Calculating Queer Acceptance and Visibility:

A Literature Synthesis on Queer Identity in Mathematics

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Abstract

Research, programs, and policies to support queer students in secondary mathematics environments remain largely underdeveloped and undertheorized. Mathematics education research has attended more closely to how race and gender are linked with dominant discourses of participation and mathematical performance. In this synthesis, we conducted a broad search of literature, resulting in 81 articles, related to queer student experience in all STEM environments to highlight potential practices to support inclusive environments specifically in secondary mathematics. Drawing on a queer stem identity framework (Mattheis, Arellano, Yoder, 2019) we highlight the unique nature of queer identity (e.g., the potential for one's queer identity to be invisible) that positions queerness as unseen and irrelevant to the pursuit of STEM. The perceived masculine and heteronormative nature of mathematics environment impacts queer students when defining their queer identity and coming out in the classroom, creating a cognitively stressful experience, and leading to less robust mathematical identity formation. In order to help promote queer students in navigating these settings we document how role models and curriculum allow for a reconstruction of the nature and mathematics by promoting a connected, inclusive, and social discipline. We conclude by highlighting the need for future studies and implications for practices in order to create environments that promote the development and visibility of queer mathematics students.

Keywords: Queer Identity, LGBTQ, STEM, Secondary Mathematics

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There is a growing and established body of literature documenting the differential experiences and outcomes for minoritized students in mathematics. While more is known about the experiences of women (Ceci & Williams, 2011; Friedman, 1989; Legewie & DiPrete, 2014; Lindberg, Hyde, Petersen, & Linn, 2010; Solomon, 2007) and students of color (McGee, 2015; Leyva, 2016; Martin, 2009), less is known about the mathematical experiences of students with a minoritized sexual identity. By minoritized sexual identity we mean students who identify as lesbian, gay, bisexual, transgender, two-spirit, intersex, pansexual or in other ways queer because of their sexual identity or non-cisgendered identity (Kumashiro, 2001). In this synthesis, we use the term "queer" to broadly refer to students with a minoritized sexual identity. The choice of the term queer is purposeful as it represents a political statement in terms of reclaiming the transgressive nature of the word queer, a term which has historically been used to denigrate individuals in society (Brontsema, 2004; Rocheleau, 2019). Additionally, the term queer serves as a mechanism to coalesce among the many different queer identities (e.g., bisexual, lesbian, pansexual) to understand their shared experiences in mathematics while also recognizing that there are differences and fluidity among these identities. For this reason, we avoid using acronyms (LGBTQ) to discuss issues for sexual minoritized students as these can imply rigid boundaries between the identities while also suggesting that they represent the totality of sexual identities.

Due in part to the limited research on the experiences of queer students in mathematics, there has been a growing interest to understand and support queer students broadly within the field of mathematics education. For instance, several professional societies are starting to form committees and create recommendations for supporting queer people in Science, Technology, Engineering and Mathematics fields. See for example the American Astronomical Society Working Group on LGBTIQ

Equity, Mathematical Association of America Committee for the Advancement of LGBTQIA+ Inclusion in the RUME Community, American Society for Engineering Education's LGBTQ+ Advocacy in STEM Virtual Community of Practice, and the American Chemical Society Division of Professional Relations Gay & Transgender Chemists & Allies Subdivision. Additionally, some schools and universities are advocating for the collection of sexual identity information in order to include queer people in the analysis of academic and STEM outcomes (Freeman, Romero, & Durso, 2018; Gordon, 2012; Langin, 2018). Collecting such data can help promote visibility and further support research on queer student experiences. Such efforts highlight the need to examine the experiences of queer students in mathematics yet there exists a dearth of research studies examining the localized context of mathematics environments for queer students. As such, this synthesis seeks to answer the following guiding research topic: *What are the experiences of queer students in mathematics environments and what are the factors that help contribute to inclusive mathematics environments for queer students?*

To address this research topic, we leverage a sociopolitical lens, which foregrounds cultural processes associated with learning, including the political nature of those interactions as influenced by power and identity. Taking such a view allows one to interrogate and disrupt taken-for-granted rules and ways of operating that have historically privileged some individuals and marginalized others. As such, we first situate our research question within existing literature documenting the ways in which racialized, gendered and disabled identities have historically been oppressed in mathematics. These acts of oppression marginalize identities by associating them with poor academic performance and exclusion in mathematical spaces; however, as we will discuss queer identities resist such associations in mathematics due in part to the less visible nature of sexualized identities. Instead queer identities are marginalized through power structures that view sexual identity as irrelevant and invisible in mathematics. We then interrogate these power structures, by drawing on a queer STEM identity framework to structure our synthesis examining queer students' experiences in mathematics

environments. Throughout the analysis we highlight practices to mitigate these exclusionary power structures to support inclusive mathematical environments for queer students. In the final section of this synthesis we discuss implications for future research and practice.

