8-2024

A Scoping Review on the Experiences of Queer and Trans Students in STEM

Elliot P. Tingey
Utah State University

A SCOPING REVIEW ON THE EXPERIENCES OF QUEER AND TRANS STUDENTS IN STEM

by

Elliot P. Tingey

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Science Education

Approved:

_____ Colby Tofel-Grehl, Ph.D. Major Professor	_____ Max L. Longhurst, Ph.D. Committee Member
_____ Mario Suárez, Ph.D. Committee Member	_____ D. Richard Cutler, Ph.D. Vice Provost of Graduate Studies

UTAH STATE UNIVERSITY

Logan, Utah

2024

ABSTRACT

A SCOPING REVIEW ON THE EXPERIENCES OF QUEER AND TRANS STUDENTS IN STEM

by

Elliot P. Tingey, Master of Science

Utah State University, 2024

Major Professor: Dr. Colby Tofel-Grehl
Department: Teacher Education and Leadership

Among efforts to increase diversity in STEM (science, technology, engineering, and mathematics), queer and trans individuals are often left out. However, some data does suggest that they are significantly underrepresented in the STEM workforce. Given that educational experiences are necessary towards achieving a STEM career, it is therefore likely that difficulties within STEM educational spaces are impacting queer and trans students. Therefore, the purpose of this study is to investigate the current available literature on the experiences of queer and trans students in STEM spaces, what means for improving these experiences are supported by current research, and where significant gaps within the literature lie. This was accomplished via a scoping review as a means of considering a broad, heterogeneous expanse of literature. Use of the analytical method of charting produced a qualitative description of the available literature as a whole. This analysis revealed that queer and trans students' experiences within STEM spaces are

primarily negative, dominated by invisibility and isolation due to the pervasiveness of cisheteronormativity within these spaces. These experiences are likely to have significant impact on students' interest and persistence in STEM. However, more research is needed in order to provide additional clarity as to the impact of these experiences on students. Research on methods to improve these students' experiences was also inconclusive due to a lack of concrete data, but some information suggests that the acknowledgement of queer and trans students within STEM spaces, greater awareness on the part of educators, and queer affinity groups may lead to better outcomes for these students. Most notably, analysis of gaps within the literature revealed a significant lack of research on queer and trans students in K-12 STEM spaces, alongside the need for more research on trans students as well as identity specific, intersectional, and STEM field specific studies. Recommendations for research and practice are provided.

(66 pages)

PUBLIC ABSTRACT

A SCOPING REVIEW ON THE EXPERIENCES OF QUEER AND TRANS STUDENTS IN STEM

Elliot P. Tingey

Efforts to increase diversity in STEM (science, technology, engineering, and mathematics) are ongoing, but within these efforts queer and trans individuals are often left out. While initial data does suggest that queer and trans individuals are significantly absent from the STEM workforce, research into the causes of such underrepresentation is scattered. Given the importance of educational experiences in the pursuit of a STEM career, it is likely that these early experiences may play a role. Therefore, the purpose of this paper is to investigate the current research on the experiences of queer and trans students in STEM educational spaces, what methods are best for supporting them, and where more research is needed. To that end this study employs the use of scoping review methodology in order to draw conclusions from a wide variety of studies. Data was organized into broad categories so as to draw qualitative descriptions of the current literature. This analysis revealed that overall, the experiences of queer and trans students in STEM are primarily negative, dominated by invisibility and isolation created by cultures of that prioritize and normalize cisgender and heterosexual perspectives and experiences and are therefore unwelcoming of queer and trans identities. More research is needed in order to determine how to improve the experiences of queer and trans students in STEM, but acknowledgements of queer and trans identities within STEM spaces as

well as queer affinity groups do seem to have some positive impact for students. Other gaps in the literature identified include a significant lack of research on K-12 queer and trans students in STEM as well as the need for studies specific to trans students, those of specific queer identities, and those engaged in specific STEM fields as well as intersectional studies. Recommendations for research and practice are included.

(66 pages)

ACKNOWLEDGMENTS

First, thanks to my committee, Dr. Max Longhurst, Dr. Mario Suárez, and especially Dr. Colby Tofel-Grehl for providing mentorship and working with me through long hours and technical difficulties. Thanks to Crius Paulus for assisting in the editing of this piece for publication. And last but certainly not least, a heartfelt thanks to my partners for providing emotional support through the many long hours of research and writing. I couldn't have done it without you.

Elliot Tingey

CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

Chapter 1 Introduction

Statement of the Problem

Increasing diversity in science, technology, engineering, and mathematics (STEM) fields is an ongoing issue (Tsui, 2007). While recent demographic data of those in STEM related jobs does note a continuing improvement in the presence of women and underrepresented racial and ethnic minorities, women still only make up about a third (35%) of the STEM workforce as compared to around 50% of the population and underrepresented racial and ethnic minorities (Hispanic, Black, American Indian and Alaska Native) combined make up around a quarter (24%) of the STEM workforce as compared to about 31% of the general population. In addition, individuals with at least one disability make up only 3% of those in STEM jobs, compared to 9% of the general population, percentages that have remained stable over the past several years. (National Center for Science and Engineering Statistics [NCSES], 2023). Women and underrepresented racial minorities also have lower median earnings than men or White individuals respectively (NCSES, 2023).

However, while the problems facing women and racial minorities have received considerable research centered around improving their representation in STEM spaces in recent decades (e.g. Clewell & Campbell, 2002; Estrada et al., 2016), the same cannot be said for another minoritized group – queer and trans individuals. While precise demographic information is often difficult to collect, a Gallup poll conducted in 2017 estimated 4.5% of adults in the US identify as gay, lesbian, bisexual, or transgender (The

Williams Institute, 2019). Another poll in 2021 found that the percentage had risen to 7.1%, with younger generations significantly more likely to identify as LGBT as compared to older ones (Jones, 2022), suggesting that this number may continue to rise in the coming years.

Despite their minoritized status and the wealth of discrimination they face (e.g. Almedia et al., 2009; Casey et al., 2019; Sears & Mallory, 2011), data on the inclusion of queer and trans people in STEM is scarce compared to other minoritized and underrepresented groups. The most recent NCSES report on diversity in STEM (NCESE, 2023), part of the National Science Foundation's (NSF) goal of broadening participation in STEM (NSF, 2022) includes only binary gender categories and no data on sexual orientation at all. A study on individuals employed by STEM related federal agencies found that just under three percent (2.8%) identified at LGBT, notably lower than national estimates (Cech & Pham, 2017). The personal experiences of LGBTQ scientists also point to a chilly atmosphere regarding non-heterosexual sexualities, where discussion or even mention of such is seen as unprofessional (Freeman, 2018), pointing to the reproduction of discrimination regarding gender and sexuality that might encourage queer and trans individuals to find employment in other, more historically welcoming fields (Forbes, 2022).

A Note on Terminology

This study uses the phrase "queer and trans" for any individual who identifies as any identity other than heterosexual or cisgender, including lesbian, gay, bisexual, transgender, gender nonbinary, gender non-conforming, or any other non-cisnormative

and/or heteronormative identity. Individual experiences of these various identities can often differ from each other, but they all are impacted by and call into question cisnormativity and heteronormativity. The use of the phrase, therefore, is intended as a way of considering their similarities and pushing back against cisheteronormativity. While trans, an umbrella term itself, may also be considered to fall underneath the even broader term of queer, the intent of separating the two is to acknowledge the difference between gender and sexuality, especially within the field of STEM, where the two are often conflated. The terminology and acronyms used in other studies are maintained when referencing those studies. These include sexual minority, same-sex attracted, LGBTQ (lesbian, gay, bisexual, transgender, and queer) and variations, SGM (sexual and gender minority), and MIoSG (minoritized identities of sexuality and/or gender).

Diversity in STEM

Many arguments for greater inclusion of queer and trans people in STEM point to the problem of economic necessity. The US Bureau of Labor Statistics projects that STEM occupations are expected to grow by 10.8% in the decade between 2023 and 2033, compared to 2.3% for non-STEM occupations (US Bureau of Labor Statistics, 2023). Therefore, in order to fill this increase, more minoritized people, including queer and trans people, will need to pursue and obtain STEM degrees and continue on into STEM careers. However, it should be noted that this economic pressure should not be the only driving force behind attempts to improve the participation of minorities in STEM. Such a focus may encourage a limited acceptance of queer and trans people, where they are expected to “pass” as heterosexual and cisgender (often referred to as being “in the

closet" or "closeted") or "cover" their queerness, assimilating into heteronormativity and cisnormativity in order to pursue STEM occupations. Employees who feel compelled to hide a stigmatized identity at work suffer from reduced performance, impacted well-being, and a sense of social exclusion (Ellemers & Barreto, 2006) as well as lower self-confidence in their work (Barreto et al., 2006).

If the goal truly is one of increasing diversity in STEM, then it should embrace the importance of diversity of thought, experience, and perspective. These ideas are incompatible with a culture that requires, explicitly or implicitly, assimilation into narrow modes of thought and behavior. Unconstrained queer and trans participation in STEM is also an issue of social justice. In the field of psychiatry, Yager et al. (2007) noted that "minority researchers bring unique perspectives to research questions and strategies concerning access, delivery, and effectiveness of care in minority and underserved populations" (p. 146). More queer and trans STEM professionals may begin to help close gaps in healthcare between cisgender, heterosexual people and their queer and trans counterparts (Casey et al., 2019). Even in STEM jobs that have a more indirect impact on minority populations, a multiplicity of perspective is an asset to any STEM endeavor and the creativity and problem-solving inherent to work in STEM fields.

