Ken is that both discussed how their primary motivation of self-preservation ultimately expanded into a desire to achieve epistemic justice in a greater capacity. For the most part, nearly all of the educators mentioned a direct connection between their own experiences with epistemic injustice and their desire to try and address transphobia and trans* epistemic erasure through their science teaching.

Trans Identity and the Nature of Science: Tentative, Creative, and Subjective*

In addition to impacting teaching motivations, the teachers (n = 6) also explored the relationships between trans* epistemologies and the *nature of science* [emergent code] as tentative, creative, subjective endeavors. This theme spoke to the similarities between the enterprise of science and trans* self-determination and was heavily related to the codes of *experiential knowledge* and *epistemic (in)justice* (Kean, 2021), as well as *unscripting gender* and *resisting definition* (Keenan, 2017). Four participants in particular, described how being trans* afforded them unique philosophical and epistemological perspectives on the congruence of scientific exploration and trans* identity, namely the expansive nature of science and gender/sex,

and the ability to update theories, schemas, and identities as more information, or data, comes available through experimentation or lived experience.

Steven. In their interview, Steven talked at length about how they always try to make students aware that the rules they learn for the chemical sciences are tentative and often simplified for science teaching.

> There are so many exceptions and everything that we don't cover because I'm trying to get them the basic rules, but I try very hard to stress this rule will work 90% of the time, but there are situations that will fit in both categories. There are situations that will fit in neither category. There are new categories that we are not talking about [*nature of science* code]. I always relate that back to real life. I don't always make it explicitly about gender, but I say just like everything in real life, there are categories we try to fit things into, and the categories will work about 90% of the time, sometimes. Sometimes it'll only work 50% of the time. We have to acknowledge when those categories help and when those categories don't help [*epistemic (in)justice* code].

> There are no real absolutes in science. Now, anytime somebody says, "We know this for sure," they usually end up being wrong, either a little bit or a lot of bit, and I think in the trans community, we see that a lot with people saying, "It's basic biology." Well, okay. Did you go back and learn anything more than what you learned in sixth grade, because you're missing a lot there [*nature of science, epistemic (in)justice* codes].

By highlighting that categorical realities in chemistry are not hard and fast rules, Steven hoped their students would become more comfortable with ambiguity and the idea that science can change.

> The biggest thing I want them to take away from me is, you can learn something, you can understand it, you can put it in a box, and then something will come along that does not fit in that box. It does not matter how zoomed out you are, or how deeply you study it. If you could study a tiny little topic for 50 years, and you will still find something that does not fit in the way that you think you understood it. Or you can just take a broad view of

> all of science, and you will find things that do not fit in the way that you understand that. That's the biggest thing, because I think that gives them the flexibility to adapt when they're confronted with new information, be it people whose identities they're not familiar with, or be it something new in science, or be it a new way of inter-personally connecting with somebody. I think that flexibility is what they really need to learn. [*nature of science, epistemic (in)justice, experiential knowledge* codes]

Steven emphasized that they were highly motivated by a desire to help students become better scientific thinkers, but also to prime students to becoming more accommodating of new ideas about gender, sex, and sexual diversity.

Parker. In their interview, Parker also focused on the notions of flexibility and fluidity in order to draw comparisons between the tentative nature of science and of personal identity. When asked if fluidity was a challenging conception for their middle school students, they responded that,

> No, it makes sense because they're not the same kids that they were a couple years ago and that's like a good example I used with them, like, "You know who you are now, isn't who you were when you were in lower school, and you know who you are now, isn't going to be who you are in upper school [*experiential knowledge* code]. It's the same with like science. We think we have an understanding, but it can change and that's okay" [*nature of science* code].They actually get it way better than I think a lot of adults do. Kids are way more flexible in their thinking.

Parker said that one way they like to engage students in thinking about the relationship between trans* and scientific epistemologies was to put up posters of root words that occur in both LGBTQIA terminology and STEM content (Gender-Inclusive Biology, 2019b, see Appendix D)For example, the word trans- comes from the Latin “other side” and can be found in words like transgender, transverse wave, trans isomer, or transition metal (Gender-Inclusive

Biology, 2019b). Parker liked that the resource "addresses that LGBTQ+ words do have connections to STEM via their roots" and that students enjoy seeing the ways that science can be connected to LGBTQ concepts. They also noted the temporality of the resource and that they would likely need to continue to keep the list updated as "our understanding of identities and science changes and grows" [*nature of science* code].

Harper. Harper also keyed in on the tentative nature of science and identity from a trans*-centered perspective. In her interview, she described the experience of transness as being inherently scientific, as is the process of addressing epistemic injustice through the centering of trans* experiential knowledge. She went so far as to say that trans* self-determination embodies what it means to be a scientist.

> I thought a lot about it when you said we're going to talk about my relationship with science and my gender expansiveness. My trans identity as an educator means that one of the things that I have come to really prioritize is this idea that when we get new data we update our story. We think we have an understanding, but it can change and that's okay. I think that's a really important part of science too. Not just because of learning outcomes but because of the skills that they help students practice and how those skills are the exact same skills of liberation.

> I love to talk to my kids about how, this is how we understand science right now, but science is always changing. While this is the truth at the moment, it doesn't mean it's going to be the truth tomorrow or a month from now or a year from now. We spend time throughout the year just talking about how science has evolved. That's how I reconcile [incongruity] because science is really fluid. That I think is helpful for me in terms of thinking about it as more of a fluid thing. It's also the truth, we like to think of science as very textbook, black and white. This is it, but it's not. I'm not. [*epistemic (in)justice, experiential knowledge, nature of science* quotes]

Also focusing on the phenomenon of fluidity, Harper shared that helping students to embrace ambiguity and change is a benefit in understanding fluctuating scientific information and personal identities in the presence of new information or evidence.

Liam. Like Harper, Liam also focused how engaging with science education through a trans*-informed lens means helping any student to reach actualization of themself as scientist by encouraging them to explore how science accommodates all identities.

> I think gender-inclusive science is good for all students because it acknowledges their identities, their curiosity to know more complex things about the world. It gives them the knowledge and the attitudes that they need to be strong members of society. It allows them to understand, I think, a few important things about the nature of science which is that you can have multiple models of the same phenomenon, for example, the binary sex model versus a spectrum.

In defining the essence of his experience as a trans*-identified science teacher, Liam concluded that his ultimate goal was to empower students to be a part of science in hopes that that they will use and change it to create a different, and more inclusive world for themselves and others. “I’m not just teaching them, well, it's this instead of this,” he said, “I’m giving them a different basis, a different structure that they can use to understand and change the world.”

Summary for Research Question 1

In summary, the emergent theme of *trans*-informed science education pedagogy* overarchingly encompassed the variety of ways being trans* impacted the development of the participants’ pedagogical philosophies. First, the desire to serve as a *visible role model*, or to be the trans* representation they lacked growing up, spurred many of the participants to want to become teachers. According to their interviews, showing up authentically was part of a desire to ensure the safety and success of queer and trans* youth. Second, participants’ experiences with

epistemic injustice in the scientific domain motivated them to want to teach and learn in ways that embraced *trans* experiential knowledge*. Relatedly, teachers connected trans* epistemologies to the *nature of science*, describing the inherent transness of scientific enterprise as foundational to their gender-inclusive science teaching philosophies.

RQ 2 – Actualization of Teachers' Trans*-Informed Gender-Inclusive Science Practices

For Research Question Two (RQ 2), teaching materials and reflective statements were triangulated with the interview data which led to the identification of three teaching practices central to the theme of *trans*-informed science education pedagogy* including *interrogating and accessing power, resisting essentialism,* and *embracing experiential knowledge and personal epistemologies*. In addition to being well aligned to the conceptual frameworks that guided this portion of the analysis, including Keenan's four principles for critical trans pedagogy (*teaching with honesty and authenticity*, *resisting essentialism and embracing complex knowledge*, *unscripting gender*, and *resisting definition*), Long et al.'s (2021) frameworks for GSD/gender-inclusive science education (*authenticity, continuity, affirmation, anti-oppression,* and *student agency*) as well as the six capacities from Wright's (2022) literature review (*heteronormativity, social justice, epistemic knowledge of science and inquiry, the identity, embodiment* and *GSD inclusive terminology*), these practices were also heavily related to, or influenced by, the teachers' trans*, science, and teaching epistemologies (RQ 1). The following sections describe the overarching themes present in the triangulated data for the six teachers who submitted instructional resources and reflections.

Interrogating and Accessing Power

> I will name [oppression] explicitly to kids, and I became a science teacher for these reasons. I want to give them the tools to access power. - Jenna

Interrogating and accessing power was represented in five participant narratives and broadly encompassed the a priori themes that related the intersection of science and the status quo including *resisting essentialism* (Keenan, 2017), *heteronormativity* and *social justice* (Wright, 2022), and *anti-oppression* (Long et al., 2021). With regards to pedagogy, this theme typically referred to engaging in lessons and activities that showcased how science has been historically used as a tool of oppression and also as a corrective measure for addressing inequity. In his interview, Ken broadly articulated the theme of questioning power and accessing it for oneself saying,

> I love the sciences. I think we have to really look at the sciences and what they've done through a social justice lens [*social justice* code] because they have been, especially as much as I love biology, especially biology has upheld a lot of harmful biased, bigoted concepts [*resisting essentialism, social justice, heteronormativity* code]. I do think that my trans identity coupled with this wall up of the science credential has meant that I feel a lot more comfortable questioning stuff [*experiential knowledge*, *epistemic (in)justice* codes] and helping my students question stuff and making tiny moments of criticality [*anti-oppression* code]. We raise people's capacity to think about power in that way which helps them to push back against systems of oppression [*anti-oppression* code].

According to the participants, students should be encouraged to consider the intersections of oppression in their own lives, and in the experiences of others. By understanding how science upholds injustice across diverse communities, students may build their capacity for questioning and disrupting power.

Harper. In their reflective teaching statement, Harper acknowledged that she tried to address examples of power and oppression within any lesson that contained content where issues such as essentialism or heteronormativity may be present [*continuity* code]. Consistently drawing attention to issues of injustice was part of her approach to culturally relevant pedagogy. In her

interview, she described how she incorporated *questioning power* into an activity where students analyze demographic representation in scientific charts and graphs.

> What I love doing about that is that the same tools that we use to build science we use to fight oppression [*anti-oppression* code]. We use for justice [*social justice* code]. The ability to analyze graphs charts that stuff, read data representations, which ends up so important when we're trying to get a bigger picture of whose data is in there and whose data isn't and what data we should be taking a look at [*anti-oppression, social justice* codes].

Harper employed this teaching technique in one of the lessons she submitted as a positive, gender-inclusive resource (Appendix E). The lesson included a presentation on gender-inclusive pedigree charts (presented in part, see Appendix E) and corresponding student worksheet (see Appendix E) modified from Gender-Inclusive Biology (2020b, see Appendix E for original). After introducing pedigrees, Harper explicitly used inclusive *GSD terminology* (e.g., using the terms male and female phenotypic sex, spouse, and sex assigned at birth) and addressed typical misconceptions related to pedigrees including (1) that pedigrees are not family trees and instead are a charts that represents passing down of genetic traits from ancestor to descendant, (2) that pedigrees usually only represent sex assigned at birth, not chromosomes or karyotype, and (3) that pedigree charts typically describe macroscopic observations of phenotypes which are then analyzed using knowledge of genetics (see slide 1).

After addressing areas of concern, Harper engaged students in explorations of representation, social justice, and anti-oppression (see Appendix E, slide 2). Presenting a pedigree chart without labels, she asked questions such as “who is not represented by these diagrams?” and “how could we create ways to represent them?” On the following slide (see Appendix E, slide 3) she challenged students to consider historical biases in pedigree chart

presentation and provided the students with solutions that scientists have developed for making pedigrees more inclusive [*anti-oppression, epistemic knowledge of science and inquiry, social justice* codes]. These included things like using annotations for intersex traits, or swapping pedigree charts for genograms which include symbols for LGBTQ identity, non-biological children, and social habits and relationships.

Liam. In his interview, Liam described that "empowering students to be a part of science" means encouraging them to become aware of issues of injustice that are grounded in misinformed and misapprehended scientific perspectives. On example he provided was the recent legal restrictions barring trans* children from playing on gender-segregated sports teams that do not align with their assigned sex at birth. When asked why science is important in debates about trans* rights Liam responded,

> Sometimes the argument about science is misused to make arguments about whether trans people should be able to do certain things. Some of those would be saying that because there is some physiological difference between say a trans woman and a cis woman, then the fact that there is any physiological or biological difference at all should mean that they shouldn't be in the same space, which one does not follow the other [*anti-oppression, social justice* codes].
>
> Often the statement about physiological differences is not well understood [*anti-oppression, social justice* codes]. Science is a practice is developed by humans, and we have ways of classifying things that are used useful, but they're not the only way to classify things. When classification is no longer useful, such as for kids playing sports, we need to recognize our freedom to not use certain forms of classification [*anti-oppression* codes.

Building from this example, Liam described that one of the best ways to teach about science and anti-oppression was through modules and case studies that explored how real-life

scientific issues impact the LGBTQ community. According to Liam, these activities are useful because they help students to "build more science knowledge and build more empathy to not use science as a divisive tool." In his instructional materials submission and corresponding reflection, Liam drew attention to the Howard Hughes Medical Institute (HHMI) Bio-interactive module "Sex Verification Testing of Athletes" (HHMI, 2018). This resource was also submitted as a positive resource by Martin and has been suggested in numerous other academic resources (e.g., Cooper et al., 2020; Hobbs, 2020; Long et al., 2021; Wright, 2022).

In the module, students explored how "biological sex" has been defined and measured throughout the history of sporting and how sex verification testing in sports is a form of oppression rooted in bioessentialist perspectives. Students learn about the biology of sex determination and human development and evaluate the results of sex-verification tests that have been used throughout sports history (HHMI, 2018). In their framework for Gender-Inclusive Biology, Long et al. (2021), specifically situate this activity as a representative example of their principle of *anti-oppression* describing that it "especially highlights the ways that people with intersex traits have been mistreated, objectified, and ostracized from the athletics community based on differences that are natural and random" (Long et al., 2021; p. 31).

Liam chose to submit this resource as a positive representation of gender-inclusive science teaching because of the way it depicts intersex athletes through their own personal stories using precise and inclusive language. He felt the resource was particularly useful in calling out "assumptions that sex is binary, and that sex necessarily confers an athletic advantage." He also commented on how the resource highlighted themes of prejudice and fairness by exploring the development of sex verification testing over time. Because the resource was framed through a lens of history and anti-oppression, Liam was able to ensure his students took home the message

that many historical methods of judging sex have "come and gone, and that there is no objective measure."

Addressing Areas of Concern. In their reflective statements, Liam and Martin also identified areas where potential misinformation or misrepresentations that might be present in the HHMI resource. Liam described that there is often a misconception that "intersex equals bad or diseased in some way" and that teachers need to reinforce that this module is focused on illuminating the way sex verification testing subjugates intersex athletes rather than positioning intersex traits as abnormal, "mistakes," or warranting controversy. In his reflection, Liam further cautioned other teachers against using the module in ways that encouraged controversy such as asking students to "broadcast opinions" for or against things like intersex or transgender individuals competing in sports or holding open forums for students to "argue" about the nature of biological advantages. He cited both examples as unnecessarily opening up opportunities for reinforcing stereotypes and misconceptions which are exceedingly harmful to students in the classroom who may share an identity with the figures in the modules or case studies.

Martin also described that because the module is focused on intersex athletes it should not be used as a direct corollary for talking about the issued faced by transgender athletes. Martin also addressed that though the module differentiates between gender and "biological sex" in order to interrogate bioessentialism, it is imperative to ensure students understand that the conception of "biological sex" is a construct that has been weaponized by the anti-trans movement. Liam addressed this in his reflective teaching statement saying that teachers can emphasize the way the resource presents "multiple, interconnected measures of biological sex" which do not necessarily confer any type of physical athletic advantage together or individually.

Within the resource is also a graphic that depicts gender identity as a spectrum with the polar ends being cisgender/transgender women and men and nonbinary identities falling somewhere in between. This method of depicting the gender identity spectrum has largely fallen out of favor given it's erasure of gender identities, such as agender, that fall outside the spectrum of binary gender completely (Mercer-Mapstone et al., 2021).

