AERA Open
January-December 2024, Vol. 10, No. 1, pp. 1–19
DOI: 10.1177/23328584241259406
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Exploring Queer and Trans Students' Mathematics Identity in Relation to STEM as a White Cisheteropatriarchal Space

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An emerging area of research on the diversification of science, technology, engineering, and mathematics (STEM) is that of queer and trans (QT) students who are interested in STEM education and disciplines. The purpose of our study was to identify differences in high school mathematics educational experiences by sexual orientation and gender identity. We used mathematics identity and Leyva's STEM as a White cisheteropatriarchal space (WCHPS) as our theoretical frameworks to guide our study. Using data from Waves 1 and 2 of the High School Longitudinal Study of 2009, our exploratory analyses uncovered significant differences between QT and HC students' mathematics identity. Regression results showed that ideological and relational dimensions of WCHPS in Grade 9 play a significant role in Grade 11 QT students' mathematics identity. Given the exploratory approach for our study, we aim for our research to begin critical conversations in mathematics education concerning QT students to promote more enriching and welcoming learning environments.

Keywords: *ANOVA/MANOVA, descriptive analysis, diversity, equity, gay/lesbian studies, gender studies, High School Longitudinal Study of 2009, mathematics identity, quantitative criticalism, queer, regression analyses, social justice, secondary data analysis, statistics, trans*

Queer and Trans Students' Mathematics Identity and High School Educational Experiences

Historically, mathematics has played a critical role in paving science, technology, engineering, and mathematics (STEM) success (Lin et al., 2018; Rech & Harrington, 2000; Torbey et al., 2020). For decades, STEM federal and institutional policy reports have pushed to increase STEM diversity (National Academy of Sciences et al., 2007; National Science Board, 2010; President's Council of Advisors on Science and Technology, 2012; U.S. Office of the Press Secretary, 2021). These policy reports, focused primarily on increasing female and People of Color participation in STEM, have consistently and persistently made economic prosperity arguments as the basis for the need to increase diversity (Basile & Lopez, 2015). In other words, the case is made to diversify STEM only because it affects the industry financially as the People of Color population increases to a majority; to survive, policymakers need to cater to People of Color, necessitating their knowledge for that reason. U.S. presidents past and present not only have emphasized the importance of increasing STEM interest in high school and earlier but also have called for diversifying the STEM workforce to further innovation (President's Council of Advisors on Science and Technology, 2012). Previous and current presidential administrations have painted a dismal picture of the U.S. role in the global economy and its lack of competitiveness when other countries, such as China, outperform the United States in STEM career productivity and, thus, STEM innovation (National Science Board, 2010). This concern for STEM career readiness is a problem considering that STEM jobs in the United States are projected to increase by 8% by 2029 (U.S. Bureau of Labor Statistics, 2020). For the U.S.

workforce to meet this demand, broadening participation in STEM of the next generation of scientists and engineers is imperative. Although we recognize the economic appeal for diversifying STEM as an attractive component of serving minoritized students, we view our intentions as complicated, thus using interest convergence to develop numerous avenues for stakeholders to invest in queer and trans communities.

To make matters worse, we are currently living in a deeply polarized political society with state legislatures that have banned historically accurate and diverse perspectives from education (Harper, 2023; Patel, 2024; Sawchuck, 2022; Staff, 2024). Political attacks have targeted lesbian, gay, bisexual, queer, and trans (we use the abbreviated queer/trans (QT[1]) from here on) students as well by forcing "outing" (Schoenbaum & Murphy, 2023), restricting restroom use and pronouns for trans and nonbinary youth, and enacting anti-QT laws, such as the "Don't Say Gay" law in Florida (Yurcaba, 2023). These attacks create an even more hostile climate for QT youth in schools than what has been documented in mathematics and other subjects (Kosciw et al., 2022). It is a moral imperative to expand the knowledge base in STEM that speaks to the experiences of QT youth to find ways to better affirm their identities and support their learning experiences.

Unfortunately, there is not much research on the experiences of QT youth in K–12 STEM education. This scholarly and professional focus is especially important considering that QT youth make up approximately 9.5% of youth ages 13–17 in the United States (Conron, 2020). Research has shown that QT students had a difficult time in high school, in large part due to queerphobia, heterosexism, transphobia, and genderism that are entrenched in every aspect of schooling, including curriculum, teaching practices, and socialization, among others (Kosciw et al., 2022). Kosciw et al. (2022) found that more than 68% of QT students felt unsafe at school because of their sexual orientation and/or gender identity. These experiences were associated with higher levels of absences, lower grades, lower self-esteem, and higher likelihood of dropping out. In addition, these students experienced affirming representations of QT individuals in only 5.1% of their mathematics classes and 12.4% of their science classes (Kosciw et al., 2022). STEM education in high school has the potential to curb negative outcomes for QT students, increase undergraduate enrollment among QT students, and thus broaden participation in STEM. Because of its importance for math identity formation, we focused on high school mathematics education experiences in Grade 9 and again in Grade 11, as Grade 9 has been shown to be a critical transition year for high school students (Fields, 2013; Gaias et al., 2020; McCallumore & Sparapani, 2010; Miller, 2022; Wheelock & Miao, 2005). Additionally, algebra tends to be the staple course in Grade 9, which research has shown is a gatekeeper for later courses, graduation, and STEM futures (Rech & Harrington, 2000; Torbey et al., 2020).

Given the centrality of mathematics for STEM pursuits, it is especially important for education researchers to examine students' mathematics identity and experiences as they relate to broadening participation in STEM education. The purpose of our study was to identify differences in mathematics educational experiences by student sexual orientation and gender identity by using one of the few, if not the only, nationally representative data sets in the field of education that identified QT youth. Our intended audiences for this study include high school and postsecondary educators with primary teaching or administrative responsibilities. Given the exploratory approach for our study, we aimed for it to begin critical conversations in mathematics education concerning QT students to promote more enriching and welcoming learning environments. Although this study is certainly not the first to research students at the intersection of mathematics education, sexual orientation, and/or gender identity (e.g., Leyva et al., 2022b), we do believe that it may be one of the first studies, if not the first, to research this topic from a quantitative lens with population-based, longitudinal data. To that end, we asked the following research questions:

1. Were there differences in mathematics identity–related experiences and perceptions (i.e., dimensions of the STEM as a White cisheteropatriarchal space framework) by sexual orientation and gender identity in high school students?
2. To what extent did the dimensions of the STEM as a White cisheteropatriarchal space framework relate to mathematics identity in high school students from Grade 9 (Wave 1) to Grade 11 (Wave 2) by sexual orientation and gender identity?

Literature Review

To better understand QT students' experiences and perceptions in mathematics education, we briefly reviewed research on gender in mathematics education, QT high school students' educational experiences, and scholarship concerning STEM and mathematics education for QT students. To our knowledge, no prior research has explored mathematics experiences and perceptions in high school for QT students by using large-scale generalizable data that are nationally representative. As such, our study is well positioned to contribute to conversations for scholars and practitioners and has the potential to disrupt myths about QT students that might permeate K–12 education discourse.