Queer and Trans Students in STEM

The importance of increasing diversity in STEM, therefore, draws consideration to the educational experiences of queer and trans students in STEM spaces. While research here can also be thin on the ground, the data suggests pervasive problems. When controlling for other variables including academic preparation and other factors found to

increase persistence, LGBQ undergraduate students who entered STEM majors as freshmen and remained at university for four years were nearly 10% less likely to persist in those majors than their straight counterparts (Hughes, 2018). Similar results were found for transgender and gender non-conforming undergraduate persistence (Maloy et al., 2022), a rate of attrition also similar to that of underrepresented racial minorities (Chang et al., 2014).

A significant factor in undergraduate STEM persistence has been found to be academic performance in high school, especially science and math preparation (Foltz et al., 2014; Radunzel et al., 2016). These years are also important for building students' interest in STEM through supportive networks, preparing a foundation for the future development of a STEM identity (Aschbacher et al., 2010). However, while information on queer and trans post-secondary students' participation in STEM is scarce, information on queer and trans students' participation in STEM prior to that is nearly nonexistent. Additionally, what information does exist is both incomplete and contradictory. Gottfried et al. (2015), using data collected from 1994 to 2002, determined that after controlling for overall academic achievement, sexual minority youth were no more or less likely to enroll in advanced science and math courses during their high school years than their straight peers. However, Pearson et al. (2007) found that sexual minority youth were more likely to perform poorly academically overall and that same-sex attracted boys in particular were less likely to enroll in advanced science and math courses.

The Present Study

The study at hand analyses the current available research on the experiences of queer and trans students in STEM, both secondary and post-secondary. Determining the current, research-based best practices for promoting the inclusion of queer and trans students will allow teachers, administrators, and other stakeholders a clearer path forwards towards accomplishing diversity goals. While guides providing recommendations on improving the experiences of queer and trans individuals in specific STEM academic fields exist (e.g. Ackerman et al., 2018; Butterfield et al., 2018, Cooper et al., 2020), this study provides an alternate focus, considering the experiences of queer and trans students across the borders of STEM disciplines to determine why queer and trans people fail to join the STEM workforce more generally. In addition, it is important to continually check these kinds of recommendations in the light of current research, especially in a field as nascent and data scarce as this one.

The present study also seeks to uncover where the most significant gaps are in the current literature and provide suggestions to researchers for future paths of study. While some broad conclusions may be drawn from the present body, the multiplicity of queer identity and STEM fields as well as intersectional issues urge continuing research even beyond the most obvious gaps. Specifically, the following research questions are presented:

1. What does the current body of research tell us about the experiences of queer and trans students in STEM?
2. What strategies does the current body of research support for improving the experiences of queer and trans students in STEM?
3. Where are the gaps in the current literature, and where is more research needed?

Chapter 2 Literature Review

Underrepresented Groups in STEM

Women, underrepresented racial minorities, and people with disabilities face significant difficulties in joining the STEM workforce. Many of the interventions designed to increase their participation focus on issues early in the journey – the preparation and persistence necessary to pursue and obtain a STEM degree, the efforts to fix the "leaky pipeline" (van den Hurk et al., 2019). These groups are less likely to persist in STEM degrees (Suárez et al., 2021), but the issues run significantly deeper than interest and adequate preparation prior to and during post-secondary education. Students of color face racial microaggressions not only from peers but from faculty and advisors as well in post-secondary STEM spaces (Lee et al., 2020) and overall issues of ingrained structural racism (McGee, 2020). Women face hostility in both the academic spaces necessary for pursing a degree (Casad et al., 2019) and, should they persist, in the workplace (Saxena et al., 2019), possibly due to STEM cultures that stereotypically align their femininity with less valued work (Faulkner, 2000). It should be noted as well that these problems compound for women of color in STEM spaces (Lee et al., 2020; Casad et al., 2019). While understudied, students with disabilities encounter stigma, inaccessibility, and difficulties receiving necessary accommodations (Prema & Dhand, 2019). In the words of McGee (2020), the focus on the idea of a leaky pipeline "has led to patchwork solutions and simplistic remedies for STEM attainment [that] do not challenge the anti-inclusive design of STEM education and participation" (pp. 633-634). The cumulative effect of these hostile STEM cultures and policies leads to White able-bodied

heterosexual men still holding positions of privilege within the STEM workforce that cannot be explained by variations in work effort or other differences (Cech, 2022) and the well documented underrepresentation of many of those who do not fit that narrow mold (NCSES, 2023).

Experiences of Queer and Trans Students

Secondary

While the issues specific to queer and trans students in STEM spaces are understudied, the research on queer and trans students' experiences in education more broadly point to environments of hostility, exclusion, and minoritization. The most recent report from the Gay, Lesbian, and Straight Education Network (GLSEN) on the climate of secondary schools for LGBTQ+ students provide some alarming statistics. Nearly all LGBTQ+ students reported hearing negative remarks and derogatory language about LGBTQ+ people at school, with 76.1% verbally harassed for their sexual identity, gender expression, or gender. In addition, a majority of LGBTQ+ students (58.9%) reported experiencing anti-LGBTQ+ policies or practices at the hands of teachers, administrators, and coaches (Kosciw et al., 2022). Understandably, much of the research around queer and trans secondary students has focused on these issues of harassment, abuse, and their negative effects – LGBQ+ students are twice as likely to experience symptoms of depression or poor mental health and three times as likely to seriously consider attempting suicide as compared to their heterosexual peers (Centers for Disease Control and Prevention, 2021). Many studies focus on the positive impact of GSAs (alternatively

Gay Straight Alliance or Gender and Sexuality Alliance) on queer and trans students. These groups have been found to improve academic outcomes, social support, and school connectedness of LGBTQ students (McCormick et al., 2015) and are associated with lower risk of in-school harassment (Kosciw et al., 2022).

More involved efforts to reform secondary school curriculum in order to normalize queerness and combat cisheteronormativity in schools, however, are scarcer. Research on curricular changes focus around the humanities (Greathouse, 2016; Helmer, 2016; Maguth & Taylor, 2014; Schmidt, 2010) and sex education (Woolweaver et al., 2023), with some investigation into queer and trans students' experiences in the arts (Millett, 2019; Palkki & Caldwell, 2018), physical education and sports (Kulick et al., 2019) and foreign language education (Baros, 2022). It should also be noted that many of these articles concerned with curriculum (e.g. Schmidt, 2010) are arguments based on theory and not research. Though in environments where even basic teacher professional development programs addressing LGBTQ issues can see significant pushback from administration (Payne & Smith, 2018), perhaps it's not surprising that even the more traditionally queer supportive space of the humanities faces significant difficulties in the practical implementation of queer friendly curriculum.

Post-secondary

Queer and trans post-secondary students continue to face many of the same challenges as their younger counterparts. Queer-spectrum and trans-spectrum students across nearly a thousand universities in the US were significantly less likely to view their campuses as safe and welcoming as compared to their heterosexual and cisgender peers

and significantly more likely to experience discrimination and harassment (Greathouse et al., 2018), with these experiences of bias and harassment also likely to go unreported by students (Weise et al., 2023). Exposure to harassment and microaggressions can negatively impact queer and trans students' academic outcomes (Mathies et al., 2019), physical health (Woodford et al., 2015), and retention in higher education (Crane et al., 2022). In a similar manner to GSAs in secondary education, LGBTQ+ resource centers and student organizations have been found to be important systems of support for LGBTQ+ post-secondary students (Pitcher et al., 2018), though it should also be noted that some queer and trans students struggle with acceptance even in these supposedly accepting spaces, including bisexual (Tavez, 2022) and asexual students (Mollet & Lackman, 2018) as well as queer students of color (Duran, 2019).

While universities and higher education can be centers of theory crafting and research for queer and trans individuals in the form of gender studies and other social science research that includes the experiences of queer and trans individuals, the segmented nature of higher education classes and majors can partition off queer curriculum only to students who actively and purposefully pursue it. This may create push and pull factors that draw students from more traditionally "chilly" climates such as STEM and towards more traditionally "warm" climates such as the humanities (Forbes, 2022). Not only do cisgender and heterosexual students in all disciplines require the opportunities to look through the window to understand queer and trans experiences, but queer students in any major also deserve to see themselves mirrored within the curriculum (Nodin, 2022) no matter what subject they pursue.

Chapter 3 Methods

Researcher Positionality

I am a gender nonbinary, queer individual working and studying in a rural, conservative area of the Intermountain West. My experiences, both positive and negative, within undergraduate science spaces and well as working at local secondary schools have undoubtably influenced my perspectives on this research. Throughout this process I have reflected often on my relation to the research and the difficulties of studying the struggles and minoritization of a group I identify with. I have sought to provide myself with a space to process those emotions and to consider my positionality on the research at hand in order to prevent my perspective from having undue impact on my analysis.

Study Design

Due to the nature of the extant literature, a scoping review has been deemed the most useful method of approach for this research. Scoping reviews are a kind of literature synthesis similar to that of a systematic review in that the data under study is a relevant section of literature. However, unlike a systematic review, a scoping review is broader both in the research questions and the body of literature under consideration (Munn et al., 2018). This broadness can be beneficial especially when the field under review is less established and yet to reach a measure of consensus in study design and measurement of data (Arksey & O'Malley, 2005). Scoping reviews can be conducted as a precursor to a systematic review, or as research activities in their own right. Due to their nature, they are

ideal for determining the breadth and depth of the available literature, including where more research may be needed (Levac et al., 2010). The reporting of results in scoping reviews also tends towards more qualitative descriptions with less focus on analysis between studies and more on the overall scope of research activities (Arksey & O'Malley, 2005). Scoping reviews have seen recent adoption into research on STEM education, with the methodology used across research on diverse topics such as education on infection diseases (Kafai et al., 2022), early elementary STEM education (Byrne et al., 2023), and data science education (Msweli et al., 2023) as well as approaches for increasing diversity in STEM (De Gioannis et al., 2023; Sultan et al., 2019).