Resisting Essentialism

Borrowing the title from Keenan's (2017) second principle for critical trans pedagogy, *resisting essentialism* referred to teaching practices that refused oversimplified scripts of gender and sex. This theme was broadly discussed by all six participants and tended to center around the a priori codes of *resisting essentialism and embracing complex knowledge* (Keenan, 2017), *affirmation* and *authenticity* (Long et al., 2021), and *the nature of identity* and inclusive *GSD-terminology* (Wright, 2022). Within the data, the sub-themes of *affirming diversity* and demanding *accuracy and scientific precision* emerged as two conduits for pedagogical resistance to essentialist framing. Practices and materials aligned with the first theme focused mainly on positioning gender and sexual diversity as normal and naturally occurring, rather than unique, abnormal, or uncommon. The second theme referred to how teachers can more effectively teach scientific phenomena by embracing complexity and resisting reductive and oversimplified conceptions of natural and biological processes.

Affirming Diversity. Strongly aligned with Long et al.'s (2021) principle of *affirmation*, the theme of *affirming diversity* referred to the ways that teachers resisted essentialism and binary thinking by celebrating diversity, variation, and the multiplicity of naturally occurring phenomena. These practices were typically centered around one of two objectives. First were materials or lessons that included positive representations of LGTBQ scientists and historical

figures. And second were materials or lessons that directly addressed scientific phenomena beyond the binary.

Jenna. In her interview, Jenna described one of her go-to activities for addressing diversity in her 6th grade science classroom. During this lesson, students are instructed to examine biases related to public perceptions of scientists by doing Google image searches for keywords like "biologist" and "physicist." They were then asked to make short presentations describing the central themes of the images (e.g., older, white, men in a laboratory, or young children looking through telescopes) and draw conclusions about how scientists are typically represented. The goal of the project was to encourage students to consider stereotypes for who does and does not do science. Unsurprisingly, the results of the image searches tend to yield images of older, white, (and perceived to be) cisgender men.

Steven. Where Jenna's example focused predominantly on representation in the sciences, Steven's submission, a radio story (Sofia, 2021) and corresponding worksheet (see Appendix F) focused on the dual themes of science and identity beyond the binary. In an 11-minute audio clip from NPR's shortwave radio show, Ariana Remmel discussed how, as a nonbinary and mixed-race scientist, they grew up struggling with feeling like they were not categorically represented in society (e.g. on medical forms and demographic surveys). According to Ari, it was chemistry that ultimately helped them to understand that it is natural and normal to be a human who exists between categories. Using the example of resonance or mesomerism, a way of describing molecules whose chemical bonds can be arrange into several different structures, Ari said,

> [W]hen we think about bonds, we're often talking about them inside molecules, which is, you know, an organization of lots of different bonds between lots of different atoms. And resonance is a property where a bond between two atoms might actually be influenced by electrons on a neighboring atom.

> But what this results in is instead of having a bond that is strictly a single bond or strictly a double bond, resonance allows this kind of in between where you get bonds that are not quite as short as a double bond but not quite as long as a single bond, a little bit more flexible than a double bond but not quite as freely wiggly. You get these in-between properties, you know. Ultimately, we're actually trying to find a way to get our heads around a single object that has kind of shared properties of the two, but it's its own unique thing.

Connecting the principle of resonance to the big picture of science beyond the binary, Ari concluded the interview with a powerful reflection on science, identity, and the fragility of categories. Reading from the personal essay that inspired the radio interview, Ari said,

> Bonds do not jump from one form to the other, just like I am not boy then girl, white then brown. They're not oscillating between two states like I might try to draw them, confined to graphite and paper, like this form in the mail would have me dissected in a database. When I really take a moment to see these bonds for what they are, a union of atoms in three dimensions, I also witness my sense of self split between mixed identities, scooch to a sweet spot in the center that is a space all its own. And with that, I finally feel my consciousness settling back into my exhausted form. Everything is OK. I'm not half of anything. I'm not back and forth, one thing to the other. I'm only me, a single hole with multiple truths. I am resonant.

In the student worksheet (see Appendix F), Steven directed students to listen to Ari's story and consider the myriad ways that social and scientific categories change and adapt over time. The questions provided on the worksheet guided students along in thinking about why categories exist, what kinds of categories exist, how categories can change, and whether or not it is useful to try and fit everything in life into categories. According to Steven, the activity was useful because it "confronts the misconception that categories are all-encompassing and impossibly strict" [*resisting essentialism and embracing complex knowledge* code]. In addition to

celebrating diverse phenomena in chemistry, the lesson also "explicitly and implicitly confronts the truth that trans* and queer folk can do science as well as taking a queer lens toward science in general" [*social justice* code] drawing in from the other themes associated with *trans*-informed science education pedagogy* including *role models* and the *nature of science*.

Liam. Liam also submitted three diversity-affirming materials that can be found on the Gender-Inclusive Biology(GIB) website. They included the Queer Species Database (Gender-Inclusive Biology, 2019a) the Diverse Reproductive Strategies Gallery Walk (Gender-Inclusive Biology, 2020a, see Appendix G) and the Animal Patterns of Reproduction Lesson Plan (Gender-Inclusive Biology, 2019c, Appendix H). In his interview, he described that using these materials was vitally important to student success and that it was his responsibility "to try to give multiple ways, multiple opportunities for somebody to feel that science is on their side or within their identity" [*affirmation, identity* codes].

On their website, GIB has a compiled a database with instances of diverse sex, gender, and sexual behavior in the animal kingdom. According to the GIB website, the database includes 200+ species that defy binary, heteronormative conceptions of gender and sexual diversity. The database includes variations in reproductive anatomy, behavior, neurobiology, and chromosomal phenomena. According to Long et al. (2021), the database can be used to provide the evidence needed to affirm diversity in the natural world. According to Liam, students are generally "fascinated" at the enormous about of variability in the animal kingdom.

In the Diverse Reproductive Strategies Gallery Walk, students read about R- and K-selection strategies and then complete a "gallery walk" through four more diverse reproductive strategies in animals. According to Liam, the gallery walk is meant to show students that sexual diversity is naturally occurring and beneficial to species' fitness, addressing the misconception

that “diverse sexuality is a human invention.” In his reflective teaching statement, Liam did address that the resource was limited in that it only included representations of animals that have been described to have binary sex. He also commented that though the resource alludes to animals having multiple genders, students should be made aware that humans are not able to ascertain whether an animal has a gender identity and can only observe their behavior. Liam suggested if he were to teach the lesson again he would like to include representations of animals that defy sex binaries (such as kangaroos, white-tailed deer, or grizzly bears).

As a companion lesson, Animal Patterns of Reproduction introduced students to diverse reproductive strategies through a series of videos. According to the GIB website, the resource addressed unique patterns of reproduction such as environmental and touch-mediated sexual development. Liam submitted this resource because he liked the way “animal behaviors (e.g. competitiveness) and physical traits (e.g. size) were teased apart from biological sex” which aided in dispelling stereotypes that all animals have the same mating patterns and strategies as cisheterosexual monogamous humans. Liam reported that the resource made the evolution unit in his curriculum more exciting saying that in one class, students made up dances inspired by the mating rituals of some of the animals such as the honeybee and the magnificent riflebird, and ornate bird-of-paradise.

In his interview, Liam also commented on challenges with affirming gender and sexual diversity in today’s political climate, specifically referring to parental concerns about the content of the lessons or curriculum. Liam recounted an experience where a parent emailed him with anxieties that their child was learning about “transgender fish,” referring to a lesson that addressed sequential hermaphroditism in clownfish.

> [The student] came home said that "We learned about transgender fish." They're talking about something about a clownfish that we talked about. The parents said, "I heard that you were learning about this," and "can we discuss how you talk about it," and "I didn't know that transgender was in the curriculum." That last part was the most concerning to me because one, it shows that someone thinks "transgender" is just one idea that could be in the curriculum or not. Also, he doesn't really know how it might fit into science.

Here, Liam refers to the common misconception that being transgender only refers to a complete mental, biological, and physical change from living as one's assigned sex at birth to living as the entirely opposite sex/gender. This conception reinforces that there are only two biological sexes, ignoring that sex is a multivariate construct and exists as a continuum which is represented many times over throughout the natural world. Continuing his reflection, Liam described how he remedied the situation with the parent.

> I sent a Word doc of the whole lesson and said, "I'm happy to meet." I believe the parent saw the Word doc and decided there was nothing that they actually were concerned about because it was about the clownfish having this reproductive pattern where when the breeding female dies, then one of the males undergoes sequential hermaphroditism to become a female. I don't think it concerned [the parent], probably just the way that the kid said it in the first place made them wonder what it was about. They probably couldn't figure out what we actually learned about because if you asked the student, I think they would repeat very little of what actually happened in the class. They just have what they took away from it, which might have been like, "Oh, we learned that fish can be transgender or change sex." That's compounded by the fact that they think like a sex change is what transgender people do that they might get confused there.

When probed about whether or not there was a missed opportunity to be more specific about the difference between being a transgender human and a sex-changing clownfish Liam responded,

> Yes, I think that because the student that thought that the fish could be transgender shows that the students can see similarities between what humans and animals do. I don't necessarily think there's anything wrong with that student saying that because at least they are using some sort of language to describe what they sees, but it's not the same. The ways you could talk about it being not the same would be, well, to talk about, can we know what an animal's identity is? Is this an act of agency due to your identity, or is this a biochemical reflex really for these fish? In that lesson, we definitely didn't talk about that.

In his interview Liam described that he was glad students were able to make comparisons because it meant they were taking away the intended message that "diversity is not just in humans." However, he also described how it is necessary that students and teaching become more reflective about the way they talk about gender and sexual diversity.

> Is there a difference between swans being gay and humans being gay? To answer that would require you to know whether to interpret the swan's behavior and to somehow use observations of the behavior to understand what they're thinking and feeling, and that might be difficult. But swans raising children together and showing affectionate behavior to each other and staying together for life? Those are all pieces of evidence from behavior that you can use [to show that nature is not heteronormative].

In this reflection, Liam exposes how difficult it can be to teach about the constructs of gender, sex, and sexual diversity given their deeply entangled social and scientific underpinnings. However, by having these conversations, students are encouraged to become curious about what they can learn from the natural biological diversity of the planet.

Addressing Areas of Concern. *Affirming diversity* was also the theme most frequently associated with the negatively framed materials the teachers submitted for content analysis. Of the nine examples submitted, seven were described as containing language that positioned

gender and sexual diversity as abnormal, odd, and/or surprising. Alarmingly, all of the provided examples are easily resourced online and have been "vetted" by various institutions for classroom use. Two submissions included the Genetics and Heredity units of standard high school biology curricula. Both Harper and Liam noted that the units described disability and intersexuality from deficit perspectives which may leave some students feel "targeted like they are something to be fixed."

Three of the instructional materials (all submitted by Liam) were articles or case studies that are available on the National Science Teaching Association website. One of submissions was the "Transgender Perspectives in the Biology Classroom" article that has previously been addressed in this dissertation (Hobbs, 2020). The other submissions were two case studies curated by National Center for Case Study Teaching in Science (NCCSTS) at the University of Buffalo (NCCSTS, 2021). These case studies, which now reside on the NSTA website, are peer-reviewed activities written by STEM educators for use at the graduate, undergraduate, and high school level. One of the submitted case studies was written from the point of view of a medical student working with intersex children (Wooten-Blanks, 2012) and the other was about a cisgender man who has just learned his fiancée is a transgender woman (Monteleone, 2007). In both cases the authors use pathologizing and outdated language (e.g., hermaphrodite, transsexual, defective) to frame sex diversity as a "shocking surprise," said Liam.

Like the Hobbs (2020) article, these case studies are examples of how easy it can be for resources designed to frame gender and sexual diversity in a positive light to end up reinforcing dangerous stereotypes and perpetuating harmful practices. Though the case study by Monteleone (2007) ends with the couple happily deciding together that trans women are women (sarcasm intended), the author encouraged students to engage in discussions about whether or not trans

people should be morally obligated to disclose their trans* status. At a time where the majority of states allow for the "gay and trans panic" defense, a legal strategy that legitimizes assaults that occur when a defendant has a violent reaction to learning about a victim's gender or sexual orientation, it is unfathomable that a case study would encourage students to debate trans* non-disclosure, which is a personal and private matter. In his reflective statement Liam acknowledged that with the right pedagogical content knowledge related to gender-inclusive practices, the articles by Hobbs (2020) and Wooten-Banks (2012) could still be useable if the language and framing were updated.

Teaching with Accuracy and Scientific Precision. In their interviews, Liam and Parker described how teaching with *accuracy and precision* was critical for resisting oversimplified, essentialist scripts about gender and sexual diversity, particularly the gender binary and unnecessarily gendered descriptions of biological processes. This theme was strongly related to Keenan's (2017) principle of *resisting essentialism and embracing complex knowledge* as well as Long et al.'s (2021) attribute of *authenticity* and Wright's (2022) principles of *identity* and *GSD-terminology*.

Liam and Parker. Liam described that taking a complex, scientific approach to teaching about gender and sexual diversity has numerous benefits at the personal, pedagogical, and institutional level. When asked why it was important to reject oversimplified conceptions, such as the gender/sex binary, he responded saying "I think it's important for students to understand complexity and to not be intimidated by that complexity, because it's truth and it gives you freedom to figure out where you stand" [*resisting essentialism and embracing complexity, authenticity, anti-oppression* codes]. According to Liam, embracing the complexity of science is inclusive of all students, not just those with diverse genders and/or sexual orientations.

> I think gender-inclusive science is good for all students because it acknowledges their identities [*identity* code], their curiosity to know more complex things about the world [*embodiment* code] It gives them the knowledge and the attitudes that they need to be strong members of society [*anti-oppression, social justice* codes] and I hope that empowers them to be a part of science [*student agency* code].

One of the submitted materials that best aligned with the theme *of accuracy and scientific precision* was the Gender-Inclusive Language Guide (Gender-Inclusive Biology, n.d., Appendix I, see Figure 3) which was submitted by both Liam and Parker. According to the GIB website, the resource was specifically designed to help teachers overcome their discomfort about using scientific terminology. In his reflection, Liam described the resource as giving "like-for-like substitution suggestions for commonly occurring language in K-12+ biology along with reasons for each substitution" [*authenticity, GSD terminology* codes]. These substitutions predominantly focused on how to talk about biological mechanisms rather than gendered outcomes when discussing evolution, genetics, and reproduction.

In their reflection, Parker described that using precise terms is actually "more accurate and inclusive and acknowledges identity *and* science" [emphasis added]. Parker also described that their students have typically accepting of learning new terminology though they will often default back to gendered generalizations. To remedy this, they suggested it is important to embed inclusive terminology into the entirety of the curriculum [*continuity, GSD terminology* codes].

Figure 3

Gender Inclusive Language Guide (short): Building Continuity in Gendered Language

Building Continuity in Gendered Language

Instead of...	Focus on...	Example	Why?
Men Male Women Female	the organ, functional activity, or role	"~~Women~~ **Ovaries** produce eggs." "~~Males~~ **XY individuals** are more likely to be color blind." "The ~~mother~~ **gestational parent** carries the fetus for 9 months."	All people, cis & trans, experience different bodies, reproduction, and families. Many organisms thrive in stable families where a male-female relationship is only one of many options.
Male/female hormones	testosterone, estrogen, and progesterone	"People with testes produce large amounts of testosterone." "In an estrogen-dominant body, the bones develop like ..."	Testosterone and estrogen also regulate many non-sexual processes. Both hormones exist in most people of any sex with active gonads.
Normal Natural Typical	patterns and probability	"In **many** species, the female provides more parental investment than the male." "XX and XY are the **most common** combinations of sex chromosomes."	Living things are diverse, with no one "typical" body or behavior. When discussing humans, many medical & scientific statistics only use data from white, cisgender, European populations.

Note. Reproduced with permission from Long, S., Steller, L., & Suh, R. (2021) Gender-inclusive biology: A framework in action—Practical strategies for teaching about gender, sex, and sexuality in biology. *The Science Teacher, 89(*1), 27–33.

In addition to being inclusive of diverse students, teaching with *accuracy and scientific precision* may also help to insulate teachers and administrators from the onslaught of anti-trans legislative attacks aimed at K-12 curriculum. On one point, by focusing on the inherently scientific nature of gender and sexual diversity, teachers may engage in inclusive pedagogy

without facing legal repercussions from states whose laws tend to target non-scientific language around "promoting" gender identity and sexual diversity.