Social Construction of Gender Ability in Mathematics Education

The last 50 years of the field of mathematics education have seen an evolution from a look at differences between boys and girls (or men and women) to a reconceptualization of how sexual orientation and gender identity shape students' mathematical experiences (Hall & Norén, 2021; Leder, 2019). The rise of feminist epistemologies paved the way for research exploring gender disparities in math education, often to justify the diversification of the STEM workforce (De Abreu, 2014; Fennema, 1974; Forgasz, 2014; Steinthorsdottir & Herzig, 2014). That is, studies focused primarily on how boys outperformed girls in mathematics and argued that this gap needed to be narrowed or closed (Fennema, 1974; Forgasz, 2014; Hall & Norén, 2021; Leder, 2019; Marsh, 1989; Steinthorsdottir & Herzig, 2014), mostly focusing on what Gutiérrez (2008) referred to as "gap-gazing."

As research on the social construction of gender evolved in feminist studies, mostly through queer theory, scholars attributed gender disparities in mathematics to the masculinization of mathematics (Damarin, 2000; Fennema & Sherman, 1977; Leyva, 2017; Steinthorsdottir & Herzig, 2014). Specifically, who was deemed as mathematically capable in comparison to others was socially constructed as inherently male (Boaler, 1997; Damarin, 2000; Wolleat et al., 1980), which Leyva (2017) referred to as the "male superiority myth." In discussing the mythical disparities that put boys' mathematics achievement and participation on a metaphorical pedestal, Leyva (2017) implored researchers to investigate how oppression and privilege may shape mathematics education experiences, perceptions, and broader discourse. This present study sought to remedy this concern by exploring differences in mathematics educational outcomes by sexual orientation and gender identity, keeping in mind socially constructed stereotypes, through a critical quantitative lens.

Queer/Trans Students' High School Experiences

The National School Climate Survey is a biennial survey disseminated to QT students from across the United States that documents aspects of school climate that may be particularly harmful or affirming to students ages 13–21 (Kosciw et al., 2022). The most recent data were collected in 2021 from more than 22,000 students. Although it is not a population-based survey, it does provide rich insight into the lives of QT adolescents and factors that may contribute to dropout, victimization, suicidality, and retention. QT students who were discriminated against were about three times as likely to be consistently absent and to have a lower grade point average, about twice as likely not to matriculate into college, and more likely to be disciplined in school, to have lower self-esteem, and to experience higher levels of depression (Kosciw et al., 2022). These outcomes and experiences were exacerbated for QT students of color. For example, almost 31% of QT Asian American and Pacific Islander (AAPI) students were disciplined (Truong et al., 2020a), compared to almost 45% of QT Black students (Truong et al., 2020b), almost 40% of QT Latinx students (Zongrone et al., 2020a), and almost 49% of QT Indigenous students (Zongrone et al, 2020b). Examples of victimization and discrimination included name-calling, bullying, assault, and discriminatory school policies and practices, such as disciplining for public displays of affection, supporting explicitly anti-QT curriculum and extracurricular activities, or prohibiting affinity groups (e.g., Gay Straight Alliance, Gender and Sexuality Alliance; GSA).

However, evidence suggests that supportive school practices and policies can have the opposite effect and that merely having a GSA in school is related to better educational outcomes for QT students (Kosciw et al., 2022). Schools with GSAs are more likely to have students report to administrators when they hear anti-QT remarks, and QT students feel safer, experience smaller levels of victimization, have fewer absences, enjoy a greater sense of school connectedness, and enjoy better overall student well-being (e.g., less depression, higher self-esteem; Kosciw et al., 2022). These positive educational outcomes for QT students may be attributed to having supportive peers and adults at the schools, greater school connectedness, and more inclusive curriculum resources, among other aspects. That said, only about 49% of QT AAPI students (Truong et al., 2020a), about 41% of QT Black (Truong et al., 2020b) and Latinx students (Zongrone et al, 2020a), and about 34% of QT Indigenous students have reported having supportive school personnel.

Queer/Trans Students in STEM

Research addressing STEM engagement, self-efficacy, and academic achievement among QT students has focused primarily on higher education (Brinkworth, 2016; Butterfield et al., 2018; Cech & Rothwell, 2018; Hughes, 2018; Leyva, 2016a, 2016b; Linley et al., 2018; Miller et al., 2021). Among college students who aspire to major in STEM, QT students are less likely than their heterosexual peers to complete a STEM degree (Hughes, 2018). Freeman (2018) attributed the lack of representation of QT people in STEM to their experiences of discrimination and bias in the field and isolation from dominant STEM culture. Relatedly, Miller et al. (2021) unearthed heterosexist cultural norms in STEM fields that alienated and isolated QT individuals. Leyva et al. (2022a, 2022b) referred to this phenomenon of STEM as a *White, cisheteropatriarchal space* (WCHPS) that excludes QT students, and in particular QT students of color, from the field.

Although these studies were focused on collegiate environments, they illuminated contextual factors within STEM that have played a role in the educational experiences of QT high school students. Two of the themes running through research in this area are the primarily heteronormative, cisnormative nature of STEM and the gatekeeping ability of mathematics courses (Douglas & Attewell, 2017). For example, Leyva (2017) found that math achievement was usually assessed quantitatively and engaged in a binary operationalization of gender, which often privileged White, heterosexual, cisgender (HC) males. Heybach and Pickup (2017) echoed these limitations in STEM research by asserting that diversity in STEM typically focused on improving access for HC women. In exploring mathematics learning environments, Fischer (2013) found that QT students experienced positive mathematics identity development through GSAs, supportive teachers and schooling environments, extracurricular support, and support from family and friends.

Queer/Trans Students in Mathematics

Research has shown that affirming QT students' queer identity is related to a strong mathematics identity (Fischer, 2013). That said, Gottfried et al. (2015) found that sexual minority students (i.e., queer students) seemed to be less likely to take advanced mathematics courses, an effect that is diluted as more factors are accounted for in models. This result suggests that although having a strong mathematics identity is important for QT students, they do not have the same opportunities as their non-QT peers to foster that strong identity in the field.

Additionally, mathematics is a field that is traditionally thought of as neutral. However, research has shown that what is seemingly "neutral" is perceived by students to lack emotion, be inherently masculine, and inhibit any show of one's sexuality and gender identity or other cultural identities, thus alienating them from the discipline (Bilimoria & Stewart, 2009; Kersey & Voigt, 2021; Leyva, 2017; Voigt, 2022). Researchers have advocated for the need to disrupt this neutrality by affirming QT students in mathematics education (Dubbs, 2016; Esmonde, 2011; Leyva, 2017; Mendick, 2006, 2014; Rands, 2019). This sentiment of alienation is echoed by QT instructors in classrooms (Cooper et al., 2019), who often feel the need to keep their sexuality to themselves without "outing" themselves to their students, even when doing so could contribute to a much warmer classroom climate for students and potentially allow them to serve as a role model. A study by Voigt (2022) of queer students in undergraduate mathematics courses found that sexuality played a role in how students interacted with their instructors and peers, their communication and discussions, their mathematics engagement, mathematics affect, and expected grade in mathematics courses. Surprisingly, asexual students seemed to report higher levels of instructor and peer interactions, a greater sense of community and participation, and a stronger mathematics affect, which Voigt (2022) attributed to asexuality's alignment with mathematics' neutrality and assumed heteronormativity. One study showed that affirmed QT students felt empowered to embrace their queer and transness, along with their STEM identity (Suárez et al., 2022). A growing body of work has provided pedagogical and administrative strategies for supporting QT students in K–12 mathematics classrooms (e.g., Suárez & Wright, 2020; Waid, 2020; Whipple et al., 2020; Yeh et al., 2020). However, research has not explicitly focused on exploring systematic differences in mathematics student experiences by sexual orientation and gender identity, which this study sought to accomplish.