Given that "queer and trans" and "STEM" are both overarching umbrella terms that add additional heterogeneity to an already small field with a variety of methods and approaches, alongside study questions that are broad, focused on the collection and dissemination of information as well as identifying gaps in the literature, a scoping review is the more relevant methodology as compared to the more focused questions and necessity for homogeneity in study designs required for a systematic review (Arksey & O'Malley, 2005). This scoping review used the framework laid out by Arksey and O'Malley (2005) along with the recommendations by Levac et al. (2010) in order to ensure clarity of research methodology and academic rigor.

Data Collection and Analysis

Initial data searches were completed using the databases Education Source and ERIC. Search terms were (lgbtq or lgbt or lesbian or gay or bisexual or transgender or homosexual or queer or sexual minority) AND (stem education or science or technology

or engineering or mathematics) AND SU (middle school students or high school students or college students). The use of subject terms was necessary in order to keep the search focused on student centered papers and to provide a manageable number of search results while also allowing for a wide net in regards to STEM education and queer identity. Results were also limited to English language papers as that is the only language the researcher speaks as well as papers that were peer reviewed and published in academic journals. The grey literature was reviewed for additional and emerging areas of scholarship, but none were observed, therefore, for consistencies sake it is not included in this review. Future studies may choose to include grey literature as the body develops.

The search was performed in March of 2024 and returned 385 articles. After the removal of duplicate articles, that number became 370. From there, title and abstract screening was performed in order to narrow in on relevant articles. Articles were required to fall under one of two broad categories:

1. The article must examine the presence (or absence) of individuals who identify as a sexuality and/or gender other than heterosexual and cisgender within the curriculum, practices, or spaces designed to teach science, technology, engineering, and/or mathematics, or
2. The article must include some measure of the experiences of individuals who identify as a sexuality and/or gender other than heterosexual and cisgender while engaged in educational experiences centered around science, technology, engineering, and/or mathematics.

This screening resulted in the removal of 359 articles removed from the study pool. An additional article was removed as it centered on student experiences in a non-

English speaking country, and as the experiences and treatment of queer people can be highly impacted by culture and language the author felt ill-equipped to consider it within the proper cultural context. This resulted in a final count of 10 articles retrieved through database searching. An additional 52 articles were found through snowball sampling and collaboration with an expert in the field and were then screened in the same manner. After this screening, a set of 35 articles remained. These articles then underwent full text screening, which removed another eight articles, resulting in a final set of 27 articles (Table 1).

Table 1

All Studies Used and Their Corresponding Analytical Categories

Authors and Date of Publication	Study Focus	Study Type	Educational Level	Queer Identities Included	STEM Field(s)	Researcher(s) Identity
Barthelemey et al. (2022)	Studying the problem	Mixed Methods	Post-secondary	Non-heterosexual and non-cisgender	Science (physics)	Not disclosed
Bazzul & Sykes (2011)	Studying the problem	Qualitative	Secondary	Non-heterosexual and non-cisgender	Science (biology)	Not disclosed
Busch et al. (2022)	Investigating solutions	Mixed Methods	Post-secondary	Non-heterosexual and non-cisgender	Science (biology)	At least one non-heterosexual researcher
Cech & Rothwell (2018)	Studying the problem	Quantitative	Post-secondary	Non-heterosexual and non-cisgender	Engineering	Not disclosed

Authors and Date of Publication	Study Focus	Study Type	Educational Level	Queer Identities Included	STEM Field(s)	Researcher(s) Identity
Cech & Waidzunas (2011)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual	Engineering	Not disclosed
Cooper & Brownell (2016)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual and non-cisgender	Science (biology)	Not disclosed
Forbes (2022)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual and non-cisgender	STEM	Not disclosed
Gottfried et al. (2015)	Studying the problem	Quantitative	Secondary	Non-heterosexual	STEM	Not disclosed
Hughes (2017)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual	Engineering	At least one non-heterosexual researcher

Authors and Date of Publication	Study Focus	Study Type	Educational Level	Queer Identities Included	STEM Field(s)	Researcher(s) Identity
Hughes (2018)	Studying the problem	Quantitative	Post-secondary	Non-heterosexual	STEM	Not disclosed
Hughes & Kothari (2023)	Studying the problem	Quantitative	Post-secondary	Non-heterosexual	STEM	Not disclosed
Kersey & Voight (2020)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual and non-cisgender	STEM	At least one non-heterosexual researcher
Kroll & Plath (2022)	Studying the problem	Quantitative	Post-secondary	Non-heterosexual and non-cisgender	Science (chemistry)	Not disclosed
Leyva et al. (2022)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual and non-cisgender	STEM	At least one non heterosexual and one non cisgender researcher

Authors and Date of Publication	Study Focus	Study Type	Educational Level	Queer Identities Included	STEM Field(s)	Researcher(s) Identity
Linley et al. (2018)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual and non-cisgender	STEM	Not disclosed
Maloy et al. (2022)	Studying the problem	Quantitative	Post-secondary	Non-cisgender	STEM	At least one non heterosexual and one non cisgender researcher
Mercer-Mapstone et al. (2021)	Investigating solutions	Mixed Methods	Post-secondary	Non-heterosexual and non-cisgender	Science (biology)	At least one non heterosexual and one non cisgender researcher
Miller & Downey (2020)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual and non-cisgender	STEM	At least one non-heterosexual researcher
Miller et al. (2021)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual and non-cisgender	STEM	At least one non-heterosexual researcher

Authors and Date of Publication	Study Focus	Study Type	Educational Level	Queer Identities Included	STEM Field(s)	Researcher(s) Identity
Parise (2021)	Studying the problem	Qualitative	Secondary	Non-heterosexual and non-cisgender	Mathematics	At least one non-heterosexual researcher
Pearson et al. (2007)	Studying the problem	Quantitative	Secondary	Non-heterosexual	STEM	Not disclosed
Snyder & Broadway (2004)	Studying the problem	Qualitative	Secondary	Non-heterosexual and non-cisgender	Science (biology)	Not disclosed
Suarez et al. (2022)	Investigating solutions	Qualitative	Secondary	Non-heterosexual and non-cisgender	STEM	At least one non heterosexual and one non cisgender researcher
Vaccaro et al. (2021)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual and non-cisgender	STEM	At least one non-heterosexual researcher

Authors and Date of Publication	Study Focus	Study Type	Educational Level	Queer Identities Included	STEM Field(s)	Researcher(s) Identity
Voigt (2022)	Studying the problem	Quantitative	Post-secondary	Non-heterosexual and non-cisgender	Mathematics	Not disclosed
Yang et al. (2021a)	Studying the problem	Mixed Methods	Post-secondary	Non-heterosexual and non-cisgender	Engineering (ECE)	Not disclosed
Yang et al. (2021b)	Studying the problem	Qualitative	Post-secondary	Non-heterosexual and non-cisgender	Engineering (ECE)	At least one non-heterosexual researcher

After the final set was identified, articles were analyzed through a method called charting in which synthesis is achieved by organizing data by key issues and themes (Arksey & O'Malley, 2005). In order to answer the first research question (What does the current body of research tell us about the experiences of queer and trans students in STEM?) articles were analyzed that fell under the second inclusion category, including those that both directly through interviews and questionaries, and indirectly through other means of measurement draw conclusions on the experiences of queer and trans students in STEM. To answer the second research question (What strategies does the current body of research support for improving the experiences of queer and trans students in STEM?) suggestions for practice given by researchers within all the relevant articles to the gathered body of data were compared to determine if there is wide scale research support for any of the suggestions repeated across articles. Lastly, to answer the final research question (Where are the gaps in the current literature, and where is more research needed?) the data set was considered widely and holistically in order to determine what has and what hasn't currently received sufficient research.

Chapter 4 Results

Research Question 1

The first research question was "What does the current body of research tell us about the experiences of queer and trans students in STEM?" Of the 24 articles in the data set out of the total 27 that either directly or indirectly measured queer and trans students' experiences in STEM spaces (see Figure 1), the overall conclusion drawn is that

these experiences are often ones of marginalization, isolation, and stress. Perhaps the most common repeated descriptor is that STEM spaces and cultures are *unwelcoming* to queer and trans students (e.g. Cooper & Brownell, 2016; Hughes, 2017; Kersey & Voigt, 2020; Linley et al., 2018; Miller et al., 2021). Thought rarely seen as actively hostile by students, reports of homophobic and transphobic remarks are common (Barthelemy et al., 2020; Cech & Rothwell, 2018; Yang et al., 2021a), often coming from peers or coworkers within STEM spaces but outside of classrooms in such places as study groups and labs (Vaccaro et al., 2021). Even within classrooms, queer and trans perspectives or even the acknowledgement of queer and trans existence within the curriculum is often entirely absent, even within such subjects as discussions of genetics or human biology where inclusion is necessary for a complete and accurate understanding (Bazzul & Sykes, 2011; Leyva et al., 2022; Mercer-Mapstone et al., 2021; Parise, 2021; Snyder & Broadway, 2004).