> When you say words like "diversity" that signals things to some people. But [precise terminology] is not something you can really directly criticize nor is teaching accurate science that matches the science practices that we're supposed to be teaching. I think that science is harder to criticize when it includes things about gender and sexual diversity because you are not usually teaching something that's perceived as an opinion or a value judgment. You're teaching that animals can have same-sex relationships, which is true. The positive effects that students get from that is to see that variation is naturally occurring and it's a part of life. You might even frame it as an interesting or celebratory affirming variation. Really, you're saying that it's just as good as anything else. You're not saying that it's better to be gay or anything. [*authenticity, affirmation, resisting essentialism and embracing complex knowledge* codes]

During his interview, Liam hoped that science teachers might face less scrutiny for teaching about gender and sexual diversity than teachers in other subjects. Alluding to the Next Generation Science Standards, Liam reflected on the duty he and other science teachers have to providing instruction about complex scientific phenomena (NRC, 2013a).

> I think if you were to be teaching English and decide what books you were going to teach, someone could say, "Why not just not pick any books about gay people or trans people?" and you could still cover all your standards. But, while in science, if you don't teach about some of these variations, you're not teaching about some of the phenomena in science. That could be something that makes it less easy to criticize. If you have an opportunity to have a conversation, you could say, "Okay, let's consider the fact that some people have a different set of chromosomes from XX or XY, and let's consider how often that happens and that that's naturally occurring." [*authenticity, affirmation, resisting essentialism and embracing complex knowledge* codes]

Secondly, including accurate scientific information may act in direct opposition to bigoted attempts to use misapplied science to justify anti-LGBTQ discrimination. This directly addresses the calls from professional science education organizations to acknowledge the way systemic gender oppression impacts the classroom. According to the National Association of Biology Teachers, the equity-minded teacher "unwilling to silently allow those disparities to continue unexamined and unaddressed" (NABT, 2021, paragraph 3). In his interview, Liam identified precise ways that science teachers can be aware of how science can be used to propagate, and disrupt, systemic oppression.

> If you're informed about science, then for something like a bathroom bill, you understand that the consequences to you [as a cis person] are nothing [*anti-oppression* code]. When it comes to sports, you understand that there's so much variation, that the consequences are so unpredictable that they could probably be called zero, nothing, no negative impact on non-trans student-athletes [*affirmation, anti-oppression, social justice* codes]. Then once you know that you'll be willing to say that as your actual opinion, which means you can't be influenced by pressure from other people, or political pressure to say something else [*anti-oppression* code]. If those three things happen, then you can arrive at-- be open about your conclusion that trans people should be and will be a part of all these places in society. It does require some science to understand that, thinking about data. People don't understand variation at the bell curve, and people don't understand how hormones work, and the fact that everyone has the same hormones in their body [*authenticity* code].

According to Liam, until science education stops perpetuating inaccurate and outdated conceptions, one of the greatest skills students can learn is the ability to "pick out science myths about gender." But he has confidence that through gender-inclusive science education that these myths can be disrupted. In his interview he reported that as a result of gender-inclusive science teaching his students are becoming "aware that [these myths] are generalizations and are starting

to realize that there's more accurate ways of seeing and talking about variation in people" [*anti-oppression, social justice* codes].

Addressing Areas of Concern. In their interviews, most participants noted that using accurate and precise scientific language was one of the more difficult challenges given the way a majority of textbooks and resources on genetics, reproduction, and evolution contain heteronormative and essentialist perspectives on gender and sexual diversity. In her interview, Harper described her frustration that even though her textbook describes sexual diversity in the animal kingdom, the content addressing human reproduction still conflated sex and gender and reinforced binary essentialism. For the teachers, having to also be aware of and develop alternative resources/scripts for teaching added to an already overfull plate. When asked if it was "too much" Steven and Sparrow, both early career teachers, felt like they often had to sacrifice doing it right for getting it done.

Embracing Experiential Knowledge and Personal Epistemologies

Four out of six teachers described pedagogical practices associated with the theme of *embracing experiential knowledge and personal epistemologies.* These teaching techniques, such as co-creation and modeling, appeared to be heavily influenced by the teachers' perceptions of science as a queer enterprise and generally encompassed the a priori codes of *embodiment* and *epistemic nature of science and inquiry* (Wright, 2022), *student agency* (Long et al., 2021) and *unscripting gender* and *resisting definition* (Keenan, 2017). Participants also connected these practices to the teaching philosophies emergent in the theme of *trans* epistemologies and the nature of science.* These philosophies described an inherent relationship between trans* and science identities and epistemologies and were associated with pedagogical practices aimed at

helping students to embrace scientific thinking by encouraging them to draw from their own observations and lived experience.

Harper. In her interview, Harper talked extensively about how the nature of science can be informed by trans* identities and experiences, and vice versa. From her perspective, *trans*-informed science education pedagogy* relies on helping students to understand themselves scientifically by encouraging them to draw from their own experiential knowledge and embodied epistemologies.

> There's a difference for me now when I stand up and I say everybody's a scientist than there used to be. There are some great teachers across the country standing out to being like, "you're a scientist too," but, that's not even what I'm thinking about. I'm thinking about how people who hold really important knowledge about bodies in the natural world, especially traditional knowledges, aren't celebrated or prioritized. *[epistemic (in)justice, experiential knowledge* codes].

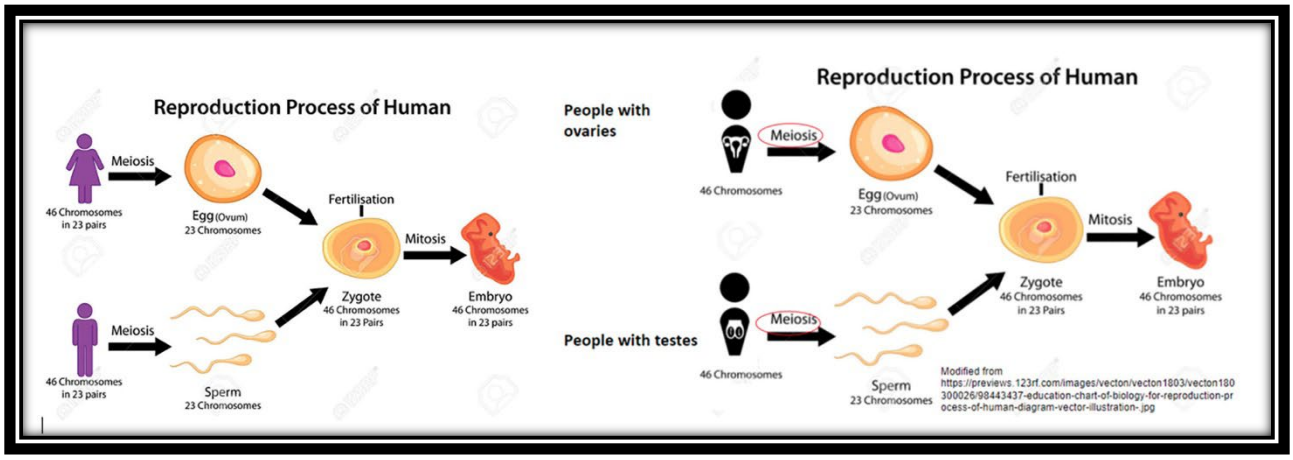
One of the primary ways Harper encouraged students to develop their own ways of knowing about gender and sexual diversity was through co-creation, allowing students to step into the role of teacher and develop their own language and models to describe scientific phenomenon [*unscripting gender, resisting definition* codes]. During implementation of the gender-inclusive pedigrees lesson from GIB (Appendix E), Harper gave students the opportunity to think about how diverse gender and sexual identities could be represented in a pedigree chart. After going through examples from other sources, the students were tasked with coming up with their own representations for the symbols (see slides 2 and 3). In the lesson, Harper also discussed the need for inclusive language when describing the individuals who contributed the gametes required for procreation [*GSD terminology* code]. In the activity, the terms "spouse" and "birth mother" and "birth father" were used with the disclaimer that "families and reproductive technologies come in all shapes and sizes!" *[unscripting gender* code]. In their reflective

statement, Harper mentioned that when they teach this lesson again, they might ask students to come up with their own names for these actors [*resisting definition* code].

Parker. The practice of co-creation was also suggested in Long et al.'s (2021) framework for Gender-Inclusive Biology, which Parker submitted in its entirety as an example of a positive resource. Under the principle of *student agency*, Long et al. (2021) suggest that students can help teachers to adapt their own lessons and curriculum by "co-creating language and diagrams that accurately describe the phenomena they are learning about" (p. 31). In the provided example, students encountered a diagram of mitosis that depicted a silhouette of person wearing a dress that was associated with an image of an egg cell (ovum). Students were challenged to think about the differences between gender expression (e.g., wearing a dress), gender, and sex and to come up with a more inclusive visual model (see Figure 4) [*unscripting gender* code].

Figure 4

Before (left) and After (right) diagrams demonstrating modifications to promote student agency.



Note. Reproduced with permission from Long, S., Steller, L., & Suh, R. (2021) Gender-inclusive biology: A framework in action—Practical strategies for teaching about gender, sex, and sexuality in biology. *The Science Teacher, 89(*1), 27–33.

According to Long et al. (2021) having students assist with revising diagrams for inclusion not only increased the accuracy of the diagram but provided students with the opportunity to create their own knowledge. By giving students the opportunity to teach using their own language and ideas, co-creation becomes an effective way to model "the way that science and language are constantly shifting to be more accurate and inclusive" (Long et al., 2021; p. 32).

Liam. While reflecting about his experience with the student and the "transgender fish," Liam noted the importance of helping youth to develop comfort and familiarity with using accurate and inclusive scientific language. However, he also described need for conceptual flexibility and an understanding of the way language around gender, sex, and sexual diversity changes as social and scientific perspectives shift.

> I would like to get students into a habit where if you're going to make a statement and the language may be ambiguous to define what you're saying [*authenticity, GSD-terminology* code]. If you're saying it like to say, "I'm going to talk about fish and I will describe them as transgender and I'm using that as my shorthand that means that they can change sex during their lifetime," which is what eventually you do as a scientist if you're discovering something new or describing something new, but I don't think they're doing that. I don't think comes naturally for them to do that [*unscripting gender, resisting definition* codes].
>
> They do the opposite, they use a word and just assume everyone knows what it means and it's the same as what they think, or they don't have the idea that they can define language as they're using it [*GSD-terminology*, *unscripting gender, resisting definition* codes]. They have an idea like, "I have to use what exists," but what if you need to describe something that doesn't exist yet, which, you know, at some point someone invented the word gay or assigned it for this purpose and the same for transgender [*unscripting gender*, *resisting definition*, *experiential knowledge* codes].

This viewpoint is well aligned to Keenan's (2017) principle of resisting definition which cautions teachers to resist trying to define the trans* experience as doing so only creates new categorical boundaries that perpetuate the policing of bodies and identities. Though using affirming and accurate *GSD-terminology* (Wright, 2022) is essential to building trans*-inclusive classrooms, students should also be allowed and encouraged to create their own words and language that describes their epistemologies and lived experiences.

R. J. Another way the participants created opportunities for students to embrace their own experiential knowledge and epistemologies about gender and sexual diversity was through inquiry-based learning approaches such as argumentation and modeling. In their interview R. J. acknowledged that modeling as a skills framework is well suited to discussing gender and sexual diversity since it is principled on developing and refining scientific models based on new information and observations.

> [Embracing personal epistemologies] seems like it's really tied into the modeling, which is we are going to make observations. From our observations, we're going to try to create explanations based on things that we can observe. It's easy in physics. You can measure distance and force and velocity. But it's even easier, I think, in biology, where we…for example, when starting to talk about classification, gave the kids a series of photos of very diverse organisms, "how would you organize this?" and we start to talk about what are systems of classification used to organize living things. We use a lot of claim and evidence reasoning. Evidence is what you can see in nature and claims have to be backed up by evidence and reasoning. What if there's new evidence? Then claims change.
>
> It's not a broad content but the practice of thinking about each concept I think is very deep and hopefully the students are learning a little bit about the process. We have students working in groups and going through the questions and talking about the material. That brings me so much joy and satisfaction. I can answer questions, but they are having to think about the model in order to construct meaning out of it.

For R. J. practices grounded in modeling and argumentation help students to be comfortable knowing that "some evidence is better than others" and that there is always "more evidence out there," including evidence from their own lived experience. In their interview, R. J. reflected on how neatly gender and sexual diversity education fits into science education saying, "its right there in crosscutting concepts, the idea that patterns are more interesting than dichotomies. Yes, we learn about dichotomies, but then we open them up." When summarizing what it means to be a trans*-inclusive science teacher, R. J. said they have a responsibility to "build spaces of plurality where binary essentialism is actively dismantled or questioned, or data is brought up that is specific to providing other angles."

Summary for Research Question 2

The emergent practices of *interrogating and accessing power, resisting essentialism,* and *embracing experiential knowledge and personal epistemologies* were foundational to participants conceptualizations of practice for *trans*-informed science education pedagogy*. The theme of *interrogating and accessing power* referred to teaching practices that built students' awareness of oppressive systems within science and society. This included instruction and activities grounded in identifying and analyzing patterns, categories, and constructs that enforce normalization and inform the status quo. When students were exposed to systems of power, it enabled them to think critically about science as a tool of oppression and liberation. Relatedly, teachers engaged in practices that went beyond developing awareness of oppressive systems, to actively resisting essentialism in their curriculum. This was accomplished by *affirming diversity* and rejecting oversimplification with *accuracy and scientific precision*. Finally, a critical component to gender-inclusive practice was to engage in activities and assignments that encouraged students to draw from their own *experiential knowledge and personal epistemologies* in order to develop

new ways of thinking about the world. This practice engaged students in unscripting gendered norms while simultaneously resisting redefinition by embracing the multiplicity of perspectives students hold within their own embodied understandings of gender and sex.

Chapter Summary

The findings presented in this chapter provide insight into the lived experience of trans*-identified science educators as invaluable sources of conceptual and pedagogical knowledge. The data was presented by research question and was organized into themes that exemplified the central philosophies and practices associated with the emergent theme of *trans*-informed science education pedagogy*. In general, these findings aligned well with the goals for critical trans pedagogy that have been identified in other conceptual frameworks for gender inclusive teaching including (1) inviting students to examine the ways that gender systems oppress all people in society, (2) preventing harm to trans* students, and (3) embracing trans* knowledge and experience (see Kean, 2021; Keenan, 2017; Miller, 2016).

For Research Question One, teachers' experiences with epistemic erasure of trans* identities and perspectives were found to have influenced their motivation to become teachers (e.g., serving as *role models*) as well as their feelings safety and authenticity in their classroom (e.g., whether or not they desired to be out and visible as trans*). Participants also reported that being trans* fundamentally shaped their epistemological relationships to the *nature of science* which subsequently informed their perspectives on science teaching and learning. For Research Question Two, triangulation of the teaching materials and reflective statements with the interview data led to the identification of tree teaching principles (*interrogating and accessing power, resisting essentialism,* and *embracing experiential knowledge and personal*

epistemologies) considered to be intrinsic to the theme of *trans*-informed science education pedagogy*.

Together, these philosophies and practices lay the theoretical and conceptual foundation for a set of teaching principles that can guide teachers in implementing gender-inclusive science teacher through a trans*-informed lens. Chapter five will articulate how these findings contribute to the existing literature and address the limitations of current gender-inclusive science reform movements. Practical and theoretical implications of this research, as well as implications for future research will be discussed.

CHAPTER 5

DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

Anti-LGBTQ curriculum laws exist in more than twenty states and impact an estimated 25 million children (Rosky, 2017). Those numbers are expected to grow exponentially over the coming years as more and more youth come out has having diverse gender and sexual identities (The Trevor Project, 2021). A significant education challenge is how to meet the needs of these students while addressing and dismantling the way the institution of science education continues to uphold genderism and other systems of oppression. Though there have been waves of gender-inclusive science education reform, these movements have been limited by a lack of cohesive guidelines for practice and a limited inclusion of perspectives that attend to the needs of an increasingly diverse population of students.