Theoretical Frameworks

To understand how QT high school students experienced and perceived mathematics education, we grounded our work in mathematics identity and STEM as a White, cisheteropatriarcal space framework. This combination enabled us to examine how sexual orientation and/or gender identity may have related to high school students' interest and/or competence in mathematics.

Mathematics Identity

Research has shown that a robust mathematics identity positively influences persistence, achievement, and school engagement for young people (e.g., Boaler & Greeno, 2000; Childs, 2017; Fernández et al., 2022; Gonzalez et al., 2020, 2023; McKoy et al., 2020). Different systematic literature reviews have found it difficult to operationalize the construct of mathematics identity, as the field of mathematics does not have an agreed-upon definition, and researchers have used a variety of operationalizations and theories, depending on their philosophical orientation (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019; Radovic et al., 2018). For example, some researchers have conceptualized mathematics identity as a fixed construct that a student is born with and follows throughout their life course (Erickson, 1968), while others have viewed it as a fluid construct that can be malleable, often influenced by pedagogical strategies, competency, and how individuals view the student, among other factors (e.g., Boaler, 2002; Carlone & Johnson, 2007; Cass et al., 2011; Radovic et al., 2018).

As mathematics identity can be a challenging latent construct to operationalize, we turned to past quantitative research to support our empirical examination. In 2015, Cribbs et al. developed the Explanatory Model for Mathematics Identity (EMMI), based on Carlone and Johnson's (2007) science identity framework. EMMI operationalizes three dimensions of mathematics identity: *interest, recognition*, and *competence/performance*. These dimensions are not mutually exclusive and interact with other aspects of one's identity (e.g., sexual orientation, gender identity, race/ethnicity, socioeconomic status). Cass et al. (2011) defined *competence* as "student's beliefs about their ability to understand mathematics," and *performance* was defined as their "beliefs about their ability to perform in mathematics" (pp. 1051–1052), which they collapsed as one construct as a result of past research factor analyses (Cribbs et al., 2015). *Interest* was defined as "a student's desire or curiosity to think about and learn mathematics" (p. 1052), while *recognition* was defined as "how students perceive others to view them in relation to mathematics" (p. 1052).

Research has shown a positive correlation between an individual's mathematics identity and their choice to pursue STEM disciplines (Boaler & Greeno, 2000; Childs, 2017; Dou et al., 2019; Fernández et al., 2022; Gonzalez et al., 2020, 2023; McCoy et al., 2020). We argue that the same is true for mathematics identity and pursuits. Students who achieve at high levels in STEM disciplines are more recognized for their work (Verdín et al., 2018). Recent evidence has shown that performance (i.e., behaving like a scientist through doing research activities, presenting) can increase the odds of choosing a STEM undergraduate major by up to 85% and can be attributed to peer and parental support (Atkins et al., 2020; Dou et al., 2019). Students learn early in their schooling that certain behaviors are associated with being "smart" in STEM (Hachey, 2020), which can vary by gender (Verdín et al., 2018), although little is known regarding variance across sexual orientation and/or gender identity. Additionally, recognition can be fostered through home, school, and extracurricular activities (Kang et al., 2019; Rodriguez et al., 2019, 2021). Regarding recognition, Dou et al. (2021) found positive and direct effects on students' STEM identity, whereas performance and competence served as mediators.

Furthermore, because mathematics identity plays an important role in so many educational outcomes, especially for minoritized students, scholars have used the High School Longitudinal Study of 2009 (HSLS:09; Alexander, 2015; Fernández, et al., 2022; Joseph et al., 2020) to explore factors that have influenced this identity. Focusing on mathematics socialization-level subscales (i.e., sociohistorical, community and family, school and institutional, intrapersonal), Joseph et al. (2020) found that sociohistorical (e.g., mathematics teacher treatment of students), school and institutional (e.g., mathematics teacher pedagogical skills), and intrapersonal (e.g., student perception of themselves in mathematics tasks) subscales predicted mathematics identity for Black girls in Grades 9–11. Using similar variables, but with mathematics teacher practices, Fernández et al. (2022) found that students' mathematics identity was influenced by their mathematics teachers' reform-oriented pedagogy (e.g., teaching connections between mathematics ideas and problem solving) and equitable practices (e.g., listening to students' ideas, treating students fairly and with respect). Alexander (2015) studied the relationship between mathematics self-efficacy and identity in students at Wave 1 and Wave 2 and determined that self-efficacy was positively related to identity. That is, students with higher self-efficacy in Grade 9 (Wave 1) reported higher mathematics identity around Grade 11 (Wave 2). Together, the findings from these studies suggest that teacher practices and student self-perceptions play important roles in determining students' mathematics identity.

STEM as a White, Cisheteropatriarchal Space

Leyva et al. (2022a, 2022b) conceptualized STEM education as a WCHPS. Within this WCHPS framework, three dimensions explain the dynamics at play in STEM education: *institutional*, *ideological*, and *relational*. The *institutional* dimension consists of all the organizational structures and barriers (e.g., policies, school climate) that produce unequal STEM access for minoritized students. The *ideological* dimension refers to the (in)visible norms (e.g., positivism) and behaviors prevalent in STEM spaces. The *relational* dimension refers to minoritized students' (re)actions to oppressive experiences in mathematics (e.g., coping strategies). We used this framework to better understand how QT high school students navigated mathematics as a WCHPS at a systemic level because mathematics identity is more individualistic. Existing research concerning school climate for QT students in STEM focused primarily on higher education (Brinkworth, 2016; Butterfield et al., 2018; Cech & Rothwell, 2018; Hughes, 2018; Leyva, 2016a, 2016b; Linley et al., 2018; Miller et al., 2021). Although these studies have been crucial in understanding the environments that QT students encountered once they arrived at a college or university, it is important to understand the contextual high school factors that played a role in STEM education for QT youth. Thus, the variables we used for the *institutional, ideological*, and *relational* dimensions enabled education scholars to better understand the disparities in the STEM pipeline at the intersection of race, gender identity, and sexual orientation. Coupled with our positionalities and regression analyses focused on a model per subgroup (i.e., queer, heterosexual, trans, cis), we actively chose to avoid the "gap-gazing" fetishization of minoritized groups (Gutiérrez, 2008) by not having a sexual orientation or gender identity reference group.

Methodology

The purpose of our study was to identify differences in mathematics educational experiences and perceptions between QT and HC students. Using mathematics identity and STEM as a WCHPS as our theoretical framework enabled us to better understand the dynamics of being a QT student in high school mathematics classrooms. In this section, we present our positionalities as QT researchers, the data used, sample, variables of interest, and our analytical strategy for each research question.