The issue of exclusion and persistent cultures of cisheternormativity often leads to a profound sense of social isolation for students as seen in Hughes (2017), Linley et al. (2018), Miller et al. (2021), and Yang et al. (2021b). This outcome was compounded for those at the intersection of multiple marginalized identities (Leyva et al., 2022; Miller & Downey, 2020). Even beyond the difficulties in finding accepting cisgender, heterosexual peers, the necessity of passing and covering techniques as means of navigating these cisheternormative spaces often means that queer and trans students are unknown to each other, stagnating the development of a sense of queer community within STEM for these students (Yang et al., 2021b). Combined these experiences led to increased negative physical and mental outcomes for queer and trans students in STEM, including increased

stress, cognitive load, and emotional strain as well as worse mental health and sleep (Cech & Rothwell, 2018; Cech & Waidzunas, 2011; Cooper & Brownell, 2016; Yang et al., 2021a).

Perhaps the only category that had any disconfirming evidence at all was the question of whether queer and trans students are significantly represented in STEM educational spaces or not. As stated toward the beginning of this paper there is some evidence that queer and trans students are significantly more likely to avoid STEM educational spaces (Forbes, 2022; Pearson et al., 2007) or to transfer out of them (Hughes, 2018; Maloy et al., 2022) as compared to their cisgender and heterosexual peers. However, Gottfried et al. (2015) found that sexual minority youth are not less likely to take advanced science and math courses in high school and Kroll and Plath (2022) determined that LGBTQ+ students were not underrepresented in the post-secondary introductory chemistry classroom. However, it should be noted that Gottfried et al. (2015) made use of a data set nearly two decades old at the time of this research and is contested by Perason et al. (2007) using nearly the same data, and the survey used by Kroll and Plath (2022) was conducted at a university well known for being LGBTQ+ friendly, potentially significantly impacting the results. Regardless of whether queer and trans students are fully represented in STEM spaces or not, the experiences of those who do interact with STEM have been shown to be significantly negative in ways that have ongoing impacts for students.

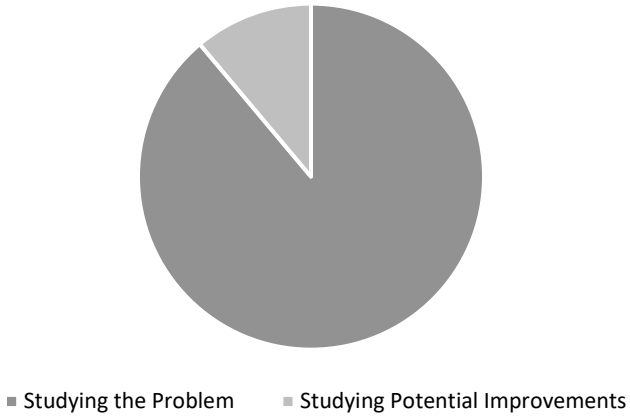
Research Question 2

The second research question was “What strategies does the current body of research support for improving the experiences of queer and trans students in STEM?” As previously stated, of the 27 articles included in the data set, 24 focused on documenting and theorizing the issues behind the negative experiences of queer students in STEM spaces (Figure 1). Only three articles focused on ways to address these problems. In one an instructor opted to reveal her LGBTQ+ identity to the class (Busch et al., 2022). In another the instructor opted to intentionally teach inclusive concepts of sex and gender in a university genetics class (Mercer-Mapstone et al., 2021). Finally, the third provided queer students with an intentionally designed supportive, queer centering STEM maker space (Suarez et al., 2022). All three were found to have some positive effect on queer students. The first two were also found to be minimally disruptive and positively received by queer and non-queer students alike. Suarez et al. (2022) offers insight into the design process for intentionally designing for the intersections of STEM and queerness. Overall then, it is possible to say that the acknowledgement of queer identities within the STEM space has a positive effect on queer students, though more research is needed in order to determine the extent of this effect beyond a singular classroom, as all three studies were small in scope and the difficulties of queer students has been shown to be widespread and pervasive.

Among the remaining 24 studies, the suggestions offered most frequently for improving student experience were educators participating in Safe Zone or other educator training that would prepare them to better support queer and trans students (recommended by 11 studies), increased support for queer STEM affinity groups for students (recommended by 12 studies), and for further action to be taken by the STEM

Figure 1

Studies Focused on Studying the Problem Versus Studying Potential Improvements



community, school, or university (recommended by 11 studies). While none of these later suggestions are directly supported via dedicated research, there is some data to suggest that they may be effective in improving queer and trans students' experiences.

One interesting finding was the perceived inability for STEM spaces to afford any space for the discussion of queer identity. For example, an undergraduate student in the study by Forbes (2022) remarked "I'm not going to go to a biology professor and be like 'I'm gay, I'm struggling, and I need this' (laughs). Give me a reason why you would consciously decide to go to your bio professor and talk to him about being gay" (p. 338). If professors and other educators are better prepared to support queer students as through Safe Zone or other educator training on queer topics, this may assist in changing students' understanding that STEM spaces and STEM educators aren't supportive places to discuss or even mention queer and trans identities.

In a similar manner, students who had access to queer or queer STEM affinity groups often cited them as significant sources of support. One of the students interviewed in Yang et al. (2021b) stated that a multicultural center with a high concentration of LGBTQ+ individuals "[provided] a sanctuary for LGBTQ+ people to just be and not be judged" (p. 20). Another student in Kersey & Voigt (2020), remarked that a local oSTEM (Out in Science, Technology, Engineering, and Mathematics, a queer STEM affinity group) chapter "helped her develop friendships with other queer students in STEM and … she can now be more open with her queer identity in STEM" (p. 21).

However, several examples of disconfirming evidence on the importance of affinity groups were noted as well. Kersey & Voigt (2020) discussed how several of the trans women in their study lacked interest in a larger queer community and as a result had no interest in affinity groups, though they still dealt with the negative effects of being trans in STEM spaces and therefore needed different kinds of supports. Leyva et al. (2022) include how several of the Black, queer students in their study were uncomfortable in queer affinity spaces that were predominantly White. Queer and queer STEM affinity spaces have been shown to be very important for some students and increased support for these kinds of groups and spaces may increase their reach, allowing more students to find community and combat social isolation, but they don't appear to be a universally useful measure and should be only part of the changes necessary for improving queer students' experiences.

As for the recommendation of action taken by the STEM community or educational administration, the recommendations given in the articles varied significantly. Some suggestions were specific in the action to be taken, such as insuring

that queer and trans people are explicitly included in university and department diversity statements and non-discrimination policy, while some were left more vague as in Barthelemy et al. (2022), who suggested that "the results [of this study] … must be taken into action by the physics community leaders and future scholar to motivate and make change. For example, programmatic interventions ranging in scale from institutional to departments to specific classes should be designed with reference to the needs of LGBT+ people, assessed for effectiveness, and transferred" (p. 16). However, on the issue of administrative change, Yang et al. (2021b) noted that:

> In many cases, inclusive policy development has focused on a 'top-down' approach in which faculty, staff, and administration implement policies that they think will impact students and improve diversity and inclusion in the department. However, these approaches are not always inclusive and can be mired in some of the oppressive culture logics they seek to disrupt. … When asked about what engineering administrators could do to help improve the experiences of LGBTQ+ engineering students at the study site, focus group participants offered and debated different ways of community-building and whether they would work for the particular department based on their personal experiences. It is obvious that these students already had nuanced ideas about institutional changes that could be made to support them; their ideas just need to be brought to the institutional table. (pp. 25-26)

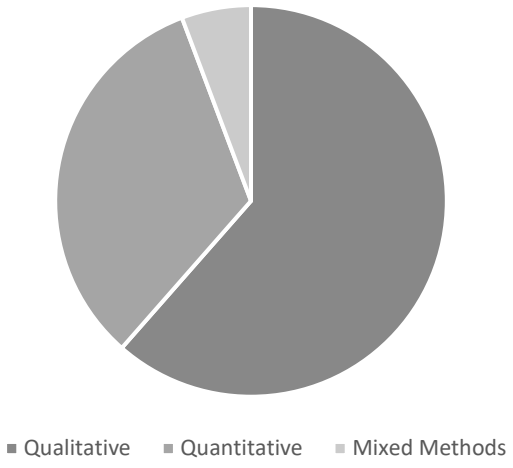
On a similar note, the study by Mercer-Mapstone et al. (2021) was undertaken due to the suggestion and with the assistance of a transgender undergraduate student who had previously taken the genetics course the study was conducted in and brought the issue of exclusive curriculum to the instructors' attention. Overall, there is not enough data to draw definitive conclusions as to the effect that administrative and departmental policies have on the experiences of queer students in STEM, though ensuring student participation in the creation of such policies does seem to hold potential.

Research Question 3

The third research question was "Where are the gaps in the current literature, and where is more research needed?" In order to understand differing trends in the literature, a number of different methods employed to conduct research on the experience of queer and trans students in STEM were examined. A majority (15 out of 27) of articles in the collected data set are qualitative in nature, with the sole means of data collection often

Figure 2

Methods Used by Studies



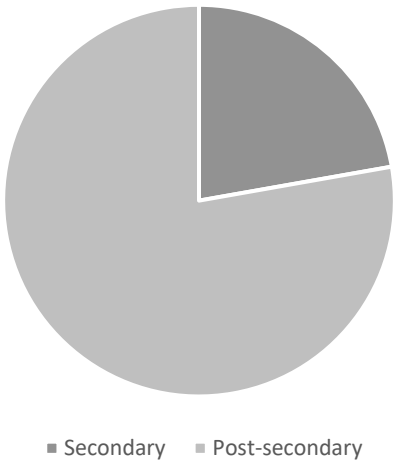
direct interviews of queer students, either individually or in focus groups. Eight of the studies were purely quantitative, often as secondary analysis on larger data sets that included information on participants' sexuality or gender identity beyond binary categorizations. Finally four studies made use of mixed methods, including surveys supplemented by interviews and surveys that included short answer questions where data

was processed qualitatively (Figure 2). While this distribution of study methods is understandable in a field that is just beginning to find its footing, future studies should consider alternate forms of data collection in order to ensure a more complete picture of the issues under study such as classroom observation, participant journals, and specifically crafted survey instruments as well as combinations of data sources.