The purpose of this study was to examine the work of trans*-identified educators in order to learn from their experiences creating gender-inclusive science classrooms. There were two research questions that guided this study: (1) How, and in what ways, does the lived experience of being a trans*-identified science teacher shape the development of teachers' gender-inclusive science practices? (2) How do trans* -identified science teachers incorporate gender-inclusivity into their science curriculum and instruction? This dissertation followed an interpretive qualitative design and included three sources of data. Sequential interviews explored the lived experience of being a trans*-identified science teacher, while instructional materials and reflective teaching statements homed in on the specific pedagogical practices employed in gender-inclusive science teaching. The data underwent several rounds of inductive and deductive coding analysis which led to the identification of the central theme of interest as well as various sub-themes that were aligned to each research question.

Discussion

The analysis of the interview transcripts, submitted instructional materials, and reflective statements led to the identification of the central theme of *trans*-informed science education pedagogy*. This theme was described from two perspectives that aligned with the research questions. For Research Question One, data analysis revealed that teachers' trans* lived experiences impacted the development of their teaching motivations, goals, and pedagogical philosophies. These experiences emerged as being foundational to the actualization of their gender inclusive science practice which coalesced into three central themes, (*interrogating and accessing power, resisting essentialism,* and *embracing experiential knowledge and personal epistemologies*) inherent to *trans*-informed science education pedagogy*.

RQ 1 – Lived Experience and the Development of Gender-Inclusive Science Pedagogies

The emergent themes aligned to Research Question One spoke to the influence of trans* experience on the development of participants' science teaching motivation, goals, and philosophies. These findings are particularly valuable as they provide a trans*-centered view of the relationships between trans* identity and science teaching and learning.

The Challenges and Benefits of Being Out in the Classroom. While describing the formative experiences that impacted the development of their trans*-inclusive science pedagogies, most participants discussed the benefits and challenges associated with being an out and visible role models to students. For the majority, serving as a role model was an important way to reconcile their own experiences growing up without any trans* representation in their schools. While many participants described that increased visibility could create openings for scrutiny and discrimination, most agreed that the risks of being visible were outweighed by the

positive impacts to queer and trans* students. However, with the recent wave of anti-LGBTQ legislation, teachers may soon be facing a future where visibility is no longer a choice.

The safety and psychological well-being of LGBTQ students has been a dominant theme across the majority of trans* inclusive K-12 education literature (Hutchinson & White, 2021) as well as literature in the K-12 LBTQ-inclusive education domain more broadly (Hutchinson & White, 2021; Wright, 2022). According to Banks (2013), the presence of supportive and representative educators is undeniably influential in helping queer and trans* students to actualize their hopes and dreams for the future (p. 182). Holstine (n.d.) described that "[s]tudents are more successful when they can see themselves in both their schools and in their curriculum; and all students benefit when they can learn from a variety of experiences and perspectives."

In their interviews, many of the teachers described the desire to show students that being trans* is not just about surviving but thriving. As Parker recalled, it was important for them to be able to show up as their authentic self so that "kids can see that you can do what you love and exist at as an adult as a queer person." But as a few of the teachers mentioned, being out in the workplace was not without risk. According to Jenna, Kylie, Parker, and Martin, being visible as trans* educators risked opening oneself up to discrimination by students and their caregivers, administrators, and the public at large. In their interview, Parker described that they had students moved out of their classroom because parents "didn't agree with [them] as a person," and once had a community member call the school to ask their administrators, "[d]o you realize you have a pedophile teaching in your middle school?"

For a time, there have been federal protections for LGBTQ educators, namely a 2020 U.S. Supreme Court ruling that protects all workers from discrimination based on sexual orientation or gender identity (Hutchinson & White, 2021). Though this ruling may have once

alleviated educators fears about the legal repercussions of being out and visible role models to their students, these laws now have the potential to be undermined by the recent flood of "*no promo homo*" laws that prohibit teachers from openly discussing gender identity and sexual orientation in the classroom (Hutchinson & White, 2021; Meyer et al., 2015). In the coming years these challenges will continue to be exacerbated by an increasingly conservative legislature. This will undoubtedly limit the safety and security of queer and trans* teachers and students by denying them access to "equitable and affirming" schooling environments (Mangin, 2021).

Epistemic (In)justice in the Scientific Domain. During their interviews, the participants all deeply reflected on the way that engaging with science as a trans* person often meant encountering epistemic erasure of trans* knowledge and identities within the scientific domain, particularly in medicine and school science. For many of the participants, coming to understand their trans* identity revealed discordances between their own lived experience and Western scientific epistemologies of sex and gender. This typically motivated their desire to mitigate that incongruence by increasing their own knowledge and epistemologies of the trans* experience. Teachers' reported that that though safety, community, and self-preservation may have initially driven them to become "exhaustively knowledgeable anytime sex and gender would come up in science [Liam]," experiences with epistemic injustice also influenced their desire to engage in gender-inclusive science practices as teachers.

This theme aligns extensively with the third principle of Kean's (2021) critical trans framework for education which emphasizes the importance of trans* experiential knowledge in the development of meaningful, inclusive education practices. The findings from this portion of the dissertation also confirm many of the limitations discussed in the literature review,

particularly a lack of positive representation of LGBTQ issues and a total absence of trans* considerations. When trans* perspectives are minimized and erased in schooling institutions, it can create unsafe spaces where trans* students struggle to show up as their authentic selves for fear of discrimination and being misunderstood.

The data also implies that trans* perspectives should be included in curriculum before high school. According to the interviews, Liam, Parker, and Sparrow all described knowing that they were trans* as early as elementary and middle school. Many of the other teachers reported that had they had the words to describe their identities, or known about trans* people earlier in life, they likely would have transitioned much sooner. This is an incredibly important implication given the recent anti-trans legislation which is focused on legislating middle and elementary school curriculum, and limiting trans* youths' access to vital gender-affirming care on the basis that children are too young to know whether or not they are trans* (Diaz, 2022; Lavietes, 2022; Migdon, 2022; Smith, 2022).

Consequently, creating trans*-inclusive classrooms must be centered around recognizing and disrupting the epistemic injustices that ignore, overlook, misrepresent, or erase trans* identities in the classroom (Kean, 2021). Safe, trans*-affirming spaces can be created by looking to the resilience, creativity, and strengths of the trans* community and honoring the unique contributions trans* students and teachers make to the study of science (Kean, 2021).

Trans* Identity and the Nature of Science. In addition to exploring the relationships between trans* experiential knowledge and epistemic injustice, the teachers also reflected on the similarities between trans* epistemologies and the nature of science. In their interviews, the participants celebrated science knowledge *and* trans* identity as tentative, creative, and subjective endeavors. Consequently, many teachers discussed how taking a nature of science

approach to the teaching of gender and sexual diversity may help students to become more comfortable with the idea that science and identity can change as new information and life experience is acquired. This approach helps students to become better scientific thinkers, but also primes them to be more accommodating of new ideas about gender, sex, and sexual diversity.

The participants' conception of science as inherently trans* is aligned to explorations of other epistemologies of science education framed through the lens of queer theory. Related to Wright's (2022) capacities of *epistemic knowledge of science and inquiry* and *embodiment*, Gilbert and Gray (2019) describe science as a "queer project that embraces subjectivities and multiple ways of knowing and thinking (p. 121). Fifield and Swain, (2002) also attest that to wonder queerly is to recognize how science is uncertain, "arbitrary and open to interrogation" (p.121) and that scientific 'facts' are "embodied, evolving, and given contested meanings by authors, teachers, and students, whose bodies of knowledge shape and are reshaped by cultural norms" (p. 177).

These studies and others (e.g., Adsit-Morris & Gough, 2017; Santavicca et al., 2019) are explicit in describing the role of students' bodies and lived experiences in the production of knowledge (Wright, 2022). While the participants' conceptions build from similar perspectives, they are also different in their emphasis on identity development and self-determination. In Miller's (2016) conception of a trans* pedagogy of refusal, the trans* body is a space of self-determination where the self can be "made and remade, always in perpetual construction and deconstruction" (p. 4), much like the enterprise of science. This perspective of science education through a trans*ed lens may be a useful in overcoming the limitations of queer theory and analysis with regards to embodiment, materiality, and self-determination.

RQ 2 – Actualization of Teachers' Trans*-Informed Gender-Inclusive Science Practices

For Research Question Two (RQ 2), teaching materials and reflective statements were triangulated with the interview data which led to the identification of three teaching principles (*interrogating and accessing power, resisting essentialism*, and *embracing experiential knowledge and personal epistemologies*) that were central to *trans*-informed science education pedagogy*. In addition to being related to, or influenced by, the teachers' trans*, science, and teaching epistemologies (RQ 1) these principles were also well aligned to the thematic foundations of the conceptual frameworks that guided this portion of the analysis, including Keenan's four principles for critical trans pedagogy, Long et al.'s (2021) frameworks for GSD/gender-inclusive science education, as well as the six capacities from Wright's (2022) systematic literature review.

Interrogating and Accessing Power. This theme drew from participants' perspectives on the epistemic erasure of trans* perspectives in science and science education and typically referred to pedagogical practices that showcased how science has been historically used as a tool of oppression and also as a corrective measure for addressing inequity. In their interviews, teachers often discussed the importance of continuously centering anti-oppression in their teaching practices. Recommendations for interrogating and accessing power included honing one's awareness of how curriculum perpetuates the status quo, directing students' attention to areas of injustice, and encouraging students to access their own power by creating inclusive scientific solutions. This requires proactive planning and reviewing lessons and activities for areas of potential concern (Long et al., 2021).

These pedagogical strategies are well-aligned to the recommendations for science practice outline in the NGGS Appendix H – Understanding the scientific enterprise: Nature of Science (NRC, 2013b). This framework emphasizes that science is a human endeavor that is not

immune to sway from social and political contexts (NRC, 2013b, p. 6). According to Long et al., (2021), creating a gender-inclusive science curriculum requires "identifying the places where societal power and oppression impact specific marginalized gender groups, including transgender, intersex, and gender non-conforming people (p. 31). Thus, practice must necessarily include engaging students in critiquing how scientific models are created, and by whom, in order to help students to access the knowledge and power to being engaging in dismantling structural inequities in science education (Bakshi, 2020; Long et al., 2021).

Resisting Essentialism. Resisting essentialism was used to describe instructional materials and practices that refuse the ways oversimplified scripts of sex and gender contribute to systemic gender-based oppression (Keenan, 2017). Materials and practices were generally able to be separated into two categorical themes, *affirming diversity* and teaching with *accuracy and scientific precision.*

Affirming diversity referred to how teachers resisted essentialism and binary thinking by celebrating diversity, variation, and the multiplicity of naturally occurring phenomena. Affirming materials typically either included positive representations of LGTBQ figures or directly addressed scientific phenomena beyond the binary (see Appendices F, G, and H). This theme also speaks directly to the recent calls from professional, science education organizations that have demand stakeholders transcend antiquated notions of sex, gender identity, and gender expression and to ensure that outdated and refuted concepts, pedagogies, and instructional practices do not perpetuate harmful stereotypes or misconceptions (NABT, 2021). According to Long et al., (2019), embracing diverse phenomena not only strengthens students' understandings of science, but encourages curiosity and acceptance of naturally occurring human diversity.

Teaching with *accuracy and scientific precision* referred to building students comfort and familiarity with using precise, scientific language when discussing gender and sexual diversity. According to Liam, "it's important for students to understand complexity and to not be intimidated by that complexity, because it's truth and it gives you freedom to figure out where you stand." Practices include recognizing when complex scientific phenomenon related to sex and sexual diversity are oversimplified into inappropriately gendered perspectives. Teachers are encouraged to focus on biological features, mechanisms, and bodily processes in gender-neutral ways. With regards to the gender/sex binary, teachers are encouraged to emphasize the biology of gender/sex as context-dependent and multi-variate. Terms like "male" and "female" need to be formally defined continuously across various contexts.

In addition to being inclusive of diverse students, teaching with accuracy and scientific precision may also help teachers to engage in gender-inclusive science practices amidst a nationwide crackdown on LGBTQ-inclusive curriculum. *No promo homo* legislation tends to be particularly vague in describing curriculum specifics, instead focusing on broader language such as a restriction on teaching about "gender identity" or "sexual orientation." By focusing on the inherently scientific nature of gender and sexual diversity, teachers may engage in inclusive pedagogy that act is in direct opposition to misapplied science used to justify anti-LGBTQ discrimination.

Embracing Experiential Knowledge and Personal Epistemologies. The pedagogical practices associated with the theme of *embracing experiential knowledge and personal epistemologies* referred to helping students to understand themselves scientifically by encouraging them to draw from their own experiential knowledge and embodied epistemologies. One of the primary ways teachers encouraged students to develop their own ways of knowing

about gender and sexual diversity was through co-creation. These typically included lessons that were grounded in modeling and argumentation and allowed students to step into the role of teacher and develop their own language and models to describe scientific phenomenon.

This pedagogical approach is distinctly different from many in the current gender-inclusive science education literature. Often, gender-inclusive science education resources attempt to do the work of unscripting hegemonic conceptions of gender but do so by replacing them with other scripts that also contribute to the policing of bodies and identities, just in new ways (for example the Gingerbread Person, Killerman, 2017 as cited by Keenan, 2017). However, encouraging students to make their own meanings embraces the multiplicity of lived experience and infinite capacity of self-determination.

Engaging students in their own personal epistemologies through modeling and argumentation also align well to the National Research Council's view of science as an "evidence-based, model and theory building enterprise" (NRC, 2013a). According to Long et al., 2019, multidimensional and systems-based approaches to learning the science of gender and sexual diversity enable students to "develop the skills, connections, and scientific knowledge to critically examine complex ideas and competing models that can bridge life experience and societal concerns" (p. 29).

Implications for Practice and Future Research

The knowledge that trans* people create through the lived experience of being trans* is critical to the development of meaningful, inclusive education practices (Kean, 2021). Together, the philosophies and practices emergent in this dissertation lay the groundwork for a set of teaching principles that have the potential to guide teachers in implementing gender-inclusive science teacher through a trans*-informed lens. Thus, I recommend six principles that science

teachers can employ in order to make their gender-inclusive science teaching more trans*-inclusive. These principles are useful in guiding the conceptualizing new practice, adaptation of existing lessons, and evaluation of public resources for trans*-affirming perspectives.

1. **Teach with Continuity and Authenticity:** Engage in the constant practice of knowing and disrupting the ways that science education reinforces social functions of gender and suppresses self-expression and self-determination. *Reflect*: *Have I interrogated my own internalized biases about sex and gender, and am I willing to consistently work to create a positive classroom experience for queer and trans* students?*
2. **Center Epistemic Justice:** Become aware of the ways that trans* representations have been minimized, erased, and misapprehended in science education, and engage in pedagogies that affirm and support trans* experiential knowledge. *Reflect: Am I actively engaged in broadening my knowledge of the issues faced by trans* communities, and do I honor their perspectives, knowledge, and stories in my classroom?*
3. **Affirm Diversity:** Resist essentialism and binary thinking by celebrating diversity, variation, and the multiplicity of naturally occurring phenomena. *Reflect: Do my lessons/curriculum/practices celebrate or stigmatize variation in sex, gender, and sexual diversity*?
4. **Embrace Scientific Complexity:** Use precise, ungendered, scientific language to explain complex scientific phenomenon. *Reflect: Are my materials and explanations oversimplifying content to the point of exclusion or inaccuracy?*

5. **Emphasize Experiential Knowledge and Personal Epistemologies:** Create opportunities for students to contribute to create their own language and meanings around gender, sex, and sexuality that are grounded in experiential knowledge and personal epistemologies. *Reflect: Do I honor the knowledge created through individual experience and encourage the sharing of student perspectives?*
6. **Critically Assess Provenance and Validity:** When selecting gender-inclusive teaching materials, assess the provenance and credibility of the resource. This is critically important given that many resources may appear to be properly researched, reviewed, and verified. *Reflect: Was this resource created by someone with the and content knowledge and experience to speak on these topics? Does the resource reinforce or reject hegemonic scripts about gender and sexual diversity?*

While these principles for *trans*-informed science education pedagogy* are theoretically and conceptually grounded, there is a need for future research studies that explore the implementation of these principles within science classrooms. This should include studies of student response and teacher integration which would help to generate data on the reliability and usefulness of the suggested practices.