Researchers' Positionalities

As quantitative criticalists (Castillo & Gillborn, 2022; Gillborn et al., 2018; Stage, 2007; Strunk & Hoover, 2019), we assert that quantitative research can be a tool for social justice, as imperfect as it may be. We are a team of QT researchers at different levels of academic privilege (e.g., assistant/associate professor, doctoral candidates) and are all part of a collective known as Queer and Trans People in Education (QTPiE). Our QTPiE research team aims to educate, advocate for, and build coalitions that advance equitable policies and practices for QT people in education. The first author (Mario) is a Mexican American trans man (he/him/*él* pronouns) and a former high school mathematics teacher in Texas. As part of the QT community, he has experienced firsthand the effects of a chilly mathematics climate at his university, stopping short of a bachelor's degree in mathematics to instead get a bachelor's degree in ethnic studies. The pipeline to higher education and eventually a doctorate came not from STEM for him but from the learning he did in the humanities as a Mexican American studies undergraduate. The second author (Jay) is a White queer cisgender man (he/him/his pronouns) who has served primarily as a university administrator, with a secondary appointment as an associate professor of education. As a statistician and institutional researcher, he has witnessed firsthand the oppressive mathematics learning environments for students with minoritized identities. He is committed to promoting and cocreating liberatory educational experiences so that all feel affirmed and welcomed in mathematics, statistics, and education research. The third author (Dolan) is a White and Latinx, queer, nonbinary (they/them/*elle* pronouns) researcher committed to QT liberation and illuminating and challenging systems of domination in STEM. Their bachelor's degree is in mechanical engineering, and they subsequently taught STEM and robotics to elementary and middle-school girls after school. Their time in the engineering field, as a student and as a professional, was riddled with White supremacist and cisheteropatriarchal bias. After earning their master's degree in higher education and student affairs and working with QT students for 6 years, they earned their doctorate in educational leadership and policy studies. The last author (Musbah) identifies as queer, Muslim, and Middle Eastern (he/him pronouns). As someone who has often felt left out of learning complex statistical analysis despite having a background in the sciences, he is especially interested in promoting a more inclusive climate in STEM and mobilizing disruptive statistical approaches that work toward QT liberation. As QT researchers, we are committed to enhancing experiences and opportunities for QT students in mathematics education. Our scholarly pursuits are informed by our sexual, gender, and racial identities, recognizing the intersectional nature of experiencing homophobia, biphobia, transphobia, and racism in educational contexts.

Data Set

HSLS:09 is a restricted-access data set administered by the National Center for Education Statistics (NCES) to examine high school contexts related to broadening participation in STEM undergraduate education. HSLS:09 includes a nationally representative sample of high school students in the United States and is rich in data, with a robust research design. The study collected data from multiple sources, all involved with the student: parents, math and science teachers, administrators, and counselors.

HSLS:09 is remarkable regarding its inclusion of demographic variables in federal education surveys. In 2016, the U.S. government convened an interagency working group to begin addressing the dearth of data for sexual orientation in federal surveys (Federal Interagency Working Group on Improving Measurement of Sexual Orientation and Gender Identity in Federal Surveys, 2016). HSLS:09 became the first population-based longitudinal study within the U.S. Department of Education to include a demographic question to identify QT students in its 2016 data collection. This data collection marked the first time that NCES included a sexual orientation and expansive gender identity demographic question in the history of its longitudinal surveys. Yet there are still methodological flaws concerning who "counts" in education research, particularly when using federal data sets. We view this entanglement of methodological benefits and limitations as an opportunity to "forge challenges, illuminate conflict, and develop critique through quantitative methods in an effort to move theory, knowledge, and policy to a higher plane" (Stage, 2007, p. 8).

Sample

Data collection for HSLS:09 began in 2009 with a randomly selected group of approximately 24,000 Grade 9 students from across the United States (Ingels et al., 2011). NCES conducted additional HSLS:09 data collections in 2012 (follow-up; Ingels et al., 2013), 2013 (high school transcripts; Ingels et al., 2013), and 2016 (second follow-up; Duprey et al., 2018). HSLS:09 includes longitudinal data across students' high school and undergraduate educational experiences, which presents unique opportunities to explore differences in mathematics education by sexual orientation and/or gender identity.

To identify QT individuals, two separate variables are included in the HSLS:09 data set. Sexual orientation (S4ORIENTATION) was measured in the 2016 collection of the HSLS:09, almost 7 years since its initial collection. The question reads, "Do you think of yourself as lesbian or gay,

TABLE 1
Descriptive Statistics and Frequencies for Variables of Interest

Variables	*n*	*M*	*SD*	Min	Max
BY Scale of student's sense of school belonging	20,680	0.071	1.005	−4.35	1.59
BY Scale of administrator's assessment of school climate	19,900	−0.375	1.053	−4.22	1.97
BY 9th grader sees himself/herself as a math person	21,350	2.510	0.946	1	4
BY Others see 9th grader as a math person	21,180	2.530	0.910	1	4
BY Scale of student's mathematics self-efficacy	18,760	0.042	0.995	−2.92	1.62
BY Scale of student's interest in fall 2009 math course	18,390	0.036	0.991	−2.46	2.08
BY Scale of student's school engagement	20,900	0.055	0.987	−3.38	1.39
BY 9th grader is enjoying fall 2009 math course very much	19,080	2.760	0.835	1	4
BY 9th grader thinks fall 2009 math course is a waste of time	19,030	3.160	0.787	1	4
BY 9th grader thinks fall 2009 math course is useful for everyday life	18,930	2.870	0.825	1	4

Note. All sample sizes have been rounded to the nearest 10, per NCES guidelines; BY = Base Year.
Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009.

that is homosexual; straight, that is, heterosexual; bisexual; don't know," or; "another sexual orientation?" Gender identity (S4GENDERID) as a variable was created from the question "What is your gender? Your gender is how you feel inside and can be same or different than your biological or birth sex," where individuals chose between male; female; transgender, male-to-female; transgender, female-to-male; genderqueer or gender nonconforming, or some other gender; or unsure (Duprey et al., 2018). Using the responses to that question, gender identity was operationalized as male only; female only; transgender, genderqueer, or nonconforming; and/or unsure. To explore differences in mathematics identity and school climate, we created groups for queer (n = 1,530; 10%), heterosexual (n = 13,800; 90%), trans (n = 260; 1.70%), and cisgender students (n = 15,140; 98.3%). Table 1 shows a specific demographic breakdown for race/ethnicity and poverty level, in addition to summary statistics for the variables of interest. Per guidelines from the Institute of Education Sciences, all unweighted sample size numbers for HSLS:09 have been rounded to the nearest 10. We decided to split sexual orientation and gender identity into separate categories for several reasons. First, sexual orientation and gender identity are separate but sometimes related constructs (e.g., there may be gay trans men or lesbian trans women). Second, although they are related, we assert that anti-QT sentiment may be experienced differently, depending on one's sexual orientation and/or gender identity. We also realize that the effect of anti-QT systemic discrimination may be exacerbated for the mathematics identity of QT People of Color. For that reason, we chose to have separate models for each sexual orientation and gender identity, with race/ethnicity as a predictor.

We also note that we retrospectively assigned a Grade 9 student the identity of queer and/or trans based on how they identified in 2016, because sexual orientation and gender identity were not collected until the HSLS:09 second follow-up. We contest that regardless of a student's disclosure of their sexual orientation and/or gender identity, their experiences of systematic, institutional, and interpersonal oppression are relevant and worthy of consideration. Furthermore, the prevalence of sexual orientation and/or gender identity data in large-scale federal education data sets is nearly nonexistent, and we have taken it upon ourselves to use these data ethically and with consideration for impact and social change. For example, in our creation of the sexual orientation variable, we chose to categorize those who responded, "don't know" or "another sexual orientation" in addition to "lesbian or gay, that is, homosexual" and "bisexual" as queer. That decision was made because we understand that many young adults may not necessarily have the language to describe their sexual orientation but know that they do not identify as "straight, that is, heterosexual." We also chose to disaggregate queer and trans as separate groups, because even though gender identity and sexuality may be related, the impacts of school climate, especially in STEM, may be felt differently for queer and/or trans individuals.