Another facet analyzed was the educational context where research was conducted. Of the 27 studies included in this review, 21 of them focused on post-secondary or university contexts, while only 6 took place within secondary contexts, representing the most significant gap in the literature determined by this study (Figure 3). Furthermore, of the six secondary studies, three were high school textbook analysis (Bazzul & Sykes, 2011; Parise, 2021; Snyder & Broadway, 2004) two were quantitative analyses that both used the same primary data set gathered on high school students from

Figure 3

Educational Context of Studies

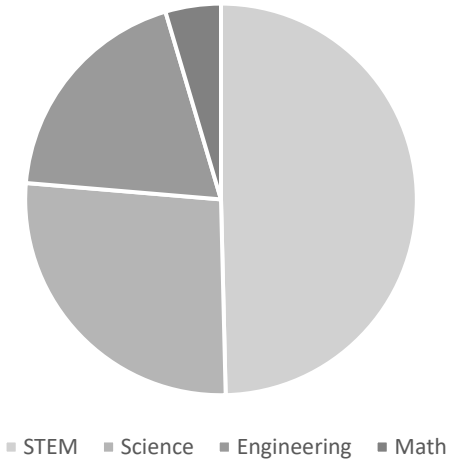


1995 – 2001 (Gottfried et al., 2015; Pearson et al., 2007), and only one included data collected directly from queer identified students engaging in STEM learning (Suarez et al., 2022). More data on the experiences of queer secondary students engaging with STEM and within STEM spaces is desperately needed, as the currently information available is significantly scarce and scattered enough as well as occasionally contradictory and out of date as the social acceptance of queer individuals changes that it is impossible to draw any kind of meaningful conclusions as to students' experiences.

Other trends and gaps in the literature are also worth noting. Around half (13 out of 27) of the studies focused on STEM contexts broadly, including data from students engaged in a variety of STEM fields, while the rest focused more narrowly on specific STEM fields (Figure 4). Five of these studies took place within engineering contexts, 2 within mathematics contexts, and 7 within science contexts. Of those within science, 5

Figure 4

Context of Studies

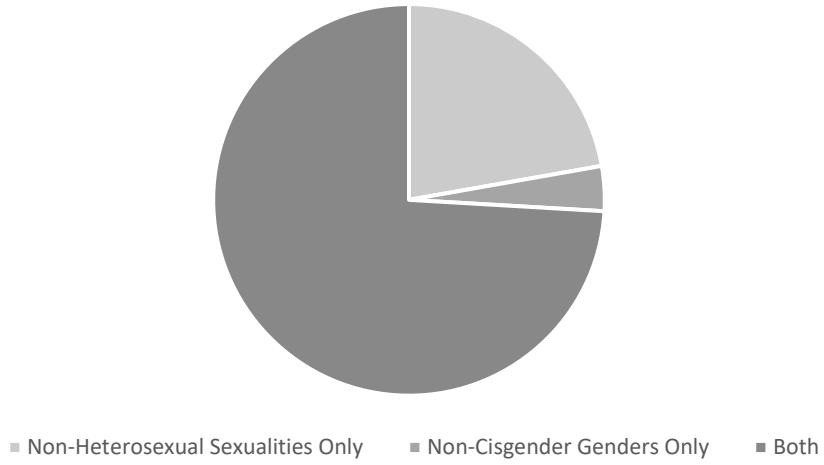


focused specifically on biology, with the other two on physics and chemistry respectively. While limited number of local eligible participants often necessitate the expansion out of narrow, subject specific studies (see Kersey & Voigt, 2020), the different subjects of STEM do have cultural differences between them that may impact queer and trans students' experiences. For example, research within the engineering context frequently notes the existence of the technical-social dualism and its connection to the gender binary as a fundamental cultural difficulty for queer and trans students (Cech & Waidzunas, 2011; Hughes, 2017), a cultural construct that likely does not exist in the same way within, for example, mathematics spaces. More research within specific STEM fields may be able to engage more fully with the specific cultural constructs within that field in order to gain a deeper understanding of how cisheteronormativity is supported within the relevant systems and culture at play. In addition, some relevant fields and subfields had no articles focused on them. In science most notably the geosciences were entirely absent, and among engineering two articles focused on the subfields of electrical and computer engineering (Yang et al., 2021a; Yang et al., 2021b), but the rest were generalized engineering with no specificity as to subfield. And while the T in STEM is often less well defined than science, engineering, and mathematics, it too has received no focus among research as of yet.

Similarly, the majority of studies (20 out of 27) include students of both non-heterosexual sexualities and non-cisgender genders, with only 6 specific to those with non-heterosexual sexualities and one to those with non-cisgender genders (Figure 5). Of those focused on those with non-heterosexual identities, one was specific to a singular identity, that of gay men (Hughes, 2017). While as previously noted there can be

Figure 5

Queer Identities Included in Studies



significant overlap of experiences among different queer and trans individuals, further exploration of the ways that those of specific identities navigate and experience STEM spaces may present a more nuanced understanding of the challenges that queer students face. In particular, some evidence suggests that trans individuals may face different and perhaps more difficult experiences as compared to their cisgender peers, even those cisgender peers who are not heterosexual (Barthelemey et al., 2022; Cooper and Brownell, 2016) and that actual or perceived gender non-conformity in gender presentation can also have a significant impact on students (Kersey & Voigt, 2020). In a similar way Miller et al. (2021) found that, while masculinity and heteronormativity were the expected norms within STEM spaces, students with MIoSG (minoritized identities of sexuality and/or gender) could find partial or limited acceptance by identifying or presenting with aspects of heteronormative masculinity, such as attraction to women or more masculine dress. Studying the effects of gender, gender expression, and gender non-

conformity on students in STEM spaces, may highlight how cisheteronormativity is upheld and how its impacts can vary for students of different genders and sexualities.

It was also noted that two studies focused on STEM students at the intersections of marginalized identities, specifically Black queer students (Levya et al., 2022) and queer students with disabilities (Miller & Downey, 2020). As previously mentioned, both highlight how these students face increased difficulty with social isolation as singular identity affinity groups often make little to no consideration for those of other marginalized identities. These sorts of intersectional analyses are vital towards ensuring that the voices of those with multiple marginalized identities are heard and their specific struggles accounted for in the progress towards greater inclusivity. More intersectional studies would help ensure that all queer students in STEM are heard, not only those who are White, able-bodied, and from higher socioeconomic background.

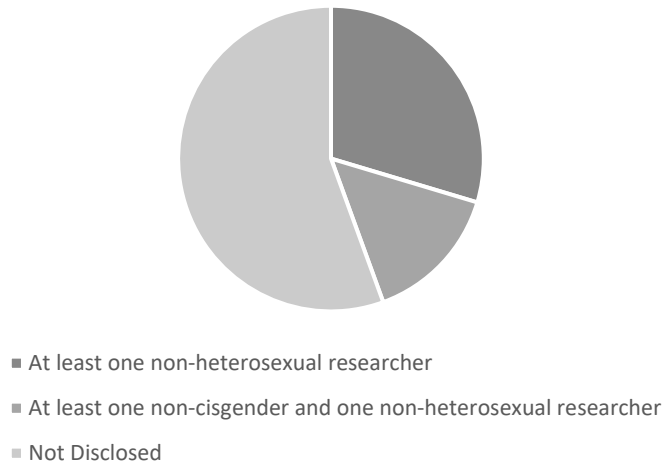
Lastly, the stated positionality and identity of researchers was considered when given. Less than half (12 out of 27) of the studies in this review contained positionality statements or any remarks on the salient identities of the participating researchers. Of those studies that did include information on researchers' queer identities, 12 had at least one non-heterosexual researcher and only 4 had at least one non-cisgender researcher (Figure 6). While self-disclosure of a queer or trans identity should always be left to the discretion of the researcher, including queer and trans perspectives in research on queer students is vital.

More inclusion of trans, gender non-conforming, and non-cisgender research perspectives in particular is necessary in continuing to expand the literature on trans student experiences. These perspectives are vital regardless of the type of study or

analysis being performed. For example, the one study specific to trans students in this data set, Maloy et al. (2022), did include a positionality statement and noted that on

Figure 6

Queer Identities of Researchers



member of the research team was non-cisgender. Among other results, the study found that trans and gender non-conforming (TGNC) students were less likely to persist in STEM majors if they reported seeking personal counseling more frequently, though no effect was found regarding reporting feeling depressed more frequently. The authors interpreted this result as STEM spaces stigmatizing seeking help for mental health, leading to TGNC students who do seek help choosing to leave those spaces. While this is a reasonable interpretation of the data, within the specific context of TGNC students it should be noted that pursuing medical transition and gender affirming care often requires personal counseling or letters of readiness for therapists (Amengual et al., 2022). Therefore, the data may also suggest that TGNC students who pursue medical transition

may be less likely to persist in STEM degrees, an interpretation that holds vastly different implications for necessary improvements. While there was a non-cisgender researcher involved in this article, no one trans individual is an expert on all aspects of trans experiences, and it is possible that this interpretation of the data was missed due to a lack of knowledge on the experiences of TGNC students regarding counseling on the part of the researchers. This example highlights the need of including a variety of trans individuals with differing experiences and viewpoints within research on trans students.