Implications for Teacher Professional Development

Though queer and trans* teachers are uniquely positioned to support LGBTQ students by nature of shared identities and epistemologies, any teacher can engage in analysis of their pedagogical philosophies and practices in trans*-informed ways. According to Sparrow, "it can be hard to learn if you aren't a part of the community, but anyone can do their research." For example, though emergent codes of *role models* and *visibility* directly referred to the lived

experience of being trans* they were also nested within Keenan's (2017) theme of *teaching with honesty and authenticity*. Under this guideline, any teacher can engage in trans* student support through consistent, everyday practices that directly trouble the way schools reinforce social functions of gender and self-expression (Keenan, 2017). This can include (1) interrogating ones' own biases about gender and sexual diversity, (2) consistently analysis teaching practices and curriculum through a diversity lens, and (3) disrupting the negative messages about gender and sexual diversity that students continuously receive from in and outside the classroom (Keenan, 2017; Long et al., 2021).

However, there have been many documented challenges to engaging cisgender and non-LGBQ teachers in implementing gender-inclusive teaching practices. A few studies have documented that most educators do not understand the relevance of learning about trans* issues as they may fail to see connections between children's' gender identities and their school experiences (Payne & Smith, 2018). Others have shown that even teachers who have received training about gender-inclusive science teachers still hold fears around implementation of practice (Payne & Smith, 2014; Wright, 2022). In their study of pre-service science teachers' (PSST) attitudes and beliefs about gender-inclusive science teaching, Wright (2022) described that the PSST participants (all of whom were cisgender) reported having general discomfort around making errors when it comes to honoring students' gender and sexual diversity. This included concerns about using the most accurate and up-to-date GSD terminology, as well as the limitations of their conceptual knowledge of intersexuality, hormones, and LGBTQ scientists (Wright, 2022). Participants' fears remained high even after taking part in an intervention designed to increase their knowledge of GSD-inclusive teaching practices (Wright, 2022).

Another study by Meyer and Leonardi (2018) showed that teachers are also reluctant to engage in professional development about gender and sexual diversity if it was not covered in their teacher preparation programs. This was due to perceived discomfort that they would experience having to expose the limits of their conceptual knowledge (Meyer & Leonardi, 2018).

According to Wright (2022), teacher preparation and professional development programs need to focus on "exposing and embracing limited knowledge" (p. 192) in addition to addressing teachers' pedagogical and conceptual knowledge around GSD topics. Learning takes time and developing new habits and ways of thinking about gender and sexual diversity can be challenging, even for those of us within the LGBTQ community. It can also be difficult for any person to keep up with swiftly shifting social and scientific conceptions of gender, sex, and sexual diversity. Part of doing this work is accepting ambiguity and knowing that you will always, invariably, be trying to hit a moving target (Airton & Koecher, 2019).

Creating classroom cultures where it is okay to make mistake can help to alleviate this discomfort of being wrong and can enable recovery from the inevitable growing pains learning new content and practices in a positive way (Cooper et al., 2020). Based on the findings from this study, situating the content of gender-inclusive science teacher preparation and professional development within a nature of science framework may be useful in helping teachers' to understand, embrace, and be more comfortable in the face of ever-changing conceptions of gender, sex, and sexual diversity.

Limitations

This study aimed to address the theoretical and conceptual limitations of current gender-inclusive practice with regards to trans* epistemologies and perspectives. While this dissertation succeeded in bringing together knowledge and perspectives that are critically absent from current

gender-inclusive science education scholarship, there were several limitations that limit the generalizability of the findings.

1. Sample size and diversity. This study was limited by the number of participants who agreed to take part in the study, however the sample size is one of the highest reported for research of this kind. The majority of studies on trans* K-12 teachers tend to be small, third-person or autobiographical studies of 1-3 teachers (Suárez, 2021). Research with larger samples were typically not restricted to a disciplinary perspective and subsequently drew in a larger number of teachers from across varied subjects. The study sample in this dissertation was varied in gender representation and included perspectives from participants who were trans men/masculine (n = 4), trans women/feminine (n = 2*[2]), and/or nonbinary or genderqueer (n = 4*). The sample was not particularly racially diverse with participants either identifying as White (n = 8) or Asian American (n = 2). Thus these results are not generalizable to, nor representative of, those teachers who are at greatest risk of experiencing epistemic erasure and discrimination including Black and Latina trans* women (Hoston, 2018).

2. Diversity of Instructional Materials. There was also limited diversity in the instructional materials submitted by the participants. In total, 50% of the resources submitted were modified or pulled from the Gender Inclusive Biology website. Because the Gender Inclusive-Biology Framework was used as a guiding perspective, it is likely that this increased alignment between the resources and the coding schema. However, there is important information that can be gleaned from this issue. First, it offers evidence that there continues to be

[2] One participant identified as a nonbinary trans woman.

a lack of publicly available content that accurately and inclusively attends to trans* perspectives in science education. Second, it also indicates that trans* teachers may have an understandable preference for using trans*-inclusive instructional materials that have created by individuals from the trans* community. Third, it establishes the validity and trustworthiness of the Gender Inclusive Biology resources, both in terms of preferential selection and alignment to other critical, gender-inclusive education frameworks (e.g., Kean, 2021; Keenan, 2017; Wright, 2022).

Chapter Summary

This chapter has provided a summary of the results of the study as well as highlighted connections between the findings and the existing literature. It has also provided a discussion of implications for practice and future research. Overall, the findings of this study make a valuable contribution to the field of science education, and the trans* community more broadly, by illuminating experiential knowledge and perspectives that are critically absent from current gender-inclusive science education scholarship. In an uncertain social and political climate, there will undoubtedly continue to be increased conversations around the needs of LBGTQ students in K-12 classrooms and schools. Further research is still needed to understand the viability of the principles identified in this dissertation as well as the impacts of such a framework on student and teacher knowledge and experiences.

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APPENDICES

Appendix A

Qualitative Interview Protocol

Part 1: Contextualization of the Experience
Begin with some general warmup conversation before beginning the interview.

Thank you so much for taking the time to meet with me today. This will be part (insert interview session number) of a three-part interview series where we will be talking about your experiences as a trans*-identified science teacher who is actively engaged in gender-inclusive science teaching. Your name, as well as any potentially identifying information about yourself, students, or your institution will be redacted from this interview. The audio from this interview will be recorded then transcribed for analysis. After transcription the original audio files will be destroyed.

During this interview we may be talking about potentially sensitive topics related to your trans* identity and experiences, including childhood, transition, and your academic and professional experiences. If at any point you feel uncomfortable we can pause, redirect, or skip the topic entirely.

We have one hour set aside for this interview. Do you have any questions before we start recording? Are you feeling comfortable and well enough to proceed? If it is okay with you I will start the recording now (if approved, start recording).

1. Can you tell me a little bit about who you are and how you identify?
2. How long have you been a science teacher?
3. Can you tell me a little bit about how you came to be a teacher?
4. What was school science like for you?
5. Which came first, transition or teaching?
6. Discuss trans coming out in terms of teaching timeline.
7. How was your gender journey related to teaching journey?
8. What was that experience like for you?
9. When did you start doing gender-inclusive science practice? What prompted it?
10. Did you have any concerns about how you were going to incorporate gender-inclusivity in your practice?
11. Have you had any training in gender-inclusivity pedagogy? Can you tell me about it?
12. Do you wish anything had been different about your training?
13. Why is it important for you to be teaching science in a gender-inclusive way?
14. Is there anything you would like to add to today's conversation?

Script: Thank you so much for a wonderful first session. This is a good place to wrap up. Next time we meet we will be discussing the specifics of your practice and talk about the kinds of activities and strategies you use to teach in gender-inclusive ways.

Part 2: Apprehending the Experience

Script: Today we are going to talk about how you prepare for and execute your gender-inclusive science teaching practices.

1. When do you begin planning gender-inclusive lessons in your curriculum?
2. What does that look like?
3. Walk me through the first day of classes. Do you openly share your trans* identity with students? Why or why not?
4. How do you approach the creation of a gender-inclusive lesson?
5. What are the important things to cover?
6. Do you address sex versus gender?
7. How do you teach about sex?
8. How do testing and standards influence your practice?
9. Where do you find your gender-inclusive science resources?
10. How do you know these resources are trustworthy?
11. Why is important to center trans expertise in resource development?
12. How might other teachers become literate in gender-inclusive science education, specifically trans*-inclusive science education?
13. Is there anything you would like to add to today's conversation?

Script: That was a fantastic session. Thank you so much. For our final meeting we will be discussing your science teaching within larger institutional and social contexts. We will talk about administrative support and how you are handling the issues of anti-trans legislation.

Part 3: Clarifying the Experience

Script: This is our final session! It has been wonderful getting to know you during our time together. Today we will be talking about the big picture of gender-inclusive science education.

1. How has your administration responded to your gender-inclusive science practice?
2. What supports are/are you not receiving?
3. Have you had any issues come up with caregivers and how have you handled those?
4. How have your experiences with your schooling community impacted your teaching philosophies and practices?
5. How has the recent anti-LGBTQ curriculum legislation impacted you?
6. What are your concerns for the future?
7. How do you intend to continue/not continue your gender inclusive practice in the face of increasing legislation?
8. How do you stay hopeful?
9. Is there anything you would like to add to today's conversation?

Appendix B

Materials Analysis: Positive Representations and Reflective Statements

Instructions

As a participant in this study, you are being asked to submit instructional materials you believe are positive representations of gender-inclusive science education. You will then be asked a series of reflective questions regarding the content and effectiveness of each resource. These may be materials you have conceptualized or created yourself or can be materials you have utilized or adapted from other sources.

Examples can include resources like posters; presentations; lesson plans; activity and reading guides; pedagogical frameworks; graphics, diagrams, and models; videos; readings, scientific papers; news articles; or any other resource used in implementing gender-inclusive science education practices.

Please submit a new form for each resource or set of related resources.
Resources or materials should not contain any student information

If you would like to submit an online resource, please include the link in the space below. If there are multiple materials listed on the webpage, please also include notes about which specific material (or set of related materials) you are referring.

[open ended text box]

You may also upload your example/s. You may upload documents, spreadsheets, PDFs, videos, presentations, drawings, images, and audio files. If your files are too large to upload, please email me at [redacted].

[file upload button]

Resource Description

1. The following statements are related to authorship of the resource submitted. To the best of your knowledge, please select all that apply.
    a. I am the original author/creator of this resource.
    b. The resource is an original work from another author/creator.
    c. I have modified this resource from another author/creator.
    d. This version of the resource, as it has been submitted, is publicly available.
2. What best describes this resource? If this is a series of related resources, please check all that apply.
    a. Pedagogical Framework
    b. Curriculum
    c. Unit

    d. Lesson
    e. Activity
    f. Textbook
    g. Supplementary Reading
    h. Diagram or Model
    i. Multimedia (video, audio, or photo)
    j. Presentation
    k. Other
3. Please describe the use of this resource in your classroom.
    a. This is a resource I have used in my classroom.
    b. I have not used this resource, but plan to.
    c. I probably won't use this resource, but still think it is positive.
4. Are you required by your school/administration to use this resource?
    a. Yes
    b. No

Reflective Questions: Positive Examples
The following questions will guide reflection into the effectiveness and/or usefulness of the instructional resource or material submitted. In some cases you will be asked to reflect on the implementation of the resource or material in the classroom. If you have not used, or do not intend to use the resource in the classroom, you may reflect on its general potential. You do not have to answer all questions. However, detailed responses are encouraged where applicable.

1. Describe how and where you found this resource.
2. If you created or modified this resource, what motivated you to do so?
3. If you did not create this resource, describe how you assessed the effectiveness or usefulness of the resource before using it.
4. What aspects of the resource make it a positive example of gender-inclusive science education?
5. What part of your curriculum does this resource support?
6. Please describe any alignment of this resource to the Next Generation Science Standards. https://www.nextgenscience.org/
7. Describe how the resource or material impacted, or might impact, student learning.
8. Describe how the resource or material impacted, or might impact, students' feelings of safety or belonging.
9. If applicable, how were gender, sex, and/or sexual diversity accurately and inclusively addressed in the resource?
10. What biases or misconceptions, if any, does this resource address?
11. What misconceptions or biases were, or might be, revealed while using this resource or material?
12. What was/is your comfort level with the topics or ideas presented in the resource? What aspects are you most and least comfortable with and why?

13. Did any difficult situations arise as a result of using this resource or material? How did you address them? (You may also consider what difficult situations may arise in the future if you have not yet used the resource.)
14. If you used this resource or material in your classroom, did anything surprise you? Please describe.
15. How did, or would, you engage students during implementation of this resource or material?
16. If you were going to use this resource or material again, what would you change and why?
17. How does this resource fit into your gender-inclusive teaching practice?
18. If you have not, and do not plan to use this resource, please elaborate on the reasons for your decision.
19. If you have not, and do not plan to use this resource, what changes would need to be made to the resource, or to your teaching environment, in order for you to decide to use this resource in your classroom?
20. You may use this space to write out any other thoughts or perspectives you have on the resource that were not covered by the questions above.

Appendix C

Materials Analysis: Negative Representations and Reflective Statements

Instructions

As a participant in this study, you are being asked to submit instructional materials you believe are negative representations of gender-inclusive science education. You will then be asked a series of reflective questions regarding the content and effectiveness of each resource. These may be materials you have conceptualized or created yourself or can be materials you have utilized or adapted from other sources.

Examples can include resources like posters; presentations; lesson plans; activity and reading guides; pedagogical frameworks; graphics, diagrams, and models; videos; readings, scientific papers; news articles; or any other resource used in implementing gender-inclusive science education practices.

Please submit a new form for each resource or set of related resources.
Resources or materials should not contain any student information

If you would like to submit an online resource, please include the link in the space below. If there are multiple materials listed on the webpage, please also include notes about which specific material (or set of related materials) you are referring.

[open ended text box]

You may also upload your example/s. You may upload documents, spreadsheets, PDFs, videos, presentations, drawings, images, and audio files. If your files are too large to upload, please email me at [redacted].

[file upload button]

Resource Description

1. The following statements are related to authorship of the resource submitted. To the best of your knowledge, please select all that apply.
    a. I am the original author/creator of this resource.
    b. The resource is an original work from another author/creator.
    c. I have modified this resource from another author/creator.
    d. This version of the resource, as it has been submitted, is publicly available.
2. What best describes this resource? If this is a series of related resources, please check all that apply.
    a. Pedagogical Framework
    b. Curriculum
    c. Unit
    d. Lesson

    e. Activity
    f. Textbook
    g. Supplementary Reading
    h. Diagram or Model
    i. Multimedia (video, audio, or photo)
    j. Presentation
    k. Other
3. Please describe the use of this resource in your classroom.
    a. This is a resource I have used in my classroom.
    b. I have not used this instructional resource or material, but plan to with modifications.
    c. I would not use this instructional resource or material in my classroom.
4. Are you required by your school/administration to use this resource?
    a. Yes
    b. No

Reflective Questions: Negative Examples
The following questions will guide reflection into the negative aspects of the instructional resource or material submitted. You do not have to answer all questions. However, detailed responses are encouraged where applicable.

1. Describe how and where you found this resource.
2. What part of your curriculum was this resource designed to support?
3. Please describe any alignment of this resource to the Next Generation Science Standards. https://www.nextgenscience.org/
4. What aspects of the resource make it a negative example of gender-inclusive science education? Are there biases or misconceptions present?
5. Describe how the resource or material might negatively impact student learning.
6. Describe how the resource or material might negatively impact students' feelings of safety or belonging.
7. What difficult situations might arise as a result of using this resource or material?
8. If possible, how might you change this resource or material to be more gender-inclusive?
9. You may use this space to write out any other thoughts or perspectives you have on the resource that were not covered by the questions above.

Appendix D

LGBTQIA Science/STEM Etymology List (Gender Inclusive Biology Project, 2019)

This is a partial list of root words that occur in both LGBTQIA issues and STEM content. This list was compiled as a tool to help teachers integrate gender-inclusive themes into their teaching.

You might ask students to speculate on the meaning of a new science word like “homozygous” based on the meaning of the familiar word “homosexual”. Or you might have students write formal definitions of “transgender” and “cisgender” to apply their vocabulary after a lesson on cis- and trans-isomers. By taking a quick moment to make the connection, you can improve student literacy and affirm diverse identities in your classroom.