Theoretical Framing

Oppression in Mathematics Education

The common view of mathematics, held both by mathematicians and in popular culture, is that mathematics is culture-free, neutral, timeless, and objective (Martin, Gholson, & Leonard, 2010; Nasir, Hand, & Taylor, 2008). This Platonic view of mathematics as perfect owes its origins to western philosophy in ancient Greece (Dancy, 2004). However, numerous scholars have problematized this view, by elucidating the close link between mathematics and culture (Gutiérrez, 2009; Nasir et al., 2008) and the evolution of mathematics over history (P. Ernest, 1992). From this perspective, mathematics is a human creation that cannot be removed from its social and historical context. In fact, the positioning of mathematics as neutral and objective is one of the ways that mathematics has been weaponized to support oppression, and this idea is used as a justification for the differential outcomes for students with marginalized identities.

Mathematics has been socially and historically constructed to be equated with intelligence or brilliance (Leslie, Cimpian, Meyer, & Freeland, 2015; Shah, 2017). In this way, doing well in mathematics classes is seen as equivalent to “being smart.” Moreover, success in math is often considered as an innate characteristic (Gunderson, Hamdan, Sorhagen, & D’Esterre, 2017). Yet success on standardized mathematics exams are known to highly correlate with racial (Mickelson, 2006), and gender privilege (Nankervis, 2011). In this way, mathematics is used to legitimize and perpetuate inequity, because standardized tests convert or sanction privilege into “intelligence.” Equating mathematics with intelligence has a longstanding racist and ableist history in its use with IQ testing, which was used to “prove” the inferiority of some populations (Persell, 1981). In this way, the discipline of mathematics has

been used to further oppressive endeavors throughout much of history by associating lower mathematical performance with minoritized identities (Shah, 2019). Thus, mathematics is used to help create the illusion of a meritocracy, based on objective measures of intelligence, however, mathematical performance is often conflated and influenced by privilege.

Scholars of race in mathematics education have drawn attention to the ways that mathematics education has been used as a tool of racist oppression (Martin, 2019; Miles, Buenrostro, Marshall, Adams, & McGee, 2019). For instance, racist narratives around mathematics ability position some racial groups as more mathematically competent than others (Joseph, Hailu, & Boston, 2017; Larnell, Boston, & Bragelman, 2014; Shah, 2017). This is made possible in part because racialized identities are made visible in social interactions, which allows them to be targeted and linked with mathematical performance. When the view that mathematics ability is innate is combined with the notion that mathematics performance is tantamount to intelligence, it supports the racist enterprise of creating a social hierarchy based on race. These racist narratives play out in structural policies regarding behavioral discipline (Carter, Skiba, Arredondo, & Pollock, 2017; Gregory, Skiba, & Noguera, 2010) and academic tracking (Oakes, 2005). They also play out at the level of classroom interactions since visible racialized identities can be impacted, through implicit bias (Staats, Capatosto, Tenney, & Mamo, 2017), microaggressions (McCabe, 2009; Suárez-Orozco et al., 2015), and inequitable opportunities to learn (J. B. Ernest, Reinholz, & Shah, 2019; McAfee, 2014; Sadker, & Zittleman, 2009). In this context, minoritized students of color must navigate a hostile system in order to succeed in mathematics and to construct meaningful identities as mathematicians.

Scholars of gender in mathematics education highlight the influence of patriarchy and sexism in mathematics education (Mendick, 2005; Y. Solomon, 2007; Y. Solomon & Croft, 2016). In particular, mathematics is a discipline that has been constructed as largely masculine, and historically cisgender[3]

[3] Cisgender is a term for individuals whose gender identity matches the sex that they were assigned at birth.

women have been excluded from mathematics (e.g., by being denied access to higher education; B. M. Solomon, 1985) and have been positioned as biologically inferior (Leyva, 2017). This sexist history has helped lead to a modern-day environment that can be implicitly and explicitly hostile towards visible gendered identities in mathematics (J. B. Ernest et al., 2019). This sexism manifests in the expectations that teachers have for their students (Robinson-Cimpian, Lubienski, Ganley, & Copur-Gencturk, 2014), the transference of math anxiety to young girls (Beilock, Gunderson, Ramirez, & Levine, 2010), how teachers make opportunities to learn available (Sadker & Zittleman, 2009), and in sexist interpersonal interactions in math classes (J. B. Ernest et al., 2019). As with minoritized racial groups, this creates explicit barriers to success and identity development for cisgender women (Y. Solomon, Lawson, & Croft, 2011).