The QT and HC student population was primarily White (50.26% and 55.45%, respectively). The full sample was primarily HC (89.60%), followed by queer and cis students (8.72%), queer and trans students (1.26%), and heterosexual and trans students (0.42%). The majority of the sample was at or above the poverty threshold (56.30%). Furthermore, the majority of the full sample was White, non-Hispanic (n = 12,260, 52.77%), with the next largest groups as Hispanic, race specified (n = 3,410, 14.68%); Black/African American, non-Hispanic (n = 2,650, 10.50%); Asian, non-Hispanic (n = 2,100, 9.02%); and more than one race, non-Hispanic (n = 1,950, 8.40%). Other races/ethnicities were much smaller: Hispanic, no race specified (n = 590, 2.54%); American Indian/Alaska Native, non-Hispanic (n = 170, 0.72%); and Native Hawaiian/Pacific Islander, non-Hispanic (n = 110, 0.47%).

Variables of Interest

To operationalize our theoretical framework, our study included variables that aligned with the dimensions of STEM as a WCHPS: institutional, ideological, and relational. See Table 1 for summary statistics of all the variables of interest and Appendix A for a summary of variable selection and operationalization. The institutional dimension was represented by latent constructs that aligned with the organization (i.e., perception of school sense of belonging, school climate). The ideological dimension was represented by items that aligned with the individual student behaviors that became internalized based on math norms (e.g., seeing themselves or being seen by others as a math person). Finally, the relational dimension was represented by items and/or latent constructs that resulted from oppressive (or lack of) math experiences (e.g., school engagement, liking math, seeing math as useful).

All variables used in this present study were collected during HSLS:09 Base Year in 2009, except for the outcome (*math identity*), which was in the second wave. A number of variables were latent constructs developed through principal components analysis by NCES ($M=0$, $SD=1$), including *math identity scale*, *school belonging scale*, *the administrator's assessment of school climate*, *math self-efficacy scale*, *scale of student's interest in fall 2009 math course*, and *scale of student's school engagement*.[2] Other variables were single-item constructs with Likert-type scales (1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly agree) focused on students' perceptions: *sees self as a math person*, *others see me as a math person*, *enjoys fall 2009 math course*, *thinks fall 2009 math course is a waste of time*, and *thinks fall 2009 math course is useful for everyday life*. Whenever a Likert-type scale was negatively worded, it was recoded to reflect a higher score with a positive experience. Face validity was used to align the HSLS:09 items to WCHPS framework dimensions—that is, the definition of each WCHPS framework dimension was used to identify the items that aligned with that dimension.

Data Analysis

Due to the limited prior research on mathematics education in high school by sexual orientation and/or gender identity, our study is exploratory in nature. To answer the first research question, we conducted separate multivariate analyses of variance (MANOVA) to comparatively explore differences in the dimensions of the WCHPS framework by sexual orientation and gender identity. Separate analyses were required rather than one all-encompassing analysis due to the separate but related nature of the constructs of sexual orientation and gender identity.

To answer the second research question, ordinary least squares (OLS) regression was used. Because school climate is a variable that was collected in the administrator base-year survey, we computed intraclass correlation (ICC) to confirm whether a multilevel model was necessary. Because the ICC was .028, we proceeded with OLS regression. Four separate models were created by using the dimensions of the WCHPS framework for queer, heterosexual, trans, and cisgender students separately. All coefficients were standardized for ease of interpretation. It is important to note that our regression analyses were of separate models for each subgroup of students for comparison purposes, in line with our quantitative criticalist lens, in part because HC groups are often used as reference groups, which we opted not to have to avoid what Gutiérrez (2008) referred to as "gap-gazing" in mathematics education by focusing only on achievement gaps. Moreover, variance inflation factor (VIF) was calculated to identify any issues with multicollinearity in each model. VIF values that were larger than 10 indicated likely issues with multicollinearity (James et al., 2013). Further, r-squared values were reported to show the percentage variance in the dependent variable that was attributed to the predictors in the model. Analytical weights were used in all cases, depending on the wave(s) analyzed. All statistical analyses were performed by using SPSS 29 (IBM Corp, 2022) and Stata 17 (StataCorp, 2021).

Limitations

This study had several limitations. As with all studies that use secondary data, our study was limited by the variables collected; in other words, there may have been more appropriate questions to ask that aligned with the WCHPS framework. Secondly, the categories used for sexual orientation and gender identity in the HSLS:09 may not necessarily reflect the spectrum of identities in the QT community. As noted earlier, retrospectively assigning a sexual orientation and/or gender identity to a Grade 9 student who may or may not have been "out of the closet" might have complicated the analyses, although we assert that the effect of cisheterosexism was still there, for queer and/or trans students, and for cisgender and/or heterosexual students. That is, just because a queer student may not have been "out" as queer in Grade 9 does not mean they did not have anti-queer institutional, ideological, and relational dimensional experiences. Best-case scenario would have been to longitudinally measure sexuality and gender identity from the base-year collection in 2009, although that information was not collected until 2016.

Results

Were There Differences in Mathematics Identity–Related Experiences and Perceptions (i.e., Dimensions of the STEM as a White Cisheteropatriarchal Space) by Sexual Orientation and Gender Identity in High School Students?

Table 2 summarizes means, standard deviations, and MANOVA results for all the WCHPS dimensions by sexual orientation, including *eta* effect sizes. Significant differences

TABLE 2

Means, Standard Deviations, and Multivariate ANOVA Statistics for Variables of Interest, by Sexual Orientation

Variable	Hetero (n=7,850)		Queer (n=850)					
	M	SD	M	SD	F ratio	df	η^2	p value
BY Scale of student's sense of school belonging	0.065	0.011	−0.238	0.033	73.854	1	0.008	**<.001**
BY Scale of administrator's assessment of school climate	−0.510	0.012	−0.587	0.035	4.311	1	0	**0.038**
BY 9th grader sees himself/herself as a math person	2.536	0.011	2.471	0.032	3.739	1	0	**0.053**
BY Others see 9th grader as a math person	2.561	0.010	2.528	0.030	1.104	1	0	0.293
BY Scale of student's mathematics self-efficacy	0.062	0.011	0.043	0.033	0.298	1	0	0.585
BY Scale of student's interest in fall 2009 math course	0.040	0.011	−0.068	0.033	9.774	1	0.001	**0.002**
BY Scale of student's school engagement	0.069	0.011	−0.006	0.032	4.825	1	0.001	**0.028**
BY 9th grader is enjoying fall 2009 math course very much	2.767	0.009	2.707	0.028	4.085	1	0	**0.043**
BY 9th grader thinks fall 2009 math course is not a waste of time	3.173	0.009	3.111	0.026	4.979	1	0.001	**0.026**
BY 9th grader thinks fall 2009 math course is useful for everyday life	2.877	0.009	2.860	0.027	0.337	1	0	0.562

Note. All sample sizes have been rounded to the nearest 10, per NCES guidelines; BY = Base Year.
P-values less than .05 in bold.
Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009.