- Sam Long, high school science teacher in Denver, CO. sam.long.mt@gmail.com

Root word	Meaning	LGBTQIA words (and occasional other interesting word s)	STEM words
A-, An-	Not	• asexual • agender • aromantic	• anesthetic • atrophy • aneuploidy • atom • acoelomate • abiotic • acellular • anhydride • astigmatism
Ad-	To, toward (often as in adding one thing to another)	• advocate (from *ad* "toward" + *vocare* "to call") • ally (from of *ad* "toward" and *ligare* "to bind one thing to another" • appropriation (from of *ad* "toward" and *propriare* "take as one's own")	• adhesion • admixture • adjacent • approximate • addition

Andro- Gyno-	Man Woman	• androgyny • androphilic • gynephilc • misogyny	• android • androgen • gynecology
Bi-, di-, dy- Mono-	Two One	• bisexual, monosexual • bigender • gender binary • dyadic (not intersex)	• biceps • bicuspid valve • bidirectional (DNA replication) • bifurcate (phylogeny, respiratory system) • binomial nomenclature • binary number system • binary fission • binocular vision • bipinnaria • bipedal • bipolar • biphenyl • biramous • bisphosphate (in RuBP and 1,3BPG) • bivalve • dilemma • diploid • dimorphic • dimer • carbon monoxide • monotreme • monomial • monocot, dicot • monoecious (species with both male and female reproductive organs in the same individual, hermaphroditic) and dioecious (not hermaphroditic) • Monozygotic and dizygotic twins • monomer • monosaccharide, disaccharide

			• adenosine diphosphate, adenosine monophosphate (ADP, AMP) • monohybrid cross, dihybrid cross • monoprotic acid, diprotic acid • monopole, dipole
-cide	Killing	• genocide • homicide • suicide	• pesticide • insecticide • herbicide • fungicide • germicide • cell suicide (apoptosis)

Demi-, semi-, hemi-	Partly (Old French, Latin, and Greek versions respectively)	• demisexual • demiboy • demigirl	• hemisphere • semiaquatic • semicircle • semipermeable • semilunar valve • semitone • semiconductor
Dia-, dias-	Across, through	• diaspora	• London dispersion force • seed dispersal • diagonal • diabetes (urine passing through bodyquickly) • adiabatic (heat not passing through) • diameter • diaphragm • diagnosis (to know thoroughly or to know apart from another)
Dis-	Off, away	discrimination (to mark differences between one from another. From *dis* "off, away" and *krei* "to sieve")	discriminant (algebra) discrete math (not continuous) discontinuity distinct displacement disease

Divers-	Different	• gender diversity	• biodiversity • divergent evolution • divergence theorem • diverticulum
Endo- Ecto-, Exo-	Inside Outside	• endosex (not intersex) • endogenous, exogenous hormones • endocrine, exocrine	• endomorph, ectomorph • endoderm, ectoderm • endosperm • endemic • endocytosis, exocytosis • endosymbiosis theory • endosome, exosome • endoderm, ectoderm • exotic species • exoskeleton • endothermic, exothermic • endoscope
Equi-	Equal, the same	• equality • equity	• equidistant • equation • equilateral • equilibrium • punctuated equilibrium • equivalence point

Gam-	Marriage, union	• monogamy	• gamete • karyogamy • plasmogamy • heterogametic
Gen-	Origin, birth	• gender • genocide	• genus • gene • genome • spontaneous generation • spermatogenesis, oogenesis • parthenogenesis • phylogeny • general form • generalization • miscegenation
Homo- Hetero-	Same Different	• homosexual, heterosexual • homoromantic, heteroromantic • homophobia • heterosexism • heteronormativity	• homeostasis • homogeneous, heterogeneous • homozygous, heterozygous • homologous chromosomes • homologous structures • homeotherm • heterotroph • heteronormativity • heterogametic • homonuclear molecule
Inter-	Between	• intersex • intersectionality	• interspecific competition • interstitial • intermembrane space • intertidal zone • intermolecular forces • constructive interference, destructive interference • interpolate • interval • Interquartile range

-ism	Doctrine or system	• sexism • cissexism	• metabolism • anabolism/catabolism • mutualism, parasitism, commensalism • polymorphism • sexual dimorphism • magnetism • astigmatism
Margin	Border or boundary	• marginalized	• Marginal Value Theorem • margin of error • marginal cost
Misce	Mix	• miscegenation • promiscuous	• miscible • mixture • admixture • miscellaneous
Neutr-	Neither one nor the other	• gender-neutral (describes things like bathrooms signs; doesn't generally describe people) • neutrois	• neutral (charge) • neutralize (acids, bases) • neutron • neutrino
Non-	Not	• nonbinary	• nonpolar • nondisjunction • nonrenewable energy • nonmetal • nonionizing radiation • nonlinear

Norm-	Typical, common	• heteronormativity • cisnormativity	• normal force • normal saline • abnormal
Pan-	All	• pansexual • panromantic • pangender	• panspermia theory • Pangaea • pandemic
Patr-	Father	• patriarchy • patriotic	• paternal • paternity • allopatric speciation (occurring in separate "fatherlands") • sympatric speciation
Phobia Philia	Fear Loving	• homophobia • transphobia • biphobia • homophile (dated term)	• hydrophobic, hydrophilic • hemophilia

Poly-	Many	• polyamorous • polysexual • polyandrous and polygynous (in human cultures and animal species)	• polymer • Polysaccharide • polyunsaturated fats • polymerase • polypeptide • polymorphism • polygenic inheritance • polyploidy • polyp • polytomy (phylogeny) • Polycystic ovarian syndrome • polyatomic ion • polycyclic aromatic hydrocarbons • polyprotic acids • polyethylene • polynomial • polygon • polyhedron
Priv-	Right, priority	• privilege	• oxygen deprivation • sleep deprivation
Radi-	From the root, fundamental	• radical (changing the fundamental nature of something)	• eradicate • radish • radioactivity • adaptive radiation • radial symmetry • radius (geometry) • radians • radical (square root) • radius (bone) • radicle (plants) • free radical

Stereo-	Stiff, solid, three-dimensional	• stereotype (meaning an image perpetuated without change. Named after a method of printing text using solid plates)	• stereocilia • stereoscopic vision • stereoisomer • stereogram (magic eye)
System-	Of a whole arrangement that stands together	• systemic barrier • systemic discrimination	• ecosystem • organ system • buffer system • closed, open system • photosystem I and II • coordinate system • system of equations

Terkw-	To twist, oblique, off-center, strange,	• queer (possibly) • genderqueer	• torque • retort • torsion
Trans- Cis-	On the other side of On the same side of	• transgender, cisgender	• trans isomer, cis isomer • trans fats • bacterial transformation • transcription, translation • transgenic • active transport, passive transport • electron transport chain • neurotransmitter • transitional fossils • signal transduction • transfer RNA (tRNA) • chromosomal translocation • transverse plane • transition metals • transuranium elements • transformer (electricity) • transverse wave • transatlantic • transversal (geometry)

Vary	To be changed	• gender variance	• variation (in natural selection) • analysis of variance (ANOVA) • variance (statistics) • independent and dependent variable • varicose veins, varicocele • variola, varicella (viruses)

Appendix E

Gender-Inclusive Pedigrees Lesson
(modified from Gender-Inclusive Biology Project, 2020)

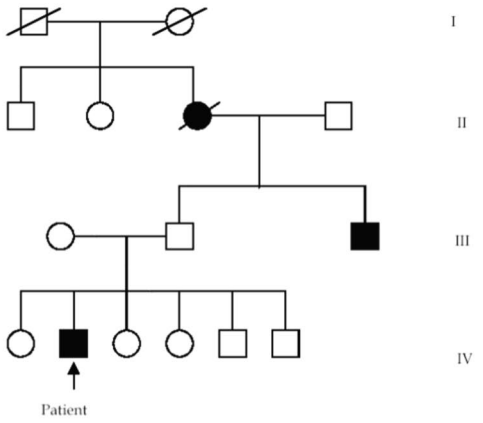
Slide 1

Important to note: people and families come in all shapes and sizes :)

- **A pedigree chart is not a family tree.** It only represents the passing down of genetic traits from ancestors to descendents.
- As most human and nonhuman individuals never receive a karyotype test, the symbols usually represent sex assignment at birth rather than chromosomal sex.
- **A pedigree chart shows phenotype and not genotype unless otherwise indicated.** We typically construct a pedigree chart out of macroscopic observations only, then we apply our knowledge of genetics when analyzing the chart.

with gratitude to genderinclusivebiology.com

Slide 2



Who is not represented by these diagrams?
Could these identities be relevant to the purposes of these diagrams?
If so, could we create a way to represent them?

Slide 3

There are many ways scientists have represented the beauty (and complexity!) of ancestry, identity, and family life:

- A traditional diamond for unknown sex - Can you think of multiple reasons why this symbol would be needed in the past? In the present?
- Symbols for relationships that have ended, and consanguinity
- Symbols for miscarriages, abortions, and stillbirths
- Symbols for adoption, infertility, not having children by choice, and sperm donors
- Annotations for intersex traits 1, 2
- Genograms, which are an alternative to a pedigree chart, used in a variety of fields outside of genetics. Genograms include symbols for LGBT identity, non-biological children, and even habits and social relationships.

Who is not represented by these diagrams?
Could these identities be relevant to the purposes of these diagrams?
If so, could we create a way to represent them?

with gratitude to genderinclusivebiology.com

Slide 4

One more note:

In today's assignment, we'll use "birth mother" and "birth father," but remember families (and reproductive technologies!) come in all shapes and sizes.

Gender-Inclusive Pedigrees Worksheet
(modified from Gender-Inclusive Biology, 2020b)

Name: _____
Period: ___

Pedigree assignment

See slides for notes and more details [redacted]!

Pedigrees...

→

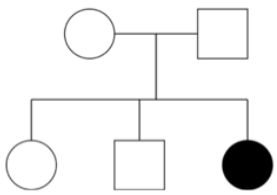
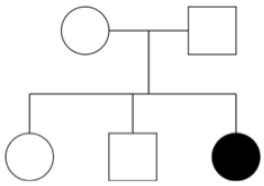
→

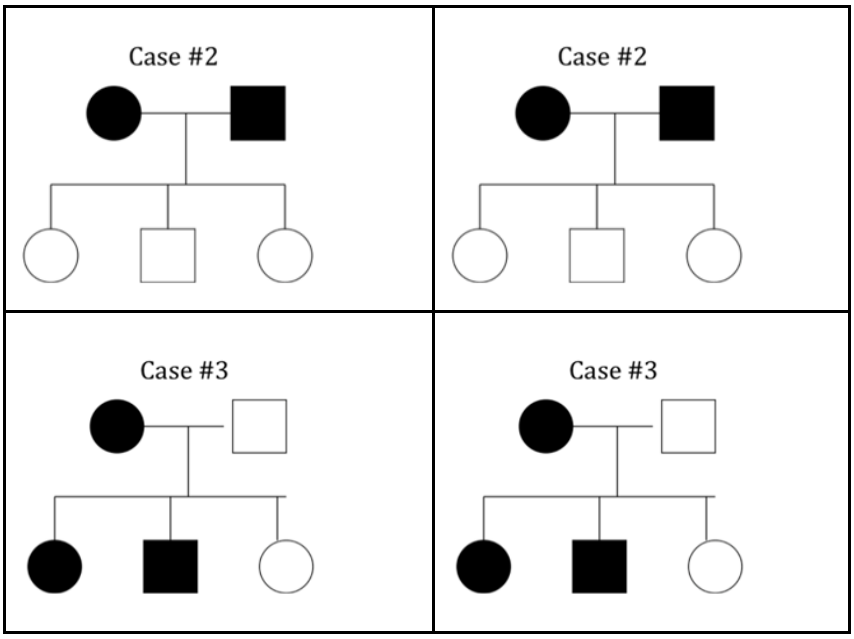
1.
2.

→

Translating Patient Information into Pedigrees:
A kid assigned female at birth who has a genetic condition has 2 cisgender sisters and one cisgender brother. Their brother has the same condition, but their sisters do not. Their birth mother has the condition but their birth father does not.
Draw the pedigree below:

Dominant or Recessive?
Assign genotypes below each person. In the space to the right of each pedigree, explain your answer to the bolded question.

What if it was <u>dominant</u>?	**What if it was <u>recessive</u>?**
Case #1 	Case #1 



GENETICIST PROBLEM: You are going to explain to a couple the probability of a child developing an autosomal genetic condition if their gametes are both used. Because little is known about the genetics of the condition, you will also characterize it to aid other medical personnel and geneticists.

Patient Information

Spouse 1

· Spouse 1(he/him) is a cisgender man and has the condition.
· You do not know additional information about Spouse 1.

Spouse 2

· Spouse 2 (she/her) is a cisgender woman and does not have the condition.
· Spouse 2's parents passed on gametes to three children in their family (including Spouse 2).
· Spouse 2 has a cisgender sister without the condition and a cisgender brother with the condition.
· Both of Spouse 2's parents have the condition.
· Spouse 2's father is an only child; his birth father has the condition, but his birth mother does not.
· Spouse 2's mother has two siblings assigned male at birth who do not have the condition; her birth mother had the condition, but her birth father did not.

Your Tasks

1. In the space below, translate the patient history into a pedigree using standard notation and symbols.
Hint: you should do a rough draft on scratch paper first.

2. A. Is the condition dominant or recessive? _____

B. In the space below, **take some quick notes about** how you can tell if the allele is dominant or recessive. Use specific relationships (between people in the patient history) to support your claim. You'll restate this more formally at the end of this assignment.

3. Add genotypes to each person in the patient history who's represented on your pedigree for #1. Use "A" for dominant allele and "a" for recessive allele.

For questions 4 and 5, show a **Punnett square***, the* **ratios of the potential genotypes** *of the child, and the* **ratios of the potential phenotypes** *of the child for* <u>*each*</u> *situation. At the end of this assignment, be sure to "translate" these into a* **description of what the Punnett square means and an explanation of the results.**

4. If Spouse 1 is heterozygous for the allele that causes this condition, what is the probability that their child will develop the condition?

5. If Spouse 1 is homozygous for the allele that causes this condition, what is the probability that their child will develop the condition?

Finally, use the explanation tool on the next page to write out a final answer!

Explanation Tool

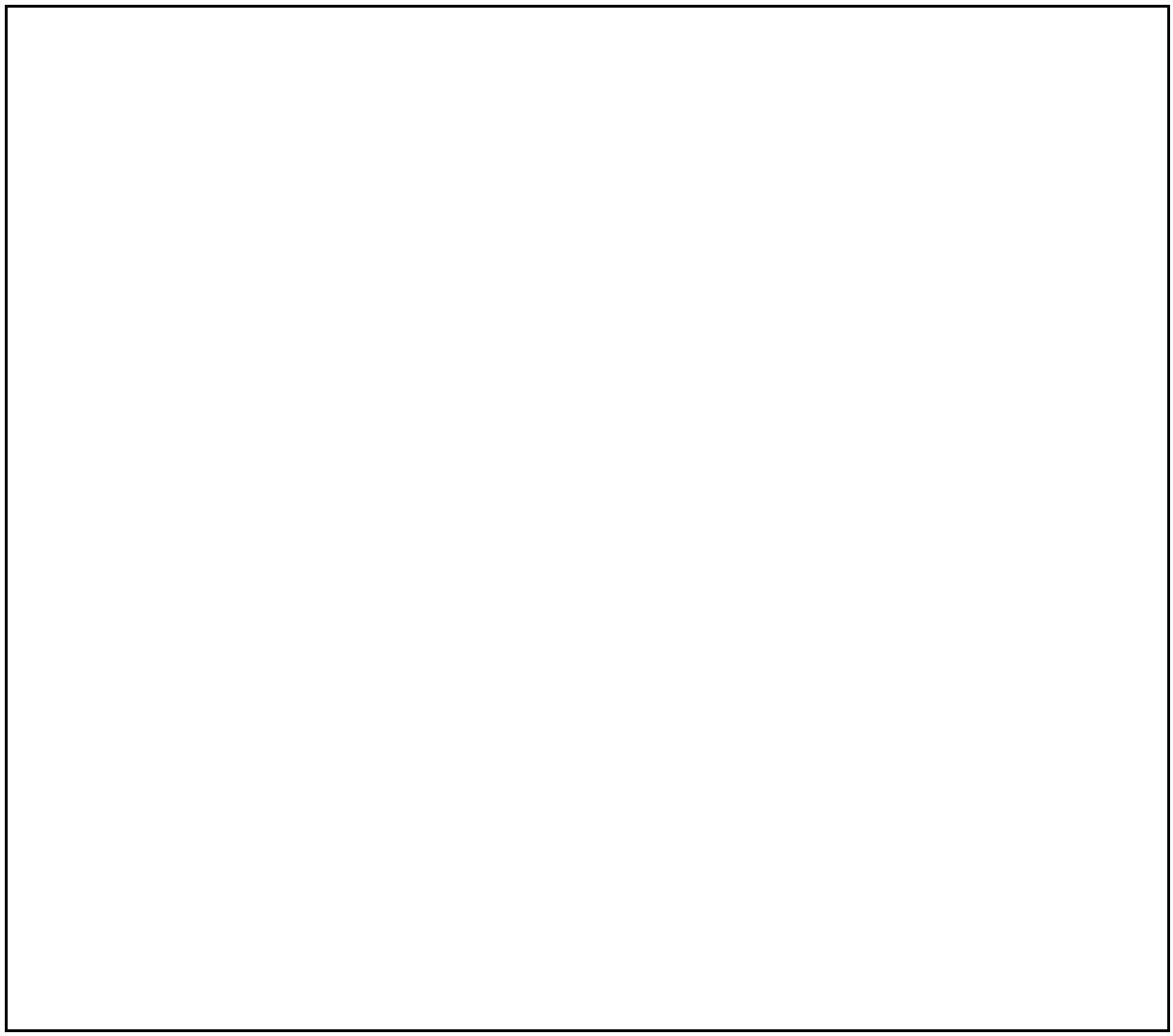
Question
What is the probability that this couple's child will develop the genetic condition?
Claim *Your claim should answer the question.*

Explanation

Full paragraphs... and the only part I'll read.
Make sure to link your claim, evidence, and science ideas.
Describe what you did above in writing...There is this much space for a reason!