Ableism is also prevalent in mathematics and serves to convey messages about which identities and bodies belong in mathematical environments. From an ableist worldview, there is a particular standard for a "normal" person that is seen as fully human, and any individual who falls short of that able-bodied standard is viewed as deficient in some way (Campbell, 2001). This contrasts with a critical perspective, which instead recognizes that dis/ability can be seen as a mismatch between an individual and a particular context. For instance, when a learning environment fails to provide appropriate supports to meet an individual's particular needs (Borgioli, 2008). The very notion of "normalized" bodies in mathematics raises one's awareness to the ways in which our bodies and the way they are perceived by others is part of the social milieu of learning (Mendick, 2014). Specifically, it highlights how such identities can be made visible to others through interactions and thus targeted for exclusion. The ways in which dis/ability status emerge through social interactions draw parallels with queer identity that depending on the context might not be readily apparent to others. The prevalence of ableism in mathematics is evident when one considers the general lack of support made available for students with dis/abilities to engage meaningfully with mathematics (Padilla & Tan, 2019).

As the above research highlights, a normative mathematics subject identity has been constructed in society, and this subject is typically a white, able-bodied cis-gendered man. When one deviates from that normative subject identity there are often oppressive structures that limit the development of one's mathematical identity. This is often compounded when we consider individuals with multiple marginalized identities who face additional and unique barriers (e.g., dis/abled women of color) in mathematics (Collins, 2015). The construction of a normative subject identity is particularly pernicious, because mathematics has also been afforded a special status in society as objective and equated with intelligence. Taken together, these constructions have been used to further white supremacist, patriarchal, and ableist forms of oppression in society. Such constructions are made possible because racialized, gendered and able-bodied identities are made visible in the social milieu of the mathematics classroom. As we argue in this synthesis, there are similar oppressive structures towards queer students to further heteronormativity and to marginalize queer students in mathematics, yet these structures are enacted differently since sexualized identities are less visible to be targeted in the social milieu of the classroom. To organize our work and highlight the existing power structures, we draw upon a queer STEM identity framework developed by Mattheis, Arellano and Yoder (2019). Utilizing such a framework allows for the interrogation and unpacking of power structures that impact the development of queer STEM identity development in mathematics environments.

Queer STEM Identity Framework

We draw on the queer STEM identity framework (Mattheis, Arellano, Yoder, 2019) to understand the power structures and experiences of queer students in mathematics environments. This framework was initially developed to understand how individuals working in STEM fields navigate personal and professional identities. It was developed through a synthesis of literature on queer identity development and STEM professional identity development. The queer identity literature draws attention to a number of important and unique issues experience of queer individuals, including: the

significance of "coming out" as an event (Eliason, 1996; D'Augelli, 1994), the potential fluidity of gender and sexual identities (Katz-Wise, 2015; Russell, Clark, & Clary, 2009), the importance of intersectionality with other identities (Brockenbrough, 2015), and the potential issues with conflating gender identity and sexual orientation in a single umbrella category (Galupo, Davies, Grynkiewicz, & Mitchell, 2014). These theories draw attention to the unique identity development issues for queer students in STEM that are not necessarily experienced by other minoritized groups. These theories were then combined with STEM professional identity development, to analyze a large corpus of online surveys, open-questionnaire emails and qualitative interviews with queer individuals in STEM. The analysis resulted in a model for a queer STEM identity framework with three key processes: defining, navigating, and forming.

Defining explains how individuals come to understand and name themselves as queer in terms of their gender and/or sexuality. Defining is a complex process especially because most social settings are heteronormative and can be hostile towards queer individuals. Despite these pressures, most individuals come to define themselves as queer at an early age, leading to a more well-developed identity as they mature. Many individuals come to understand their queer identity by "coming out" or revealing their queer identity to others. Coming out is not a singular event that simply happens once, but instead is a process that individuals continually negotiate and re-negotiate in different settings. How this process is negotiated depends on the individual and their own sense of their queer identity. Some individuals may choose to express their identity publicly, while others may not, and this at least in part relates to how the individual defines their own identity. Defining one's queer identity is also impacted and interwoven by familial history, other salient identities (e.g., queer Latina), and the sociopolitical context.

Forming refers to how individuals construct their own specific STEM identities. Forming a STEM identity includes how one develops a personal interest in their subject matter. An internal interest in STEM typically develops through socialization, in early life, schooling, and university settings. The

process of forming captures how an individual comes to know what it means to be a member of a particular discipline (e.g., a mathematician) through training and experiences. In addition to creating a view of a mathematician, individuals must form their own identity as someone who belongs to that group.

Navigating describes how the interplay of professional (or academic) and personal influences impacts expression of identity in places of work and study. For instance, in a mathematics classroom, a queer student needs to navigate whether and how to express their queer identity to peers, and how much detail of their personal life to share or not. This is a negotiation process that straight, cis-gender students typically do not encounter in the same way. Here the focus is on how the STEM environment impacts the expression of their identity as opposed to the defining processes where coming out is viewed as one process for understanding their own identity.