Chapter 5 Discussion

The most significant finding of this review is the near complete lack of research on queer and trans students in K-12 STEM spaces. With the notable age of the data set used and disagreement between the only two available statistically analyses of STEM coursetaking patterns for queer high school students (Gottfried et al., 2015; Pearson et al., 2007), it is impossible to even determine whether queer and trans students are represented in the secondary STEM classroom, let alone what their experiences might be. Textbook studies such as Bazzul and Sykes (2011), Parise (2021), and Synder and Broadway (2004) may suggest experiences of exclusion for queer and trans students, but on their own they do not paint a clear enough picture as to students' day-to-day experiences and their perceptions of these subjects and spaces, instead merely gesturing towards what their experiences may be. Given the importance of secondary STEM experiences in the development of a STEM identity (Aschbacher et al., 2010) and in STEM persistence through post-secondary education (Foltz et al., 2014; Radunzel et al., 2016), attempts to improve the diversity of STEM in regard to queer and trans students must start in

secondary and even elementary spaces if they are to be ultimately successful. More focus on queer and trans students in K-12 STEM spaces within the research will therefore be necessary in order to determine how best to serve queer and trans students in those spaces.

Even within the literature on post-secondary STEM spaces, significant gaps are apparent. While both queer and STEM are useful umbrella terms for compiling commonalities, the variety of experiences they both encompass also points to the eventual necessity of disaggregation. Preliminary research has shown significant differences in experiences for trans (Barthelemy et al., 2022), gender non-conforming (Kersey & Voigt, 2020), and bisexual individuals (Voigt, 2022) as well as those at the intersections of marginalized identities (Leyva et al., 2022; Miller & Downey, 2020). Further research will be needed in order to determine how queer and trans individuals of a variety of identities and background experience STEM spaces and how best to work towards greater inclusion. Additionally, several individual disciplines within STEM are also understudied. Only two articles focused specifically on math contexts, one each on physics and chemistry, and none on the earth sciences or technology education. Just as the technical-social dualism in engineering culture causes specific difficulties for queer and trans students (Cech & Waidzunas, 2011; Hughes, 2017), specifics in the cultures of STEM fields and subfields may have significant impacts on queer and trans students in those spaces, changing how best to approach efforts towards more meaningful diversity and inclusion. Again, more research is needed in order to understand where the commonalities and differences lie across a variety of STEM disciplines.

Experiences of Queer and Trans Students in STEM

Despite the lack of specificity within the literature, overall, the current research shows that queer and trans students' experiences in STEM spaces are primarily negative, characterized by invisibility and isolation. The perceived neutrality of STEM provides a shield for near complete curricular silence in regards to queer and trans individuals and helps to support pervasive cisheteronormativity embedded throughout the culture. This silence both inside the classroom and outside it, coupled with well documented homophobic and transphobic jokes and comments by others within STEM spaces, often pushes queer and trans students into strategies of passing, covering, and minimization of their queer and trans identities as means of coping with and surviving marginalization and abuse. In turn these coping strategies make it significantly more difficult for queer and trans students to find each other within STEM, increasing feelings of isolation and stunting necessary community growth and support. These environments and experiences can have negative physical and emotional tolls on students as well as social and academic consequences. Students' repeated negative experiences as recorded through qualitative research also help to contextualize quantitative studies that show that queer and trans students are less likely to persist in post-secondary STEM majors (Hughes, 2018: Maloy et al., 2022) and suggest that LGBT individuals are significantly underrepresented in the STEM workplace (Cech & Pham, 2017).

While it is clear that individual interactions do form a portion of the negative encounters that queer and trans students experience, their pervasiveness across multiple contexts and research sites point to deeper problems within the culture of STEM. Leyva et al. (2022) theorize STEM as a space in which ideological, institutional, and relational

systems interlock in order to support and uphold White cisheteropatriarchy, creating systemic oppression for those who do not fit inside that narrow mold. Vaccaro et al. (2021) form a grounded theory model of complex interactions and meaning making for students that also highlights the way that systems of power and oppression within STEM effect students with MIoSG in a variety of ways. These models provide means of understanding the ways in which negative individual encounters stem from and feed into a pervasive, cisheteronormative STEM culture.

Recommendations for Research

As previously mentioned, research on queer and trans students in K-12 STEM spaces is desperately needed. Focus should be placed both on quantitative explorations of coursetaking patterns among queer and trans secondary students as well as more qualitative measures to capture students' experiences and perceptions of STEM as a discipline and STEM spaces. Additionally, within post-secondary spaces further studies should investigate how the diversity of queer and trans student populations impacts those students' experiences as well as the impact that differing STEM cultures may have on the manifestation and maintenance of cisheteronormativity within their spaces and how these affect queer and trans students. It should be noted, however, that as research expands there is a necessity of ensuring sufficient diversity not only within study populations, but also within the research team. In particular trans, gender non-conforming, and non-cisgender individuals are underrepresented among the research on queer and trans students in STEM, both as a study population and as researchers. While it is possible for cisgender researchers to conduct significant and sound research on trans individuals, trans

researchers bring additional understanding of trans experiences to analysis and interpretation of data that cisgender individuals may not consider due to differences in lived experiences. While trans academics also face significant marginalization and additional stresses within academia that may increase when involved with queer research (Pitcher, 2017; Scharrón-Del Río, 2018; Veldhuis, 2022), these individuals need not be the only source for research teams. Mercer-Mapstone et al. (2021) present research in which a trans undergraduate student both motivated the study and assisted in the research, being included as one of the study's authors. With the increase of younger generations identifying as LGBT (Jones, 2022), queer and trans undergraduate and graduate students may be important sources of diversity for research teams conducting more identity and subject specific research.

This research with additional specificity will help to construct a more complete picture as to the issues at hand that may then be leveraged towards efforts to create and implement improvements that will assist in increased acceptance and inclusion of diverse queer and trans students within STEM spaces. More research is also needed here, on the efficacy of suggestions made in order to improve the inclusion of queer and trans individuals in STEM as well as novel methods working to alter cultures of silence and systems of cisheteronormativity. While it is understandable that a field as nascent as this has put its focus first into a documentation of the problem, the goal of improvement and providing research-based recommendations to educators and administrators requires an expansion out of documentation and into testing methods of improvement.

Recommendations for Practice

While definitive research on improvements for practice is still scarce, taken as a whole the literature does provide some recommendations for improving the experiences of queer and trans students in STEM. First, educators need to be made aware of the pervasive problems facing queer and trans students. The overwhelming presence of cisheteronormativity may be such that educators are not aware of the necessity of considering students who fall outside of it, especially in the supposedly apolitical realm of STEM. Even the use of correct names and pronouns for trans students (Cooper & Brownell, 2016) or brief acknowledgement of queer individuals' existence (Busch et al., 2022) has been shown to be significant for queer and trans students mired in cultures that render them invisible and silent. Educator training may be a means whereby the importance of these small but vital steps towards inclusion can be communicated in order to begin breaking the silence. Even without specialized training, the use of correct names and pronouns for students, inclusive and gender-neutral language when applicable, or the display of a rainbow flag to demonstrate allyship are likely to go a long way towards helping queer and trans students feel more welcome in STEM.

Secondly, given the repeated issue of isolation for queer and trans students within STEM, the founding and support of affinity groups, especially queer STEM affinity groups such as oSTEM or Out to Innovate (formerly the National Organization of Gay and Lesbian Scientists and Technical Professional (NOGLSTP)) may help provide a means by which students may develop a sense of community and connection as well as academic and career support. However, work must also be done to ensure that these spaces remain comfortable and welcoming places for all queer students, as well as acknowledging that these spaces may not be useful for all queer and trans students and

that alternative forms of support and community building should be made available in order to support students with a wide variety of needs, identities, and lived experiences.

While these are both important steps that should be taken by all STEM educational spaces, it should be noted that they are merely initial steps. The problems facing queer and trans STEM students are systemic in nature, and therefore tackling these problems means tackling the systems that give rise to and perpetuate them. However, there are still significant questions surrounding how to best approach these deeply embedded issues and what administrative changes would be most effective. Discussions on these topics should include administrators, STEM educators, and the queer and trans students that will be directly affected by changes in policy in order to ensure that they adequately address the genuine difficulties faced by those students and work towards making STEM spaces open and welcoming to all students.

Limitations

The most notable limitation of this research is the methods chosen. While a scoping review does allow for the inclusion of broad swaths of literature, the analysis created by such a review is equally broad and qualitative in nature. Significant aspects of individual studies may have been omitted in order to provide a holistic understanding of the literature in its entirety. Secondly, this analysis was limited based on the current number of available studies, which almost surely as of yet does not encompass the whole of queer and trans experience within STEM educational spaces. It is the sincerest hope of the author that more research in the future expands the scope of the literature far beyond what is currently available at this time.

References

Ackerman, N., Atherton, T., Avalani, A. R., Berven, C. A., Laskar, T., Neunzert, A., Parno, D. S., & Ramsey-Musolf, M. (2018). *LGBT+ inclusivity in physics and astronomy: A best practices guide*. The American Astronomical Society.

Almeida, J., Johnson, R. M., Corliss, H. L., Molnar, B. E., & Azrael, D. (2009). Emotional distress among LGBT youth: The influence of perceived discrimination based on sexual orientation. *Journal of Youth and Adolescence, 38*, 1001-1014.

Amengual, T., Kunstman, K., Lloyd, R. B., & Janssen, A. (2022). Readiness assessments for gender-affirming surgical treatments: A systematic scoping review of historical practices and changing ethical considerations. *Frontiers in Psychiatry, 13*, 1006024.

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology*, *8(*1), 19-32.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching*, *47*(5), 564-582.