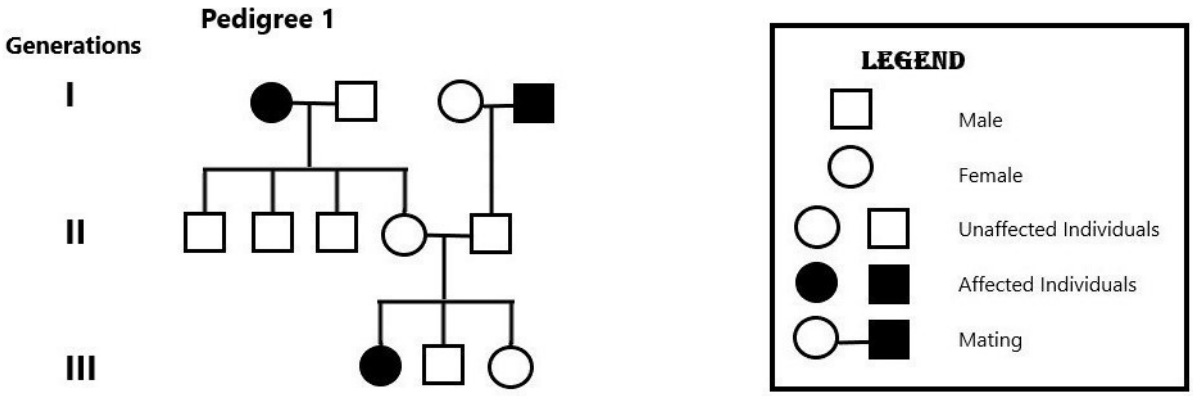
Your answer should show you were able to…

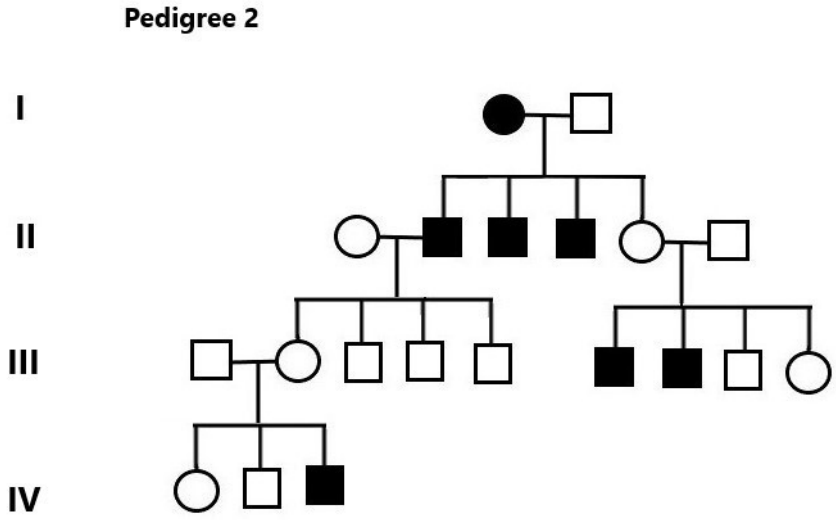
1. make a pedigree from the given information
2. correctly describe the genetics of this genetic condition
3. correctly assign genotypes to individuals
4. use these genotypes to construct Punnett crosses
5. use the Punnett crosses to predict the probability of the genetic condition in the child



Gender-Inclusive Pedigrees Original Activity
(Gender-Inclusive Biology, 2020b)

Gender-Inclusive Pedigree Charts





A typical pedigree chart in biology education.
Image from https://www.theknowledgeroundtable.com/tutorials/decoding-pedigrees-made-easy/

What is a pedigree chart?

A pedigree chart is a diagram that shows the occurrence of phenotypes through several generations of genetically related individuals. Because a pedigree chart uses symbols to

differentiate males from females, and is often taken as a “family tree”, it is important for educators to give clear and inclusive messaging to their students about these charts.

Pedigrees in context

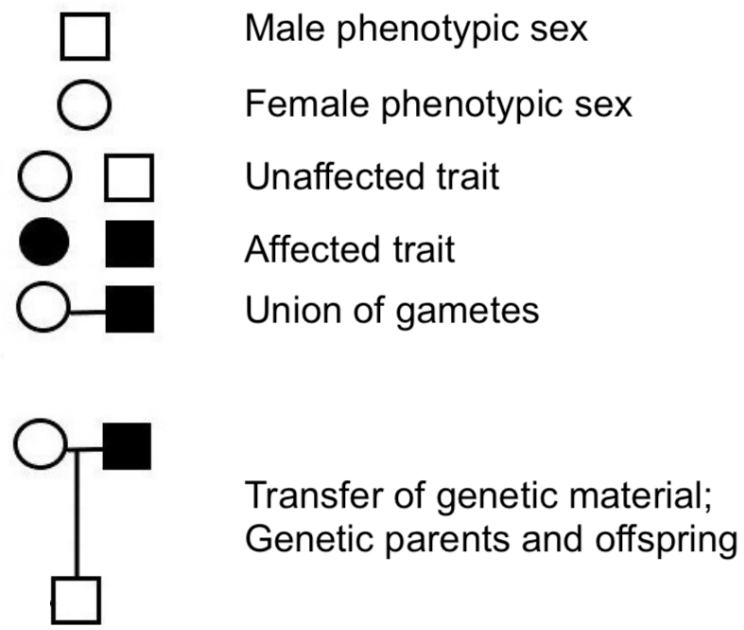
Every diagram is created for a specific purpose. The pedigree chart was originally developed to track the “purity” of nobility bloodlines in England. It also had early use in selective breeding of animals. Today, with new knowledge about genetics, we mainly use pedigrees to observe and apply patterns of genetic inheritance. The pedigree chart is useful in studying genetics, but it does not fully represent anybody’s family or relationships.

Precise and pertinent language

When teaching about pedigree charts, we encourage educators to modify existing diagrams and/or give supplemental instruction to make the following technical points:

- A pedigree chart is not a family tree. It only represents the passing down of genetic traits from ancestors to descendents.
- Squares and circles denote male and female sex, respectively (not gender.) As most human and nonhuman individuals never receive a karyotype test, the symbols usually represent external genitalia rather than chromosomal sex.
- A pedigree chart shows phenotype and not genotype unless otherwise indicated. We typically construct a pedigree chart out of macroscopic observations only, then we apply our knowledge of genetics when analyzing the chart.
- When two individuals are connected by a horizontal line, this represents a union of their gametes. It does not necessarily represent a marriage, relationship, or even sexual activity because reproductive technologies may be used to unite egg and sperm.
- Vertical lines represent genetic parent-offspring relationships, with about 50% of the parent’s genetic material being transferred. These lines do not necessarily represent parenting, caregiving, legal guardianship, or any social relationship.

Suggested legend or key for basic pedigree charts



Representing diversity

The pedigree tradition has a history of misrepresenting people with marginalized identities, with a notable example in transgender history. For many generations, British genealogists have compiled large books called peerages which list names and relationships within noble families. L. Michael Dillon, an early 20th century transgender man and the son of a Baronet, was publicly outed when a tabloid reporter noticed that two different peerage books listed him under two different names and genders.

Today, most of the pedigree charts used in K-12 science education have no means of representing diverse family structures or representing individuals who are lesbian, gay, bisexual, transgender, queer, or intersex (LGBTQI+). We suggest asking your students, *"Who is not represented by these diagrams? Could these identities be relevant to the purposes of the diagram? If so, could we create a way to represent them?"* This will get students thinking about the limitations of the diagrams and possible solutions that could fulfill a need.

Students can compare their created representations to some of the symbol systems that are displayed online. There are no absolutely standard symbols, with different systems used throughout the years and across disciplines, including:

- A traditional diamond for unknown sex - can you think of multiple reasons why this symbol would be needed in the past? In the present?
- Symbols for relationships that have ended, and consanguinity
- Symbols for miscarriages, abortions, and stillbirths
- Symbols for adoption, infertility, not having children by choice, and sperm donors
- Annotations for intersex traits 1, 2
- Genograms, which are an alternative to a pedigree chart, used in a variety of fields outside of genetics. Genograms include symbols for LGBT identity, nonbiological children, and even habits and social relationships. Basic, More in depth (start on slide 16)

Additional Resources

- What is intersex? Frequently Asked Questions from interACT
- There Are More Than Two Human Sexes - Video by SciShow
- GLSEN Gender Triangle - A graphical foundation for understanding gender identity
- Signaling Inclusivity In Genetics Topics - Article By Karen G. Hales
- The Misuse of Pedigree Analysis in the Eugenics Movement - Article by Mark Shotwell (starts page 10)
- Beyond circles and squares: A commentary on updating pedigree nomenclature to better represent patient diversity - Article by Tuite, Piazza, Brandi, & Pletcher

From GenderInclusiveBiology.com

Appendix F
Organic Chemistry Helped Me Embrace My Identities

Link to Radio Episode: https://www.npr.org/2021/06/28/1010893563/organic-chemistry-helped-me-embrace-my-identities

Transcript: https://www.npr.org/transcripts/1010893563

Directions: Listen to or read the transcript for the Short Wave episode "Organic Chemistry Helped My Embrace My Identities", then answer the following questions based on both the interviews and your own experiences. Be sure to answer the questions with full sentences.

1. In science, we often attempt to put the world into categories based on properties and behaviors. What is an example of categories that exist in the scientific world, and what would you put in the categories? You can use examples we have discussed in class this year, or things you learned outside of class.

2. Sometimes, scientific categories change or break down. The Ancient Greeks used to suggest that all matter was made up of fire, water, earth, and air. Do we still use these categories? If so, where; if not, what do we use instead?

3. Society often attempts to put us into different categories. What are some examples that Ariana Remmel mentions in their interview of ways they've been asked to categorize themself? Can you think of other examples of categories we are asked to put ourselves into?

4. Ariana talks about molecules having "resonance" rather than having a single chemical bond or a double chemical bond. What does it mean for a molecule to have resonance, and how does it fit with the categories of "single bond" and "double bond"?

5. Scientists argue day in and day out about how to define categories. There are many different ways to determine what animals are different species, many different ways to categorize types of chemicals, and many different ways to describe people. Are these categories still useful, even if not everything and everybody fits neatly into one category or another?

Appendix G
Diverse Reproductive Strategies Gallery Walk
(Gender-Inclusive Biology, 2020a)

U7d13 Reproductive Strategies

Name: _____ Per: _____

Do Now

Read the information below about two different reproductive strategies. Then answer the questions.

Many organisms differ in their number of offspring and the amount of care they provide to offspring.

R-strategists and *K-strategists* are terms that describe two different patterns of reproduction.

R-strategists such as the tuna fish (*Thunnus thynnus*) reproduce at a high rate, and their offspring receive little parental care. Child mortality (death) is common, but a small fraction survive because they have small bodies and they reach reproductive age quickly. R-strategists are successful in unstable environments where resources such as food are not consistently available.

K-strategists such as the chimpanzee (*Pan troglodytes*) raise one or a few offspring, each receiving a high level of parental care. This parental investment minimizes the chance of child mortality, with the trade-off that only a few offspring can be raised this way. K-strategists usually have large bodies and long lifespans so that they can care for their young for as long as possible. This strategy is successful in stable environments where resources such as food are available in a consistent and predictable pattern.

[1] Describe the difference between R-strategist and K-strategist species.

_____

_____

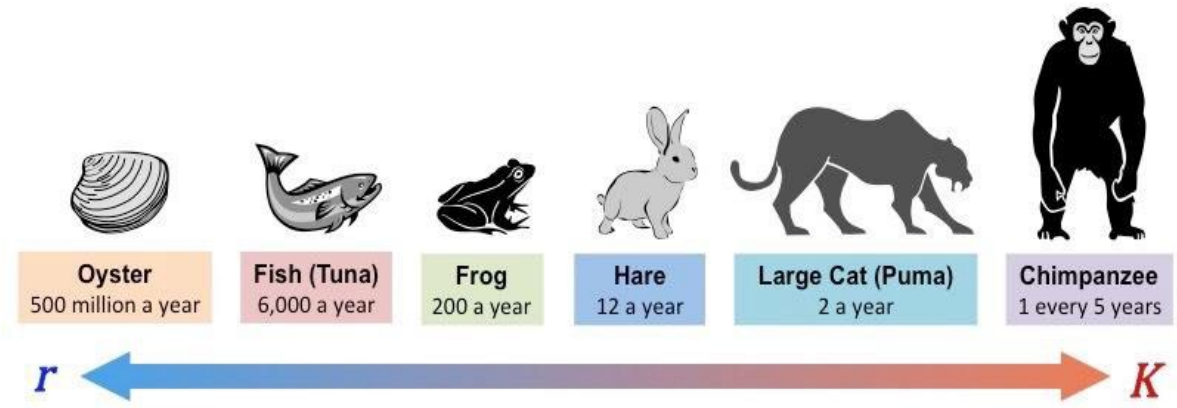
_____

[2] Both strategies can be considered successful, but it depends on the environment. In what environment is each strategy more successful?

_____

_____

_____



Question of the Day:

Why are different species adapted to reproduce with different strategies?