In developing this model for queer STEM identity, Mattheis and colleagues (2019) found that "heteronormative assumptions frequently silence conversations about gender and sexuality in STEM" which result "in complicated negotiations of self for queer professionals" (p. 22). When queer individuals are not able to share their identities due to such an environment, it often creates pressure to conceal one's identity, which causes additional stress for queer individuals. In the following section we discuss how these complicated negotiations and silencing pressures are experienced by queer students in mathematics.

Methods

In order to address this research topic, we conducted a literature search via Academic Search Premier and Google Scholar using the keywords math/mathematics along with the terminology queer, gay, lesbian, bisexual, LGBT, LGBTQ, and sexual orientation. This revealed a sparse number of 20 relevant articles. In order to better document the experiences of queer students in mathematics we expanded the search criteria to include STEM disciplines as it provided a greater number of studies that

can help to shed light on this topic through related content domains. Although mathematics as a discipline is distinct from other science, engineering and technology fields, there exist similar patterns across STEM fields which leverage evidence-based practices, and utilize model and theory building to extend, refine, and revise knowledge (Bybee, 2014). Our expanded search revealed a total of 81 articles or documents that were deemed relevant to our research topic.

Each of the 81 articles were reviewed in relation to our research question, "What are the experiences of queer students in mathematics environments and what are the factors that help contribute to inclusive mathematics environments for queer students?" The major findings from the article, the student population, relevant constructs, and the content domain were extracted from the included studies. Our analysis of this extracted data followed that of thematic analysis as described by Braun and Clarke (2006). Thematic analysis is a qualitative approach that involves "identifying, analyzing and reporting patterns (themes) within data. It minimally organizes and describes the data set in rich detail. However, frequently it goes further than this, and interprets various aspects of the research topic" (Braun and Clarke, 2006, p.79). Employing thematic analysis, we first identified findings from each study and then analyzed across extant data to identify emerging themes related to our research question. The emerging themes were then organized around the Queer STEM Identity framework.

Results

We organize the results of our analytic synthesis according to the three dimensions of the queer identity framework: defining one's queer identity, forming a STEM identity and navigating identity expression in STEM environments.

Defining

"Coming out" is one of the fundamental processes related to how queer students define their identities. Here we focus on two key areas related to coming out in mathematics: (1) coming out can be a cognitively stressful process for students, especially for students with intersectional minoritized

identities, and (2) that coming out can be supported by changing environmental, social and curricular factors in mathematics environments.

Coming Out and Making Space

As queerness has become more broadly mainstreamed in American culture and society there are a growing number of students who are coming out during middle and high school grades (Denizet-Lewis, 2009). Coming out is an important identity development process where an individual comes to understand and name themselves as queer. One might reveal their queer identity to others, which can promote a sense of self-integration and personal empowerment (Corrigan and Matthews, 2003; Baiocco et al., 2016); however, the ability and decision to reveal one's queer identity is often multifaceted and situational. For instance, Toynton (2016) puts forth the notion of queer identity in STEM as the "invisible other" such that being queer is an experience of being the "other" and yet invisible if wished. The invisible nature of the identity provides agency to reveal one's identity while at the same time requiring ongoing decision making to determine whether and how to disclose this identity. Given that coming out is an ongoing process of negotiation this can create a cognitive burden for queer students in mathematics environments. For example, research indicates that having to navigate coming out in educational spaces creates more emotional and psychological work for queer students than that of straight students, and often results in daily decisions about revealing their sexuality in the classroom (Eliason & Turalba, 2019; Lopez & Chims, 1993; Savage & Harley, 2009; Toynton, 2016). As such, there is documented evidence that navigating this emotional work has negative impacts on classroom factors such as students' academic performance (Pearson et al., 2007; Russell et al., 2001), self-esteem (Toynton, 2016), and classroom participation (Eliason & Turalba, 2019). Additionally, coming out in mathematics environments is perceived as more challenging since the subject is perceived as less relevant to queerness, thus creating power structures to separate queer identities from mathematical identities. This results in individuals in mathematics reporting being less open about their queer identity

when compared to social science and other disciplines (Linley, Renn, & Woodford, 2018; Yoder & Mattheis, 2016).

The issue of coming out is further complexified for students who may be minoritized in other ways in mathematics classrooms, due to the existence of multiple problematic discourses (Leyva, 2016). For example, some lesbian women report facing a form of "double jeopardy" by having both visible and invisible identities that are marginalized by normative mathematical practices (Trauth & Booth, 2013). Nonetheless, the salience of any particular identities is situational. For example, a study of queer students of color found that gender and sexual identity was more salient for the students than racial identity, when considering the erasure of queer diversity in STEM (Ware, 2018). Given these complexities, queer students of color often make their own efforts to "create space" for themselves in white, heteronormative institutional spaces. For instance, Venzant, Chambers and McCready (2011) documented the ways in which Kevin, a gay black high school student, was able to "make space" through artistic and performative acts that rejected dominant notions of masculinity. Kevin challenged dominant notions of masculinity by transgressing against the masculine dress code by wearing "yarn wigs" and performing what he called his "gay boy illusion." In doing so, Kevin made his queer identity more visible, thus freeing himself from the emotional work of coming out. However, by making this identity visible it was met with taunts from male peers, acts which served to marginalize and challenge the presence of queer identity in the educational environment. Yet his female friend group was quick to defend his performative identity, which mitigated against the marginalizing pressures by giving him the support of a peer group. Kevin's experience highlights the navigational strategies of coming out and the power structures that seek to oppress queer identities. The idea of "making space" is a construct that can leveraged by students and teachers to mitigate against the stressors of coming out in the classroom and build inclusive environments. In order to do this, teachers can provide the opportunities to "make