TABLE 3

Means, Standard Deviations, and Multivariate ANOVA Statistics for Variables of Interest, by Gender Identity

Variable	Cisgender (n=8,580)		Transgender (n=130)					
	M	SD	M	SD	F ratio	df	η^2	p value
BY Scale of student's sense of school belonging	0.037	14.444	−0.263	15.751	12.129	1	0.001	**<.001**
BY Scale of administrator's assessment of school climate	−0.517	14.958	−0.539	15.376	0.061	1	0	0.804
BY 9th grader sees himself/herself as a math person	2.530	13.552	2.160	14.691	22.021	1	0.003	**<.001**
BY Others see 9th grader as a math person	2.560	12.820	2.240	14.465	17.685	1	0.002	**<.001**
BY Scale of student's mathematics self-efficacy	0.059	14.096	0.033	15.100	0.101	1	0	0.751
BY Scale of student's interest in fall 2009 math course	0.034	14.176	−0.265	14.030	12.533	1	0.001	**<.001**
BY Scale of student's school engagement	0.061	14.020	−0.055	12.334	1.952	1	0	0.162
BY 9th grader is enjoying fall 2009 math course very much	2.770	11.947	2.500	14.025	14.037	1	0.002	**<.001**
BY 9th grader thinks fall 2009 math course is not a waste of time	3.170	11.241	3.170	11.582	0.001	1	0	0.972
BY 9th grader thinks fall 2009 math course is useful for everyday life	2.880	11.787	2.660	13.284	9.616	1	0.001	**0.002**

Note. All sample sizes have been rounded to the nearest 10, per NCES guidelines.
P-values less than .05 in bold.
Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009.

emerged with all the variables, except for others seeing the Grade 9 student as a math person, Grade 9 mathematics self-efficacy, and the Grade 9 student thinking of their fall mathematics course as useful for everyday life. Queer students had significantly lower scores for sense of school belonging, school climate, seeing themselves as a math person, interest in math course, school engagement, enjoying math course, and thinking that math course was not a waste of time.

Table 3 summarizes means, standard deviations, and MANOVA results for all the WCHPS dimensions by gender identity, including *eta* effect sizes. Significant differences emerged with all the variables, except for the administrator's assessment of school climate, Grade 9 mathematics self-efficacy, student's school engagement, and the Grade 9 student thinking that their fall mathematics course was not a waste of time. Trans students had significantly lower scores for sense of school belonging, seeing themselves as a math person, others seeing them as a math person, interest in math course, enjoying math course, and thinking that math course was useful for everyday life.

TABLE 4

Standardized Regression Results of Associations Between Race/Ethnicity, WCHPS Dimensions at Wave 1 and Mathematics Identity at Wave 2, by Sexual Orientation and Gender Identity

	Queer	Hetero	Trans	Cis
Variables of interest	β (SE)	β (SE)	β (SE)	β (SE)
Student's race/ethnicity [ref = White]				
American Indian/Alaska Native, NH	0.039	0.009		0.012
	(0.357)	(0.139)		(0.128)
Asian/Native Hawaiian/Pac Islander, NH	0.063*	0.041***	0.359***	0.035***
	(0.151)	(0.047)	(0.318)	(0.045)
Black/African American, NH	−0.001	0.013	0.010	0.009
	(0.101)	(0.032)	(0.251)	(0.030)
Hispanic	−0.021	−0.002	0.112	−0.003
	(0.083)	(0.025)	(0.363)	(0.024)
More than one race, NH	0.012	−0.004	0.017	−0.007
	(0.091)	(0.039)	(0.242)	(0.035)
Institutional				
BY Scale of student's sense of school belonging	−0.022	−0.040***	−0.195*	−0.033**
	(0.030)	(0.011)	(0.095)	(0.010)
BY Scale of administrator's assessment of school climate	0.043	0.015	0.082	0.018*
	(0.029)	(0.009)	(0.079)	(0.009)
Ideological				
BY 9th grader sees himself/herself as a math person	0.340***	0.338***	0.097	0.344***
	(0.047)	(0.016)	(0.128)	(0.015)
BY Others see 9th grader as a math person	0.168***	0.168***	0.145	0.167***
	(0.047)	(0.016)	(0.130)	(0.015)
BY Scale of student's mathematics self-efficacy	0.072	0.101***	0.291**	0.089***
	(0.037)	(0.013)	(0.095)	(0.012)
BY Scale of student's interest in fall 2009 math course	0.244**	0.247***	0.346	0.245***
	(0.082)	(0.026)	(0.272)	(0.025)
Relational				
BY Scale of student's school engagement	0.067*	0.029**	0.226**	0.030**
	(0.035)	(0.011)	(0.111)	(0.010)
BY Enjoys fall 2009 math course very much	−0.194**	−0.144***	−0.452*	−0.141***
	(0.076)	(0.024)	(0.219)	(0.023)
BY Thinks fall 2009 math course is not a waste of time	−0.046	−0.095***	−0.070	−0.095***
	(0.057)	(0.019)	(0.150)	(0.018)
BY Thinks fall 2009 math course is useful for everyday life	−0.059	−0.013	0.211*	−0.019
	(0.041)	(0.013)	(0.101)	(0.012)
Observations	830	7680	130	8410
VIF	2.38	2.06	3.00	2.08
R squared	0.329	0.339	0.444	0.338

Note. Standard errors are in parentheses; all sample sizes have been rounded to the nearest 10, per NCES guidelines. NH = Non-Hispanic.
Source. U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009.
$*p < 0.05$. $**p < 0.01$. $***p < 0.001$.

To What Extent Did the Dimensions of the STEM as a White Cisheteropatriarchal Space Predict Mathematics Identity in High School Students From Grade 9 (Wave 1) to Grade 11 (Wave 2), by Sexual Orientation and Gender Identity?

Table 4 summarizes the OLS regression results for the WCHPS dimensions in Grade 9 (Wave 1) predicting students' mathematics identity in Grade 11 (Wave 2), by sexual orientation and gender identity. Findings from the queer students' model show that Asian/Native Hawaiian/ Pacific Islander (ANHPI) queer students reported higher math identity in Grade 11 compared to queer White students. None of the institutional dimensions from Grade 9 were found to be significantly associated with queer students' math identity in Grade 11. Additionally, all the ideological dimensions from Grade 9 showed significant positive associations for queer students' math identity in Grade 11, except for math self-efficacy, which was not significant. Finally, two relational variables were found to be significant for queer students: A higher score for school engagement in Grade 9 was associated with higher math identity in Grade 11, while enjoyment of the math course in Grade 9 was negatively associated with math identity. The variables in the model accounted for almost 33% of the variance in queer students' Grade 11 math identity.

When compared to heterosexual students, ANHPI queer students showed a larger effect size for math identity at Wave 2. Within the institutional dimension, queer students' sense of belonging was higher than that of heterosexual students, although not significant. Concerning the ideological dimension, heterosexual students showed a larger effect size for math identity at Wave 2 compared to queer students for seeing themselves as a math person, others seeing them as a math person, math self-efficacy, and interest in Grade 9 math courses. Referencing the relational dimension, queer students reported having a higher math identity in Grade 11 and higher levels of school engagement compared to heterosexual students, while heterosexual students reported higher levels of math identity when they enjoyed their math course and when they thought that it was not a waste of time. That said, queer students reported having a higher math identity for thinking that their Grade 9 math course was not a waste of time than heterosexual students, although it was not significant.