Baros, J. N. (2022). Linguistically invisible: The experiences of transgender students in Spanish language courses. *Journal of Homosexuality*, *69*(13), 2326-2347.

Barreto, M., Ellemers, N., & Banal, S. (2006). Working under cover: Performance-related self-confidence among members of contextually devalued groups who try to pass. *European Journal of Social Psychology*, *36*(3), 337-352.

Barthelemy, R. S., Swirtz, M., Garmon, S., Simmons, E. H., Reeves, K., Falk, M. L., Deconinck, W., Long, E. A., & Atherton, T. J. (2022). LGBT + physicists: Harassment, persistence, and uneven support. *Physics Education Research*, 18(1), 010124. https://doi.org/10.1103/PhysRevPhysEducRes.18.010124

Bazzul, J. & Skyes, H. (2011). The secret identity of a biology textbook: Straight and naturally sexed. *Cultural Studies of Science Education, 6*, 265-286.

Busch, C. A., Supriya, K., Cooper, K. M., & Brownell, S. E. (2022). Unveiling concealable stigmatized identities in class: The impact of an instructor revealing her LGBTQ+ identity to students in a large-enrollment biology class. *Life Sciences Education, 21*, 1-21.

Butterfield, A. E., McCormick, A., & Farrell, S. (2018). Building LGBTQ-inclusive chemical engineering classrooms and departments. *Chemical Engineering Education*, *52*(2), 107-113.

Byrne, E. M., Jensen, H., Thomsen, B. S., & Ramchandani, P. G. (2023). Educational interventions involving physical manipulatives for improving children's learning and development: A scoping review. *Review of Education, 11*(2), article e3400.

Casad, B. J., Petzel, Z. W., & Ingalls, E. A. (2019). A model of threatening academic environments predicts women STEM majors' self-esteem and engagement in STEM. *Sex Roles, 80*, 469-488.

Casey, L. S., Reisner, S. L., Findling, M. G., Blendon, R. J., Benson, J. M., Sayde, J. M., & Miller, C. (2019). Discrimination in the United States: Experiences of lesbian, gay, bisexual, transgender, and queer Americans. *Health Services Research*, *54*, 1454-1466.

Crane, P. R., Swaringen, K. S., Rivas-Koehl, M. M., Foster, A. M., Le, T. H., Weiser, D. A, & Talley, A. E. (2022). Come out, get out: Relations among sexual minority identification, microaggressions, and retention in higher education. *Journal of Interpersonal Violence, 37*(9-10), NP8237–NP8248.

Cech, E. A. (2022). The intersectional privilege of white able-bodied heterosexual men in STEM. *Science Advances, 8*(24), 1-14.

Cech, E. A., & Pham, M. V. (2017). Queer in STEM Organizations: Workplace Disadvantages for LGBT Employees in STEM Related Federal Agencies. *Social Sciences*, *6*(1), Article 1. https://doi.org/10.3390/socsci6010012

Cech, E. A. & Rothwell, W. R. (2018). LGBTQ inequality in engineering education. *Journal of Engineering Education, 107*(4), 583-610.

Cech, E. A., & Waidzunas, T. J. (2011). Navigating the heteronormativity of engineering: The experiences of lesbian, gay, and bisexual students. *Engineering Studies, 3*(1), 1-24. doi:10.1080 /19378629.2010.545065

Centers of Disease Control and Prevention. (2021). *Youth risk behavior survey: Data summary and trends report*. https://www.cdc.gov/healthyyouth/data/yrbs/pdf/YRBS_Data-Summary-Trends_Report2023_508.pdf

Chang, M. J., Sharkness, J., Hurtado, S., & Newman, C. B. (2014). What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups. *Journal of Research in Science Teaching*, *51*(5), 555-580.

Clewell, B. C, & Campbell, P. B. (2002). Taking stock: Where we've been, where we are, where we're going. *Journal of Women and Minorities in Science and Engineering, 8*, 225-284.

Cooper, M. K., Auerbach, A. J. J., Bader, J. D., Beadles-Bohling, A. S., Brashears, J. A., Cline, E., Eddy, S. L., Elliott, D. B., Farley, E., Fuselier, L., Heinz, H. M., Irving, M., Josek, T., Lane, A. K., Lo, S. M., Maloy, J., Nugent, M., Offerdahl, E., Palacios-Moreno, J., Ramos, J., Reid, J. W., Sparks, R. A., Waring, A. L., Wilton, M., Gormally, C., & Brownell, S. E. (2020). Fourteen recommendations to create a more inclusive environment for LGBTQ+ individuals in academic biology. *CBE – Life Sciences Education, 19*(6), 1-18.

Cooper, K. M. & Brownell S. E. (2016). Coming out in class: Challenges and benefits of active learning in a biology classroom for LGBTQIA students. *CBE Life Science Education, 15*(3), ar37.

Duran, A. (2019). Queer *and* of color: A systematic literature review on queer students of color in higher education scholarship. *Journal of Diversity in Higher Education, 12*(4), 390-400.

De Gioannis, E., Gian Luca, P., & Flaminio, S. (2023). Empowering women in STEM: A scoping review of interventions with role models. *Internation Journal of Science Education, Part B: Communication and Public Engagement, 13*(3), 261-275.

Ellemers, N., & Barreto, M. (2006). Social identity and self-presentation at work: how attempts to hide a stigmatised identity affect emotional well-being, social inclusion and performance. *Netherlands Journal of Psychology, 62*(1), 51-57.

Estrada, M., Burnett, M., Campbell, A. G., Campbell, P. B., Denetclaw, W. F., Gutiérrez, C. G., Hurtado, S., John, G. H., Matsui, J., McGee, R., Okpudo, C. M., Robinson, T. J., Summers, M. F., Werner-Washburne, M., & Zavala, M. (2016). Improving underrepresented minority student persistence in STEM. *CBE—Life Sciences Education, 15*(3), 1-10.

Faulkner, W. (2000). Dualisms, hierarchies and gender in engineering. *Social studies of science*, *30*(5), 759-792.

Freeman, J. (2018). LGBTQ scientists are still left out. *Nature, 559*, 27-28.

Foltz, L. G., Gannon, S., & Kirschmann, S. L. (2014). Factors that contribute to the persistence of minority students in STEM Fields. *Planning for Higher Education, 42*(4), 1-13.

Forbes, T. Q. (2022). Queer-free majors?: LGBTQ+ college students' accounts of chilly and warm academic disciplines. *Journal of LGBT Youth, 19*(3), 330-349.

Gottfried, M., Estrada, F., & Sublett, C. (2015). STEM education and sexual minority youth: Examining math and science coursetaking patterns among high school students. *The High School Journal*, *99*(1), 66–87. https://doi.org/10.1353/hsj.2015.0018

Greathouse, M., BrckaLorenz, A., Hoban, M., Huesman Jr., R., Rankin, S., & Stolzenberg, E. B. (2018). *Queer-spectrum and trans-spectrum student experiences in American higher education: The analyses of national survey findings.* Tyler Clementi Center, Rutgers.

Greathouse, P. (2016). Make us question, think, reflect, and understand: Secondary students' beliefs and attitudes towards the inclusion of LGBTQ themed literature in the English classroom. *SRATE Journal, 25*(2), 42-48.

Helmer, K. (2016). Gay and lesbian literature disrupting the heteronormative space of the high school English classroom. *Sex Education, 16*(1), 35-48.

Hughes, B. E. (2017). "Managing by not managing": How gay engineering students manage sexual orientation identity. Journal of College Student Development, 58(3), 385-401.

Hughes, B. E. (2018). Coming out in STEM: Factors affecting retention of sexual minority STEM students. *Science Advances*, *4*(3), 1-5. https://doi.org/10.1126/sciadv.aao6373

Hughes, B. E., & Kothari, S. (2023). Don't Be Too Political: Depoliticization, Sexual Orientation, and Undergraduate STEM Major Persistence. *Journal of Homosexuality, 70(*4), 632–659. https://doi.org/10.1080/00918369.2021.1996101

Jones, J. M. (2022, February 17). *LGBT identification in US ticks up to 7.1%.* Gallup. https://news.gallup.com/poll/389792/lgbt-identification-ticks-up.aspx

Kafai, Y. B., Xin, Y., Fields, D., & Tofel-Grehl, C. (2022). Teaching and learning about respiratory infectious diseases: A scoping review of interventions in K-12 education. *Journal of Research in Science Teaching, 59*(7), 1274-1300.

Kersey, E. & Voigt, M. (2020). Finding community and overcoming barriers: Experiences of queer and transgender postsecondary students in mathematics and other STEM fields. *Mathematics Education Research Journal, 33*(4), 733-756.

Kosciw, J. G., Clark, C. M., & Menard, L. (2022). *The 2021 National School Climate Survey: The experiences of LGBTQ+ youth in our nation's schools*. New York: GLSEN.

Kroll, J. A. & Plath, K. L. (2022). Seen and unseen identities: Investigation of gender and sexual orientation identities in the general chemistry classroom. *Journal of Chemical Education, 99*, 195-201.

Kulick, A., Wernick, L. J., Espinoza, M. A. V., Newman, T. J., & Dessel, A. B. (2019). Three strikes and you're out: Culture, facilities, and participation among LGBTQ youth in sports. *Sport, Education, and Society, 24*(9), 939-953.

Lee, M. J., Collins, J. D., Harwood, S. A., Mendenhall, R., & Huntt, M. B. (2020). "If you aren't White, Asian or Indian, you aren't an engineer": racial microaggressions in STEM education. *International Journal of STEM Education*, *7*, 1-16.

Levac, D., Colquhoun, H., & O'Brien, K. K. (2010). Scoping studies: Advancing the methodology. *Implementation Science, 5*(69), 1-9.