space" in the math classroom by affirming and encouraging the transgression of heteronormative practices thus freeing students from the emotional work of disclosing their queer identity.

Environmental, Social and Curricular Factors.

Coming out in educational spaces is impacted by situational variables that relate to the climate and reported comfort levels in disclosing sexual identity. Educational research with queer students has suggested that students are more comfortable coming out in smaller classes where they know the other students (Eliason & Turalba, 2019) and where they perceive the classroom climate and instructor as more accepting (Lopez & Chims, 1993). In a recent study in biology, students reported that coming out was more salient in active learning classrooms due to the increased interaction with their peers (Cooper & Brownell, 2016). Students navigated these situations by having an awareness of the types of people they prefer not to collaborate with (e.g., jocks) and, when assigned new groups, it required them to test the level of acceptance of their peers (Cooper & Brownell, 2016). Alternatively, students pointed to the benefit of increased peer interactions because it allowed them to find similar others who associated with the queer community. Although Cooper and Brownell's study was in the context of undergraduate biology, the same themes would likely appear to hold and be relevant in middle school math classrooms, especially as there is a shift towards more cooperative group work in line with the Common Core State Standards for Mathematical Practices (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). Thus, the interactional nature of the classroom environment makes the relational power structures and potential oppression of queer identities more readily apparent (Ernest, Reinholz, Shah, 2019).

It is through social interactions that queer identity can be marginalized and oppressed within education even without students disclosing one's queer identity. These marginalizing forces occur through the presence of microaggressions (e.g., derogatory statements, invalidations, insults) that creates barriers for students in coming out (Vaccaro, 2012; Vaccaro & Koob, 2018). For instance, 99% of

queer youth report hearing the derogatory use of phrases such as 'that's so gay' or 'you're so gay' in school (Kibirigie & Tryl, 2013). These forms of oppression help align education with a heteronormative experience. In order to create inclusive math environments instructors must confront and challenge microaggressions against queer students when they occur in educational environments.

The development of inclusive curricular materials is one mechanism to support queer students and counteract the hostile schooling environment that make queer identity invisible and irrelevant (GLSEN, 2013). In fact, high schools that have implemented inclusive curricula report increased rates of acceptance for queer students, indicating that academic disciplines can have an impact on the overall school climate (GLSEN, 2013). Unfortunately, K-12 mathematics classes have the lowest percentage of students (4.8%) across all disciplines reporting positive portrayals of queer people in their classroom (Kosciw, Greytak, Palmer, & Boesen, 2017). In comparison, positive portrayals of queer topics occurred in 58.5% of social sciences or history classes (GLSEN, 2013). This is especially problematic if one hopes to encourage queer students to take an interest in mathematics during this formative period of their lives. Queer students are especially vulnerable during the identity development period in high school as they are often susceptible to stress derived from cultural and social prejudices towards queer individuals (Meyer, 1995).

Extending beyond general curricular revisions, there is a need to revise the mathematics curriculum specifically to combat heteronormative ideologies. For example, consider the well-known "stable marriage problem" in mathematics that reinforces normative assumption of gender and heterosexuality, "There are n men and n women. Each person ranks those of the opposite gender for marriage. The goal is to find a way to create a set of stable pairings" (Gale & Shapley, 1962). Rubel (2016) problematizes the stable marriage problem as heteronormative and highlight that even the original framing of the problem has been that of men selecting wives. The stable major problem not only assumes heteronormative relationships but also puts forth a notion of binary gender constructs.

Removing such curricula or using different contexts can still preserves the exploration of the mathematical structure, while removing the power structures that promote a heteronormative environment in mathematics.