Findings from the trans students' model show that ANHPI trans students had a higher math identity in Grade 11 compared to trans White students. With regard to the institutional dimension, a higher sense of school belonging in Grade 9 was associated with a lower math identity in Grade 11. Moreover, within the ideological dimension, higher scores for math self-efficacy in Grade 9 were related to higher math identity in Grade 11. Lastly, three relational variables were found to be significant for trans students: A higher sense of school engagement and thinking that their Grade 9 math course was useful for everyday life were associated with a higher math identity in Grade 11, and enjoyment of math course was related to a lower math identity. The variables in the model accounted for almost 44% of the variance in trans students' Grade 11 math identity.

When compared to cisgender students, ANHPI trans students showed a much larger effect size for math identity at Wave 2 than cis students. Within the institutional dimension, trans students reported a higher math identity with higher levels of sense of belonging and school climate than cis students, although school climate was not significant. With respect to the ideological dimension, cisgender students showed a higher math identity in Grade 11 when they saw themselves as a math person or others saw them as a math person, and with higher interest in their Grade 9 math course, compared to trans students. However, trans students showed a higher math identity in Grade 11, with higher levels of math self-efficacy, compared to cis students. Finally, regarding the relational dimension, trans students reported a higher math identity than cis students when they were more engaged in school, when they thought that Grade 9 math was useful for everyday life, and when they thought that their Grade 9 math course was not a waste of time. However, the latter was not significant.

Discussion

The present study showed through representative and longitudinal data that the mathematics educational landscape for QT students was very challenging and that the WCHPS framework was useful to operationalize and situate QT students' math identity. In this section, we summarize some of the most notable findings with regard to QT students' math identities during Wave 2 of HSLS:09.

We discovered that queer students reported a significantly lower sense of belonging, that their administrator reported lower levels of school climate, and that they were less likely to see themselves as a math person, were less likely to be interested in their Grade 9 math course, had lower levels of school engagement, and were less likely to enjoy Grade 9 math and think that it was not a waste of time. Results were very similar for trans students' math identity. In other words, strong institutional and relational dimensions of WCHPS were associated with higher levels of math identity. This finding is noteworthy, as this study showed evidence that ideology (the self) might not be significantly related to students' math identity, placing greater emphasis on the systemic issues in mathematics. Overall, these findings align with and support others' empirical findings from smaller-scale STEM studies (e.g., Barthelemy et al., 2022; Freeman, 2018; Hughes, 2018; Kosciw et al., 2022; Miller et al., 2021) that together may explain why the STEM pipeline for QT students has not widened. Past research has shown that a sense of belonging can be a significant predictor of grades and retention (Cwik & Singh, 2022; Van Canegem et al., 2022), particularly for minoritized students (Gummadam et al., 2016; Sánchez et al., 2005). Specifically, Gummadam et al. (2016) found that a strong ethnic identity (and, in our case, sexual orientation and/or gender identity) was associated with strong self-worth when a sense of belonging was not present or addressed.

Findings from the regression analyses highlight the roles that the ideological and relational dimensions of the WCHPS played in QT students' math identities in Grade 11. School engagement shows great promise for QT students' math identity, as they showed the highest levels of math identity when they reported higher levels of school engagement. This result could be attributed to a student's greater sense of internal identity and pride that may have then been reflected in an increase in school engagement. Other research has shown increased school engagement with positive ethnic identity (e.g., Jones et al., 2017; Shin et al., 2007).

Additionally, this finding is meaningful because school engagement and social connectedness have been shown to be predictors of academic achievement and student well-being (Chase et al., 2014; Dotterer & Lowe, 2011; Garcia et al., 2020; Wong et al., 2024). Another noteworthy finding is that of trans students' positive relationship between math identity in Wave 2 and their perception that their Grade 9 math course was useful for everyday life, which was not significant for any of the other groups. It is possible that this result could be attributed to the societal attempt to invalidate trans identities, and thus, if trans students see utility to everyday life in math, they may perceive it as math "seeing" them. Regardless, this finding is interesting and merits further research, although past work has shown that finding utility in courses improves one's attitude toward that discipline (George, 2003) and that there is a positive causal relationship between one's attitude in mathematics and one's achievement in mathematics (Ma & Kishor, 1997). Finally, ANHPI QT students had the highest math identity ratings in Grade 11, not only compared to their White counterparts but across the board compared to their HC counterparts. Positive effects were found across all ANHPI sexual and gender identities, although they were larger for QT students. Although research has shown that many Asian students feel pressured to meet the "model minority" stereotype in mathematics (McGee et al, 2017), this case may warrant further study, as there may be specific cultural aspects for ANHPI students that teachers could use to help foster math identity for all QT students. We also recognize that this study did not disaggregate this group further and that there may have been intra-AHNPI differences not captured by collapsing everyone in this category. Future research in this area may want to look for differences within this population as well as push back on the "model minority" myth that may further stereotype AHNPI students.

Furthermore, of the three WCHPS dimensions, institutional dimension had interesting findings for trans students. Specifically, a higher sense of belonging in Grade 9 was related to lower math identity in Grade 11. This finding is counterintuitive to what one would expect with regard to the culture and policies of the school. However, it could be that hypervisiblity with regard to sense of belonging may be negatively affecting trans students. There were some interesting findings within the ideological dimension, mostly for queer students. In particular, there were positive associations between the Grade 9 student seeing themselves as a math person, others seeing them as a math person, and interest in Grade 9 math courses and their math identity in Grade 11. However, of the ideological dimension variables, only Grade 9 mathematics self-efficacy was significant for trans students. The findings from this dimension show that the norms and behaviors prevalent in mathematics had a positive impact on QT students' math identity. Thus, if teachers are not explicitly teaching these norms to QT students, they should consider doing so. Lastly, the relational dimension of the WCHPS showed how QT students' school engagement could improve math identity and how finding real-world connections to their Grade 9 math course could relate to an increase in trans students' math identity in Grade 11, while enjoyment of that course may do the opposite. Mathematics is a discipline that historically has alienated QT and other minoritized students, as we presented in the literature review. However, finding joy in real-world applicability and engagement seems to counteract the effect of math as a "joyless" discipline, which could be influencing QT students more than their HC counterparts. In part, we think that this result could be attributed to, as the WCHPS framework explains, the notion that mathematics was created by and for HC individuals. Therefore, HC students might not have a need for it because they would have a strong math identity in any space because that is what it was *designed* to do. Overall, QT students seemed to be thriving in specific areas related to the WCHPS with regard to their math identity in Grade 11, which is a narrative not seen in the literature that should be explored further. As QT students are less likely to matriculate into STEM disciplines in college (Hughes, 2018), the fact that their math identity was higher than cishet students in some areas tells us that there are potentially systemic issues between Grades 9 and 12 with continuing QT students' joy in math that merit further research. We see this challenge as systemic and necessitating a cultural shift in mathematics from that of a positivist, objective field that is cisnormative (Leyva et al., 2022a, 2022b) to one with a more welcoming environment for anyone who does not meet the normative expectations of a "STEM person."