Leyva, L. A., McNeill, R. T., Balmer, B. R., Marshall, B. L., King, V. E., & Alley, Z. D. (2022). Black queer students' counter-stories of invisibility in undergraduate STEM as a white, cisheteropatriarchal space. *American Educational Research Journal, 59*(5), 863–1048. https://doi.org/10.3102/00028312221096455

Linley, J. L., Renn, K. A., & Woodford, M. R. (2018). Examining the ecological systems of LGBTQ STEM majors. *Journal of Women and Minorities in Science and Engineering, 24(*1), 1-16.

Maguth, B. M & Taylor, N. (2014). Bringing LGBTQ topics into the social studies classroom. *The Social Studies, 105*(1), 23-28.

Maloy, J., Kwapisz, M. B., & Hughes, B. E. (2022). Factors influencing retention of transgender and gender nonconforming students in undergraduate STEM majors. *CBE—Life Sciences Education*, *21*(1), article 13. https://doi.org/10.1187/cbe.21-05-0136

Mathies, N., Coleman, T., McKie, R. M., Woodford, M. R., Courtice, E. L., Travers, R., & Renn, K. A. (2019). Hearing "that's so gay" and "no homo" on academic outcomes for LGBQ+ college students. *Journal of LGBT Youth, 16*(3), 255-277.

McCormick, A., Schmidt, K., & Clifton, E. (2015). Gay-straight alliances: Understanding their impact on the academic and social experiences of lesbian, gay, bisexual, transgender, and questioning high school students. *Children & Schools, 37*(2), 71-77.

McGee, E. O. (2020). Interrogating structural racism in STEM higher education. *Educational Researcher*, *49*(9), 633-644.

Mercer-Mapstone, L., Bajan, S., Banas, K., Morphett, A., & McGrath, K. (2021). Breaking the binary: Teaching inclusive conceptions of sex and gender in undergraduate science. *Teaching & Learning Inquiry, 9*(2), 1-29.

Miller, R. A. & Downey, M. (2020). Examining the STEM climate for queer students with disabilities. *Journal of Postsecondary Education and Disability, 33*(2), 169-181.

Miller, R. A., Vaccaro, A., Kimball, E. W., & Forester, R. (2021). "It's dude culture": Students with minoritized identities of sexuality and/or gender navigating STEM majors. *Journal of Diversity in Higher Education, 14*(3), 340–352. https://doi.org/10.1037/dhe0000171

Millett, T. V. P. (2019). Queering the arts classroom: Queering matters. *International Journal of Art and Design Education. 38*(4), 809-822.

Mollet, A. L & Lackman, B. R. (2018). Asexual borderlands: Asexual collegians' reflections on inclusion under the LGBTQ umbrella. *Journal of College Student Development, 59*(5), 623-628.

Msweli, N. T., Mawela, T., & Twinomurinzi, H. (2023). Data science: A scoping review. *Journal of Information Technology Education: Research, 22*, 263-294.

Munn, Z., Peters, M. D., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology, 18*(143), 1-7.

National Center for Science and Engineering Statistics. 2023. *Diversity and STEM: Women, Minorities, and Persons with Disabilities 2023*. Special Report NSF 23-315.

National Science Foundation, 2022. *Leading the World in Discovery and Innovation, STEM Talent Development and the Delivery of Benefits from Research - NSF Strategic Plan for Fiscal Years (FY) 2022 – 2026.*

Nodin, N. (2022). Queering the curriculum: Reflections on LGBT+ inclusivity in higher education. *Psychology Teaching Review, 28*(1), 21-30.

Palkki, J. & Caldwell, P. (2018). "We are often invisible": A survey on safe space for LGBTQ students in secondary school choral programs. *Research Studies in Music Education, 40*(1), 28-49.

Parise, M. M. (2021). Gender, sex, and heteronormativity in high school statistics textbooks. Mathematics Education Research Journal, 33(4), 757-785.

Payne, E. C. & Smith, M. J. (2018). Refusing relevance: School administrator resistance to offering professional development addressing LGBTQ issues in schools. *Educational Administration Quarterly, 54*(2), 183-215.

Pearson, J., Muller, C., & Wilkinson, L. (2007). Adolescent same-sex attraction and academic outcomes: The role of school attachment and engagement. *Social Problems, 54*(4), 523-542.

Pitcher, E. N. (2017). 'There's stuff that comes with being an unexpected guest': Experiences of trans* academics with microaggressions. *International Journal of Qualitative Studies in Education, 30*(7), 688-703.

Pitcher, E. N., Camacho, T. P., Renn, K. A., & Woodford, M. R. (2018). Affirming policies, programs, and supportive services: Using an organizational perspective

to understand LGBTQ+ college student success. *Journal of Diversity in Higher Education, 11*(2), 117-132.

Prema, D., & Dhand, R. (2019). Inclusion and accessibility in STEM education: Navigating the duty to accommodate and disability rights. *Canadian Journal of Disability Studies, 8*(3), 121-141.

Radunzel, J., Mattern, K., & Westrick, P. (2016). *The role of academic preparation and interest on STEM success*. ACT Research Report Series, ACT, Inc.

Saxena, M., Geiselman, T. A., & Zhang, S. (2019). Workplace incivility against women in STEM: Insights and best practices. *Business Horizons*, *62*(5), 589-594.

Scharrón-Del Río, M. R. (2018). Intersectionality is not a choice: Reflections of a queer scholar of color on teaching, writing, and belonging in LGBTQ studies and academia. *Journal of Homosexuality, 67*(3), 294-304.

Schmidt, S. J. (2010). Queering social studies: The role of social studies in normalizing citizens and sexuality in the common good. *Theory & Research in Social Education, 38*(3), 314-335.

Sears, B., & Mallory, C. (2011). *Documented evidence of employment discrimination & its effects on LGBT people*. The Williams Institute, UCLA.

Snyder, V. L. & Broadway, F. S. (2004). Queering high school biology textbooks. *Journal of Research in Science Teaching, 41*(6), 617-636.

Suárez, M. I., Dabney, A. R., Waxman, H. C., Scott, T. P., & Bentz, A. O. (2021). Exploring factors that predict STEM persistence at a large, public research university. *International Journal of Higher Education, 10*(4), 161-174.

Suárez, M. I., Hawkman, A. M., Tofel-Grehl, C., MacDonald, B. L., Searle, K., Feldon, D. F., Sommers, T., & Hernandez, M. (2022). STEM as a cover: Towards a framework for Queer Emotions, Battle Fatigue, and STEM identity. *International Journal of Qualitative Studies in Education, 35*(9), 960–979. https://doi.org/10.1080/09518398.2022.2031333

Sultan, U., Axell, C., & Hallström, J. (2019). Girls' engagement with technology education: A scoping review of the literature. *Design and Technology Education, 24*(2).

Tavarez, J. (2022). "I can't quite be myself": Bisexual-specific minority stress within LGBTQ campus spaces. *Journal of Diversity in Higher Education, 15*(2), 167-177.

The Williams Institute. (2019). *Adult LGBT population in the United States*. UCLA.

Tsui, L. (2007). Effective strategies to increase diversity in STEM fields: A review of the research literature. *The Journal of Negro Education*, *76*(4) 555-581.

US Bureau of Labor Statistics. (2023). *Employment projections: Employment in STEM occupations*. https://www.bls.gov/emp/tables/stem-employment.htm

Vaccaro, A., Miller, R. A., Kimball, E. W., Forester, R., & Friedensen, R. (2021). Historicizing minoritized identities of sexuality and gender in STEM fields: A grounded theory model. *Journal of College Student Development, 62*(3), 293-309.

van den Hurk, A., Meelissen, M., & van Langen, A. (2019). Interventions in education to prevent STEM pipeline leakage. *International Journal of Science Education, 41*(2), 150-164.

Veldhuis, C. B. (2022). Doubly marginalized: Addressing the minority stressors experiences by LGBTQ+ researchers who do LGBTQ+ research. *Health Education & Behavior, 49*(6), 960-974.

Voigt, M. (2022). A quantitative exploration of queer-spectrum students' experiences in introductory undergraduate mathematics courses. *PLOS ONE, 17*(10), e0275325. https://doi.org/10.1371/journal.pone.0275325

Weise, J., Courtney, S., & Strunk, K. (2023). "I didn't think I'd be supported": LGBTQ+ students' nonreporting of bias incidents at southeastern colleges and universities. *Journal of Diversity in Higher Education, 16*(5), 607-618.

Woodford, M. R., Kulik, A., & Atteberry B. (2015). Protective factors, campus climate, and health outcomes among sexual minority college students. *Journal of Diversity in Higher Education, 8*(2), 73-87.

Woolweaver, A. B., Drescher, A., Courtney, M., & Espelage, D. L. (2023). Leveraging comprehensive sexuality education as a tool for knowledge, equity, and inclusion. *Journal of School Health, 93*(4), 340-348.

Yager, J., Waitzkin, H., Parker, T., & Duran, B. (2007) Educating, training, and mentoring minority faculty and other trainees in mental health services research. *Acad Psychiatry, 31*(2), 146-51. doi: 10.1176/appi.ap.31.2.146.

Yang, J. A., Sherard, M. K., Julien, C., & Borrego, M. (2021a). LGBTQ+ in ECE: Culture and (non)visibility. *IEEE Transactions on Education, 64*(4), 345-352.

Yang, J. A. Sherard, M. K., Julien, C., & Borrego, M. (2021b). Resistance and community-building in LGBTQ+ engineering students. *Journal of Women and Minorities in Science and Engineering, 27*(4), 1-33.