Reproductive strategy	**Summarize the strategy**	**What is the evolutionary benefit of this strategy?**
(1) R- and K-strategists	Done in the Do Now	
(2)		
(3)		
(4)		

(5)		

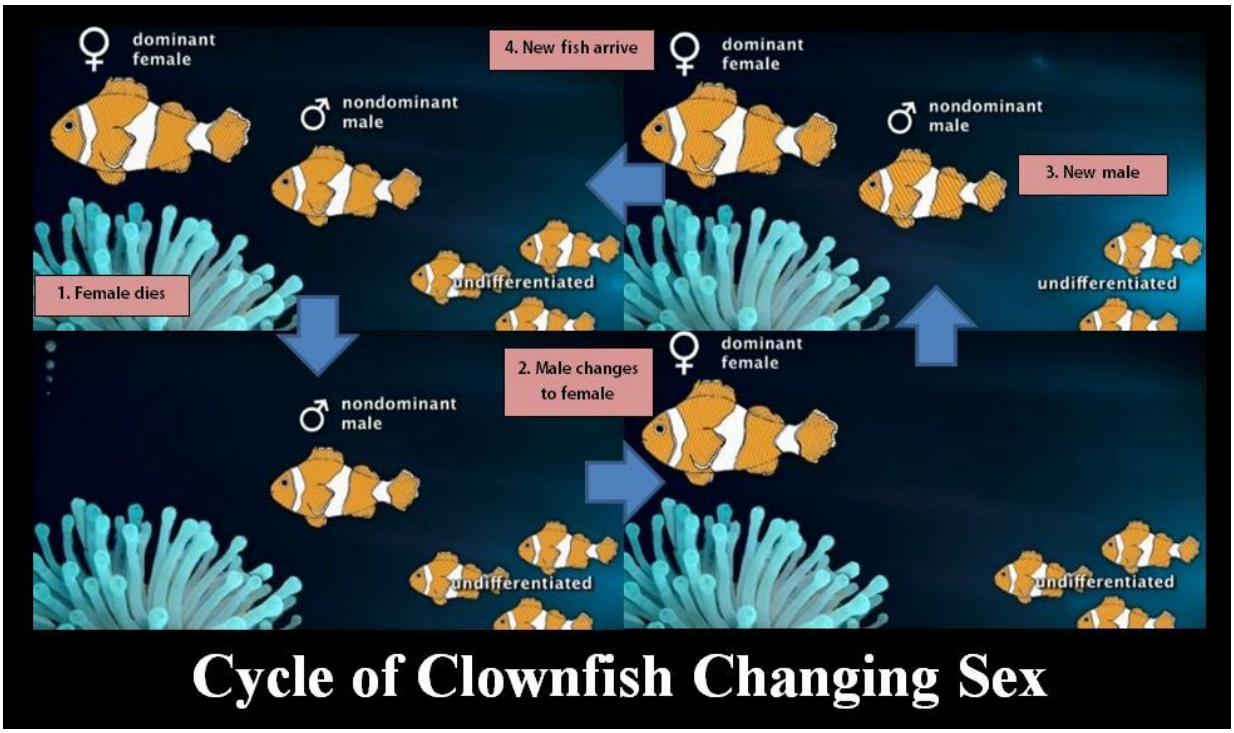
Exit Ticket
In a paragraph:
(4 points) Describe two different reproductive strategies used by different animal species. Explain how each strategy contributes to passing on genes for that species in that environment.
(2 points) Explain why the strategy of one species might not work for the other species.
Type your paragraph in the Exit Ticket google form or write your paragraph on lined paper.

Reproductive Strategy: **Female Phalaropes Compete for Males**

A genus of duck-like birds called phalaropes are unique because they have a sex-role reversal in their breeding system. In most birds, males are larger than females and sexual selection takes the form of male-male competition or female mate choice. But in phalaropes, females are polyandrous, meaning that have many male mates. Females compete for males and for nesting territories, and they are larger, more aggressive and more brightly colored than males. After the females have laid their eggs, they depart on their southward migration, leaving the males to incubate the eggs and raise the young.

Source: https://www.audubon.org/news/wilsons-phalarope-rebel

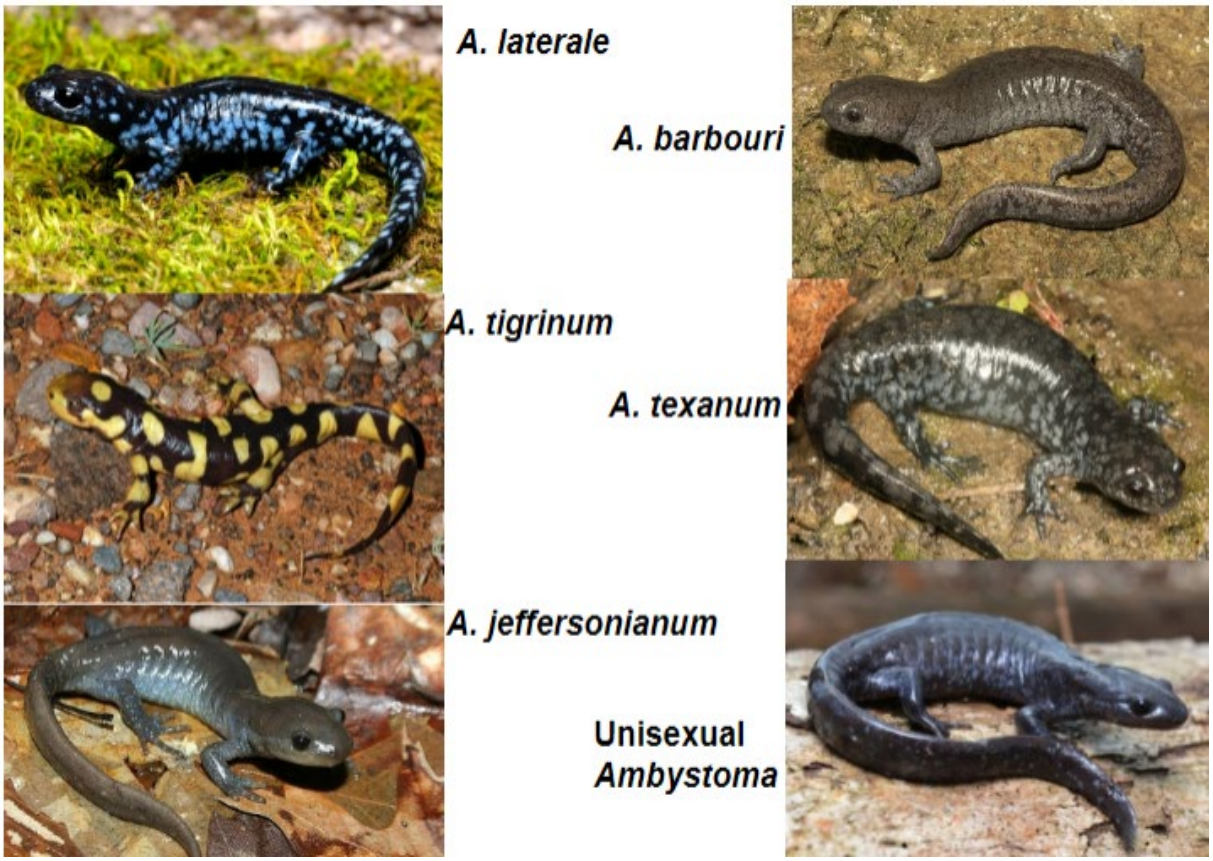
Reproductive Strategy: **Sequential Hermaphroditism in Clownfish**
Clownfish (*Amphiprion percula*) live in families led by one dominant female which has the largest body. The rest of the fish are males or undifferentiated juveniles, meaning they have not developed sex characteristics yet. When the dominant female dies, a nondominant male undergoes a change in physical sex to become the new dominant female. This process is called sequential hermaphroditism in animals. This process ensures that the colony will always have a dominant female that is able to lay eggs, with no competition from other reproducing females.



Source: http://www.exeter.ac.uk/news/featurednews/title_594884_en.html

Reproductive Strategy: **Unisexual female salamanders steal genes from other species**
Some populations of *Ambystoma* salamanders are made up solely of females (bottom right image). To give birth to new daughters, the adult

females “steal” some genes from the sperm packets of other salamanders (not *Ambystoma).* This allows *Ambystoma* to gather genes from any of 5 other species of salamander (see image) and pass them down to their daughters. By using "stolen" genes from local salamanders, the mothers can “customize” their offspring, meaning the offspring are adapted to specific local environmental conditions such as heat, humidity, and coexisting species.

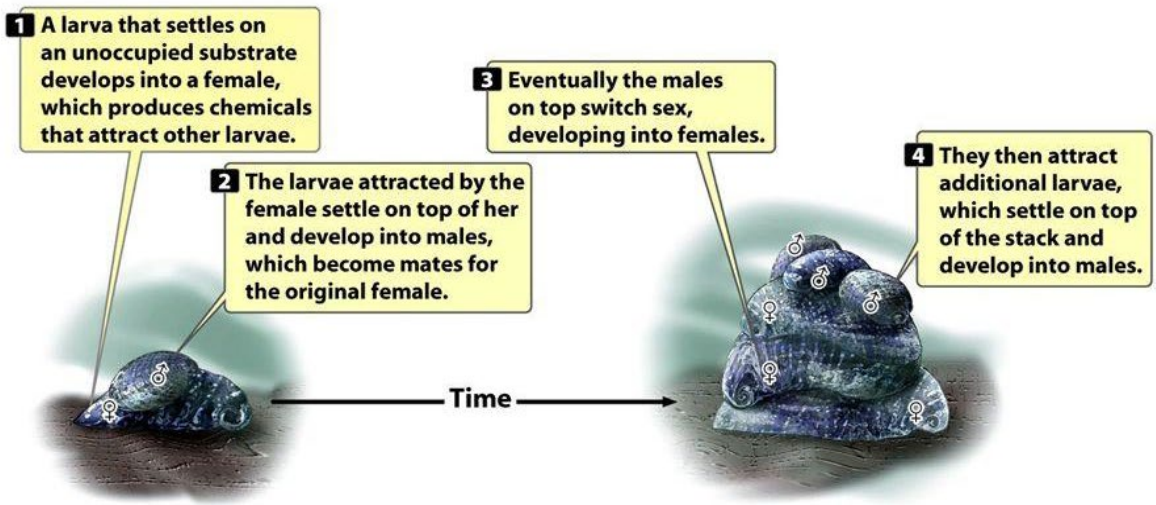


Source: https://www.sciencealert.com/researchers-find-this-all-female-polyamorous-salamander-has-three-equal-daddies

Reproductive Strategy: **Environmentally Determined Sex in Slipper Limpets**

Slipper limpets (*Crepidula fornicate*) are a slug-like organism that is very slow-moving. Limpet larvae (young) fall onto the bottom of the ocean and by random chance, they may or may not land near a potential mate. So why do they not go extinct? The following strategy increases their chances of reproducing:

1. If the larva lands on empty ocean floor, it develops a female sex and releases chemicals that attract other larvae.
2. Other larvae that land on top of a female larva will develop a male sex due to their contact with the female. These two larvae can now mate.
3. As more larvae land on top of the stack, the physical contact triggers the males undergo a physical change to female sex. This allows them to mate with the newly landed females.



Source: https://www.newswise.com/articles/the-power-of-touch?sc=dwhn

Appendix H

Animal Patterns of Reproduction Lesson Plan
(Gender-Inclusive Biology Project, 2019c)

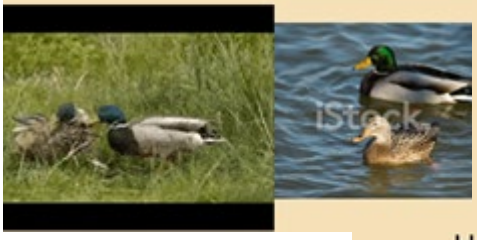
Animal Patterns of Reproduction

The nine species below show just some of the diverse patterns of reproduction existing in the animal kingdom alone. Before researching, look at the images and make predictions about how each species' appearance or behavior may help it to reproduce.

Elephant seal

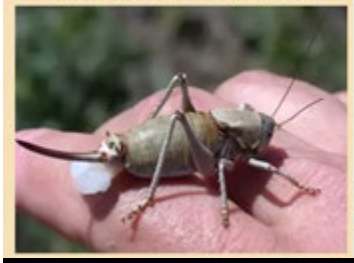
Seahorse

Mallard duck

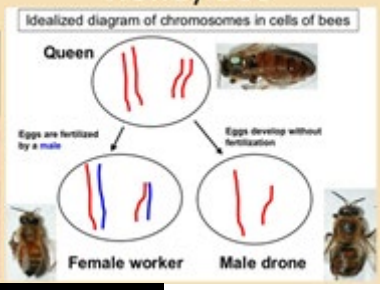


Indian peafowl (peacock and peahen)

Mormon cricket

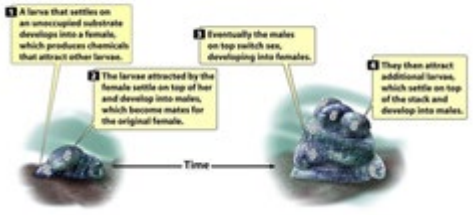


Honey bee



Magnificent Riflebird

Crepidula fornicata - slipper limpet



Use online research with credible sources to learn about the reproductive patterns used by each species. As you learn, keep a tally of whether males or females show each trait. If the species follows another pattern, put a tally mark in "Other Pattern".

Males	Females	
		Show-off: Is larger, more colorful, or more attractive than the opposite sex.
		Competitive: Fights with others of the same sex to show dominance and win access to mates.
		Picky: Gets to choose its favorite mate from a group of the opposite sex.
		Caregiver: Provides the most parental care for the offspring.
		Other Pattern: A totally different pattern of sexual selection

[1] What is the most common pattern that you noticed in the reproduction of these nine species?

[2] **Sexual dimorphism** refers to distinct appearances in appearance or behavior between makes and females of the same species. Out of the species covered in this activity, what percent show sexual dimorphism?

_____

[3] When an individual's reproductive success depends on appearance or behavior that attracts a mate, this is a special type of natural selection called **sexual selection.** What are some examples of physical or behavioral traits that are selected for in sexual selection?

[4] How do the above traits contribute to survival and reproduction?

Appendix I

Gender-Inclusive Language Guide (Long)
(Gender-Inclusive Biology Project, n.d.)

Physiology	
☹ **Instead of...**	👍 **Try...**
"*Men* produce sperm." "*Males* produce sperm."	"**Testes** produce sperm."
"*Women* produce eggs." "*Females* produce eggs."	"**Ovaries** produce eggs."
"When women menstruate, their bodies prepare the uterus for a fertilized egg to implant itself so a baby can form."	"For those with ovaries, the pituitary glands and ovaries interact to start menstruation." "If you have ovaries, then you might begin to menstruate. Your pituitary glands may…"

“Boys and men produce sperm every day.”	“For those with testicles, sperm cells are produced daily once puberty has begun.”
repeating “people with <body part>”	Avoid cumbersome or repetitive language by streamlining with “*if* you have a <body part>..., then your…”
“*male* or *female* hormones”	testosterone or estrogen “_____ is dominant. “These lizards are only one sex, regulated by estrogen.”
“gender reveal party”	Consider removing this non-biologically essential activity from your curriculum. Cis- and transgender students alike have different relationships with their birthdays. What essential standard do students learn from this that another activity offers? If you must, try relabeling as: “embryogenesis party” “chromosome reveal party”

“male reproductive organs”	“penis and testicles”
“female reproductive organs”	“Vulva, vagina, uterus, and ovaries”
“When the mom gives birth to the fetus or infant…”	“When the baby exits the womb…”
“mom”	“birth parent” “carrier”

“normal” / “natural” / “typical”	“most common,” “frequent,” or “many people / bodies / parts”
Genes	
Instead of...	**Try...**
“Mom gave you her genes, Dad gave you his.”	“You received a mix of genes from sperm and egg.”
Evolution	
Instead of...	**Try...**
“A major characteristic of life is reproduction. Things are alive if they reproduce.”	Your cells are always reproducing asexually within your body for growth and repair. Reproduction is required for a species, not an individual.

"The goal of every organism is to survive and reproduce"	Individuals who produce more offspring have their genes represented in the next generation at a higher number.
“Females choose the best genes.”	Organisms choose the best resources. In many mate choice systems, the egg producer must invest more biological resources than the sperm producer. Often the egg producers show preferences for certain traits. Scientists associate these traits with genes to infer the producers are choosing genes.
Sex Ed (see tipsheet for genderinclusive sex ed)	
Instead of...	**Try...**
“Women should get regular PAP tests.”	“People who have a cervix should get regular PAP tests.”
“Men should check their testicles regularly for lumps.”	“Testicle-having people should check them regularly for lumps”

“Guys, roll a condom onto your penis before you start having sex.”	“Use a condom on penises or sex toys.”
repeating “people with <body part>”	streamlining with “*if* you have a <body part>..., then your…”
“Men and boys ejaculate when…”	“Ejaculation happens when…”
“Women normally menstruate at age…”	“Menstruation most often begins at…”

Teacher Talk

Even if you can’t say the above, try showing examples in the spirit of the below. You know what is right for your students.

"I want everyone to get used to using accurate language for body parts and functions without assuming that there are only two sexes and that everyone within a particular sex is the same. It's important to be able to communicate about our bodies in accurate ways."

(Source: AIDS Community Care Montreal & sextEd. ***Inclusive Sex Ed Language Checklist*** *available at https://www.shorecentre.ca/wp-content/uploads/Adapting-Sex-Ed-Language-Guelph-Checklist.compressed.pdf)*