Rather than making suggestions that put the onus of responsibility on the student (the ideological dimension), these findings are indicative of the larger systemic inequities that others in STEM have largely written about (the institutional and relational dimensions). One of the biggest strengths of this study is that due to the nature of the HSLS:09, results from this work are generalizable and can be used to inform research, policy, and practice. This study also served as a large-scale generalizable study that supported Leyva et al.'s (2022a, 2022b) theoretical framework of STEM as a WCHPS. To transform STEM from being a normative WCHPS, researchers, teachers, and practitioners must remember to address the multiple dimensions: institutional, ideological, and relational (Leyva et al., 2022a, 2022b). QT-affirming policies and school climates would address the institutional dimension, keeping in mind that sense of belonging may need to be reevaluated for QT students to look differently. Ideologically, math leaders must work to dispel and disband invisible norms, such as positivist assumptions in math or what a math person "looks" like, to be more welcoming to QT students and show that QT students can be "math people" just as they are, without having to sacrifice their sexual orientation and/or gender identity (i.e., disidentify; Bilimoria & Stewart, 2009; Cooper et al., 2019; Kersey & Voigt, 2021). Finally, administrators and teachers must be ready to understand minoritized students' oppressive experiences in mathematics and work alongside their students to prevent and address harm.

Although exploratory, this present study gave a first look at the landscape that is beginning to shape QT students' mathematical experiences and, consequently, their pipeline into STEM. We have many questions, potential analyses, and routes for future research that we plan to explore with this longitudinal data set that we were unable to fit into this manuscript. A suggestive next step in future research could look at the predictive capacity of math identity on STEM retention in high school, high school graduation, and STEM enrollment in college. Additionally, we applaud NCES and the Department of Education for exploring possibilities for sexual orientation and gender identity data collection in their population-based surveys, as this information has the potential to expand a knowledge base that had not been investigated before the release of the second follow-up wave of the HSLS:09. We also advocate for NCES and other federal agencies either beginning or continuing to collect sexual orientation and gender identity (SOGI) data in their surveys.

Implications for Practice

This study's findings have extensive implications for K–12 educators, administrators, and school counselors. These practitioners must work together and recognize the connections between K–12 math identity and the WCHPS dimensions. As we found, the institutional and relational dimensions were significant in our results, which practitioners have the ability to influence.

First, math educators (and all educators) are on the frontlines in the classroom and are able to have a more direct impact on their QT students, whether they are "out" or not. In particular, math educators have an ability to influence math utility, self-efficacy, and math identity through the classroom environment they create and the pedagogical approaches they use to teach and develop mathematics curricula that may help QT students see themselves reflected in the field. Administrators should be aware of the general climate with regard to QT students in their schools and should consider how the school environment could signal inclusion and a sense of belonging to QT students. Adults who work with students have a unique opportunity to help them develop their math identity by contributing to the recognition of their sense of self as a math person through others seeing them as a math person. Counselors may not be aware of QT students in the student body, which complicates their ability to support these students. That said, steps should be taken to create a welcoming and inclusive school climate for all students and to debunk misconceptions about who is able to pursue a STEM field and who is excluded. One of the key contributions of this study and Leyva's WCHPS framework is that we can operationalize what a supportive math *space* (emphasis on *space* from the WCHPS) that fosters a positive math identity can look like into observable constructs.

Related to climate is the role of federal and state legislative attacks on QT people in creating a hostile community for QT high schoolers. Banning QT books, histories, topics, and discussions will only exacerbate the inability of schools to be safe and welcoming havens for QT students. The effects of legislative attacks on QT issues will only exacerbate the preexisting lack of belonging that QT students experience and will eventually trickle down to how they perceive themselves as STEM people and whether they choose to pursue STEM education in high school and beyond. Counselors and administrators also have an opportunity to advocate at the district level for the development of policies for interventions that increase sense of belonging and against policies that harm QT youth, such as Florida's "Don't Say Gay" bill (Diaz, 2022) and Kentucky's Senate Bill 150 (HRC Staff, 2023), which prohibit teachers from creating inclusive and welcoming spaces for QT students.

Conclusion

The present study explored whether differences in mathematics identity-related experiences, perceptions, and WCHPS dimensions existed for high school students by sexual orientation and gender. We found that QT students' WCHPS dimensions were lower than their HC counterparts. Education researchers know relatively little about QT students in mathematics education due to the lack of data on sexual orientation in population-based education surveys. To our knowledge, this study is the first quantitative review in mathematics education with such a large QT sample that was examined longitudinally in Grades 9 and 11. Although more work is needed, this study explored the landscape in high school mathematics for QT students, with the goal of beginning a much larger and longer conversation in the field about ways to use quantitative data collection to investigate QT educational experiences.

APPENDIX A

Variable Overview

Variable	Coding scheme	Wave
Scale of student's mathematics identity	Latent construct developed through principal components factor analysis; $M=0$, $SD=1$	BY, U
Institutional		
Scale of student's sense of school belonging	Latent construct developed through principal components factor analysis; $M=0$, $SD=1$	BY
Scale of administrator's assessment of school climate	Latent construct developed through principal components factor analysis; $M=0$, $SD=1$	BY
Ideological		
9th grader sees himself/herself as a math person	1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly agree	BY
Others see 9th grader as a math person	1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly agree	BY
Scale of student's mathematics self-efficacy	Latent construct developed through principal components factor analysis; $M=0$, $SD=1$	BY
Scale of student's interest in fall 2009 math course	Latent construct developed through principal components factor analysis; $M=0$, $SD=1$	BY
Relational		
Scale of student's school engagement	Latent construct developed through principal components factor analysis; $M=0$, $SD=1$	BY
9th grader is enjoying fall 2009 math course very much	1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly agree	BY
9th grader thinks fall 2009 math course is a waste of time	1 = Strongly agree, 2 = Agree, 3 = Disagree, 4 = Strongly disagree	BY
9th grader thinks fall 2009 math course is useful for everyday life	1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly agree	BY

Note. BY = base year; U = 2013 Update.
Source. U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009.

Acknowledgments

We have no known conflict of interest to disclose. We would like to thank Dr. Kim Wright and Dr. Colby Tofel-Grehl for feedback on ideas from this manuscript. We would also like to thank the reviewers for their thoughtful and constructive feedback.

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Notes

1. *Queer* and *trans* as terms tend to be used as umbrella terms for sexual orientation and gender identity subgroups outside heterosexual and cisgender identification. As such, we also acknowledge the political beginnings of the term that served to "unsettle the complacency of 'lesbian and gay studies'" (Halperin, 2003, p. 340). We define *queer* as an umbrella term for sexual orientation that encompasses all sexual orientations outside heterosexuality. We define *trans* as an umbrella term for gender identity that encompasses all gender identities that do not align with their medically assigned sex at birth. Later, we address its operationalization in this study due to the limitations of secondary data collection and the categories used in HSLS:09. Additionally, we use the terms *transgender* and *trans* interchangeably, as well as *cisgender* and *cis*.

2. The following scales are latent constructs created from items in the HSLS:09 survey by the developers of the instrument: math-identity scale, school-belonging scale, the administrator's assessment of school climate, math self-efficacy scale, and scale of student's school engagement. For further information, see Section 5.5.1 in the Base-Year Data File Documentation at https://nces.ed.gov/surveys/hsls09/pdf/2011328_1.pdf (Ingels et al., 2011).

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