In addition to revising and problematizing heteronormative curriculum there is also a need to create queer inclusive curriculum. Although there are difficulties and concerns with including queer themes within mathematics problems there are emerging examples that demonstrate that such curricula are possible. Dubbs (2016) highlights two approaches for having queer inclusive math curricula. The first approach incorporates queer context to the names or mathematical settings, referred to as the "add queers and stir" model. One such example was developed by Kellermeier (1995, 2002) and used lesbian, gay and bisexual word problems to contextualize statistics problems. A second approach incorporates queer notions to reconceptualize the nature of mathematics referred to as "mathematical inqueery." As an example of queering the notion of mathematics, Rands (2013) draws on data related to queer discrimination and factors impacting intervening to help students understand and unpack issues of proportional reasoning and statistics. This model is more aligned with mathematical inqueery since it problematizes open-ended exploration of queer topics. Another example of this approach presented by Rands (2009) describes a math problem under the scenario of a curriculum night at school where families are invited to attend. A description of several families is given (e.g., 1 kid lives with two moms sometimes and a mom and a dad other times, 8 kids live with a dad and a mom, 2 kids live with a grandma) and students are asked a series of questions about the amount of materials needed as well as what kinds of families are represented and what kinds of families are possible. These few examples demonstrate that queer inclusive curriculum in mathematics is possible and different avenues for approaching such topics deserves further investigation.

Forming

Forming relates to how individuals construct their own identities as mathematicians. This relates to both (1) interest and success in the field, and (2) also how one comes to see oneself as a member of that field (i.e. one's mathematical identity development). We highlight research that shows that when students are supported to develop their queer identities, it can support their development of mathematical identities.

Academic Success

Research on STEM identity development highlights the importance of success within a field as a part of developing one's identity as a member of that field (Hyater-Adams, Fracchiolla, Finkelstein, & Hinko, 2018). Thus, studies of academic performance and course-taking patterns provide insight into opportunities that queer students have to form identities as learners and doers of mathematics.

A handful of studies have examined academic (mathematics) outcomes for queer youth by using the National Longitudinal Study of Adolescent Health data, often resulting in mixed findings. The data used in these studies comes from approximately 20,000 students in grades 7 through 12 that contains data on adolescents' romantic attractions, well-being, and attitudes toward school. Gottfried, Estrada and Sublett (2015) through analysis of this data indicated that a student's queer status was a significant predictor of their math and science course-taking patterns. Pearson, Muller and Wilkinson (2007) showed that queer students score worse on measures of academic achievement, higher on measures of emotional distress and substance abuse, are less socially integrated to their schools and teachers, and have lower expectations for attending college. Pearson and colleagues showed that, even when controlling for feelings of attachment and engagement in school, gay boys are approximately 47 percent less likely to complete algebra II and 41 percent less likely to complete chemistry compared to their straight peers. Interestingly, this same trend was not present in course taking patterns for foreign language, suggesting that something is "unique about mathematics and science that makes them more intimidating than other subjects" (Pearson et al., 2007, p. 113). Russell, Seif, and Truong's (2001)

analysis of the same data supports the notion that queer youth have lower academic outcomes and that relationships with teachers may play a leading role in explaining this difference. This marginalizing trend continues into collegiate settings such that queer students are 7% more likely to switch from a STEM major to a non-STEM major (Hughes, 2018). Research seems to indicate that factors impacting this switch are often related to power structures that impact a student's perceptions of feeling "fit and community" within the environment (Stout & Wright, 2016) or is negatively correlated with reported experiences of discrimination (Schneider & Dimito, 2010). In order to foster inclusive math environments for queer youth there appears to be a need to focus on the types of relationships they form with mathematics teachers in order to bolster their mathematical identity.

Positive teacher relationships have a clear impact on students' academic success and are correlated with reports of coming out and feeling safe in the classroom. As stated earlier, queer students' decisions to come out in the classroom are related to the receptiveness of the instructor (Lopez & Chims, 1993). Instructors are often seen as a more positive and critical ally than peers in STEM environments since they represent the instructional authority in the learning environment (Garvey, BrckaLorenz, Latopolski, & Hurtado, 2018; Linley et al., 2018). Queer students report more positive experiences with women math teachers compared to men since women may mitigate the perception of mathematics as a masculine heteronormative discipline (Kersey, 2018). STEM teachers were viewed as supportive when they confronted homophobic language, challenged normative heterosexist discourses within the curriculum, and utilized inclusive language within the classroom (Cooper & Brownell, 2016; Linley et al., 2016). Additionally, informal mechanisms outside the classroom were also seen as supportive such as displaying "Ally" placards and attending community events. In summary, positive instructor relationship help queer student form more robust STEM identities.

Mathematical identity development

Fischer (2013) explored how queer youth affiliated with a local pride center integrated their queer identity with their mathematical identity. Fischer documented that having support for one's queer identity at school was found to relate to possessing a stronger mathematical identity. For example, having a gay math teacher as a role model, receiving tutoring supports at the pride center, and having gay-straight alliances supported students' success and engagement in mathematics. Alternatively, students who spoke of feeling sexualized in math classrooms and not wanting to ask questions for fear of being labeled as that "gay kid asking questions" presented challenges for engaging fully with their mathematical identity (Fischer, 2013). Fischer draws on the idea that a leading identity, such as a queer identity, can support other subordinate identities, such as a mathematical identity. Fostering a "strong queer identity creates a personal environment that is conducive to understanding and absorbing other information and knowledge" (Fischer, 2013, p. 113). Fischer suggested that educators need to support students' identity development through the "queering" of mathematics (Mendick, 2006) in order to make it less male-centric and to counter the absolutism and binary construction of mathematics. Fischer's study also points to the ways in which the growing number of middle school gay-straight alliances are necessary and relevant to the development of inclusive mathematical environments by supporting students queer and mathematics identity.

Another potentially powerful mechanism for supporting queer students STEM identity development is the presence of queer role models (such as an instructor) in the mathematics classroom. Research shows that having role models that share aspects of your identity such as race and gender supports students' persistence and academic performance in math (Drury, Siy, & Cheryan, 2011; Marx & Roman, 2002). While there have yet to be studies to document the same effect on academic performance and persistence for queer students there are a growing number of STEM professionals advocating for coming out in math and science to provide visible role models for youth (Barres, Montague-hellen, & Yoder, 2017; Esposito, 2019; Knezz, 2019; Restar & Operario, 2019; Smith, 2014).

Yet at the same time research indicates that there are pressures in the STEM disciplines for instructors to not disclose their identity (Yoder & Mattheis, 2016). Queer teachers in math report having to "cover" their queer identity and report needing to perform masculine roles (Mayo, 2007). In a study of two queer high school math teachers Whipple (2018) documents how the heteronormativity of math spaces and a lack of a supportive environment for the teacher's queer identity caused both teachers to leave their position for a more supportive school. This research showcases how the lack of a supportive environment for teachers can result in the absence of available queer role models for youth in schools. Because queer identity is the "invisible other" the ways in which role models are present for queer youth has yet to be researched, and it is unclear if the same mechanisms that support women and students of color from seeing similar others transfers to queer youth.

Navigating

Navigating focuses on how the interplay of professional (or academic) and personal influences impact identity expression in school and work settings. Here, we focus both on (1) the STEM workplace as a proxy of academic classrooms, and (2) how masculinity is an overriding pressure within the environment. These are important areas to consider, given that mathematically successful queer students may ultimately one day choose to join the STEM workforce. In addition, the presence of more openly queer individuals in STEM fields helps create greater representation and role models, which is important in the ways that we have described above. In addition, the privileging of masculinity may impact members of the queer community in different ways.

The STEM Environment

The process of navigating one's professional and personal identities is likely more pronounced in mathematics and other STEM fields. As stated earlier by Pearson and colleagues (2007) there is something unique about mathematics that might make marginalization due to sexuality felt more acutely within STEM-related disciplines that favor heterosexuality. The majority of existing studies that

have examined environments within STEM disciplines have almost exclusively focused on undergraduate spaces and largely focused on faculty and professional reports. Toynton (2007), who examined the de-representation of queer science students in higher education, showed that students expressed feelings of otherness, isolation, and vulnerability and reported monitoring their thoughts and actions. In a study with gay undergraduate students in STEM, Smith (2014) suggests, "being gay in the heterosexist society is never easy but being gay in a heterosexist environment and in an academic program that devalues your sexual orientation and encourages you to hide your identity for the sake of efficiency can have very negative consequences" (p. 85). Faculty and professionals largely report similar experiences such as "overt hostility, a sense of invisibility, interpersonal discomfort, and pressure to 'cover' one's sexuality" (Bilimoria & Stewart, 2009, p. 85). For example, Autumn Kent, who identifies as a trans mathematician spoke of the overt transphobia and homophobia from academics and mathematicians, especially in social media. As a trans mathematician in academia, Kent points to issues related to health care, changing articles published under their 'dead name' and transitioning in front of students, which all contribute to carrying around dread and psychological anguish in everyday tasks (Lamb, 2017).

Although most STEM faculty suggest that their workplaces are safe for queer people, only a minority (43%) of respondents are out to their colleagues (Yoder & Mattheis, 2016) and there is evidence that faculty who are out to their colleagues are less comfortable in their department and more likely to report wanting to leave their institution (Patridge, Barthelemy, & Rankin, 2014). Some of the mitigating factors to support the level of comfort and outness in STEM disciplines is the percentage of women within the field (Yoder & Mattheis, 2016) and more likely to occur in social disciplines than applied or pure fields. One of the reasons that applied and pure fields are less favorable environments is that these fields have put more emphasis and priority in favoring technical skills rather than communicative skills (Cech & Waidzunas, 2011; Leyva, Massa, & Battey, 2016; Linley, Renn, & Woodford, 2018). Mathematics as a field sits in the borderland between promoting technical proficiency

and recently emphasizing mathematical communication and reasoning, which has the power to shift the culture to one that is more inclusive for queer students.

The perceived objectivity and normative practices within mathematics creates dissonance among students that their queer identity is irrelevant and should not impact their experiences. For instance, although queer students report neutral climates in STEM spaces, this in part because they report not having connections with queer communities and don't believe their queer identity relates to the discipline (Cech, 2013; Gunckel, 2009; Haverkamp et al., 2019; Hughes, 2017). These students often cast STEM as an escape from their queer identity since "STEM creates objective viewpoints where orientation is not considered…[and] gender and sexuality are not important to the efficiency of work" (A. R. Smith, 2014, p. 60). This belief that queer identity is irrelevant resulted in queer students feeling uncomfortable revealing their sexual orientation in STEM spaces, because of their desire to not make others uncomfortable, and since coming out created a sense of constant vulnerability that meant staying closeted was safer and easier in these spaces (A. R. Smith, 2014). When you combine students' personal views of coming out with pressure within the field to depoliticize STEM and thus remove any mention to social identities, it results in an erasure and oppression of queer identities in STEM (Cech, 2013).

Privileging Masculinity

Marginalization in mathematics due to sexuality also co-occurs with normative gender practices that privilege masculinity. There is well documented evidence that mathematics as a discipline has often privileged separate knowing as compared to connected knowing the former of which is often associated with beneficial outcomes for men (Boaler, 1998; Kersey, 2018; Trentacosta & Kenney, 1997). Mendick (2006), in a highly influential piece, interrogates the ways in which mathematical discourses have been cast in terms of dichotomies that position femininity and masculinity in opposition to one another, with mathematics firmly fixed on the masculine side. Mendick analyzed why choices of doing mathematics

were gendered for these students, and highlighted how through doing mathematics, people are performing masculinity and that this introduces more tensions for girls and women than for boys and men. Students often made sense of math and their relationship to it through a series of binary oppositions such that the discourses of mathematics are aligned with those associated with stereotypical masculinity (e.g., fast, dynamic, objective, reasonable). Access to these positions are often highly dependent on a person's assigned gender and thus perpetuate gender disparities in mathematics. The discourses in mathematics that align it with masculinity also serve to enforce gender stereotypes that can be at conflict with queer identities. For instance, when gay men are presented with effeminate contexts it can trigger stereotype threat such that they perform worse on mathematical tasks than when they are presented neutral contexts (Raymond, 2014). Thus, challenging and deconstructing gendered normative practices in math can help create inclusive math spaces for queer students.

Summary

Our synthesis highlights the ways that research has shed light on queer identity development in mathematics. While some of this research comes from educational environments or STEM environments more generally, what we know about the field of mathematics, and how it can be used as a tool of oppression, allows us to contextualize the findings for mathematics. In particular, we utilized a framework for queer STEM identity in the workplace, to organize these findings for schooling settings. What we found is that queer students face many of the same types of barriers experienced by other minoritized populations, but there are a number of key differences (e.g., the potential for one's queer identity to be invisible), which necessitate a greater research focus on queer students in mathematics. As such, the totality of these pressures cast queer identity as invisible and irrelevant to the pursuit of STEM in part because it cannot be associated with performance and belonging in the same ways that gendered, racialized and able-bodied identities have been in mathematics.

When it comes to *defining* one's queer mathematical identity, it is essential to recognize that this identity is not always visible. This requires students to "come out" in mathematical classroom settings, which can be a very stressful event, due to the heteronormative construction of mathematics. However, students can be supported to come out by modifying the environmental, social and curricular factors that lead to the oppression of queer individuals. The heteronormative assumptions in mathematics can also be challenged through the use of queer inclusive curricula that may make coming out easier and more relevant for queer students.

The process of *forming* one's queer mathematical identity relates both to the definition of a mathematician and how one sees oneself as fitting (or expanding) that notion. The popular images that one encounters of mathematicians—either in society or in the classroom—has a large impact on what students perceive a mathematician to be, and whether or not they fit that notion. Because queer students may not often see themselves represented in the mathematics community, this creates a barrier for identity development. In addition, the stress associated with being queer in an oppressive society can lead to lowered academic outcomes, which may further push students not to identify as a mathematician. However, teacher relationships and queer role models can help the forming of mathematical identities.

Finally, *navigating* relates to how individuals work in professional settings, and how they choose to disclose their identities or not. In general, mathematics (and STEM) environments are seen as particularly hostile towards queer individuals. This is due to the construction of an ideal heteronormative, masculine mathematical subject identity, and the idea that mathematics is perfect, objective, and timeless. Together, this creates an "othering" environment for queer individuals who do not fit that stereotype. In order to help promote queer students in navigating these settings we must reconstruct the nature and view of mathematics to promote a connected, inclusive, and social discipline.

Future Research

Although this review sheds light on some of the existing experiences of queer identities in mathematics, many of the studies cited here were conducted with undergraduate students in the context of STEM. As such there are only a limited number of studies on the experiences of queer youth in mathematics. In our synthesis, we identified a few key areas for future research.

First there is a need to understand the lived experiences of queer youth in secondary mathematics courses through qualitative research. Most of the literature on queer youth in mathematics comes from large scale quantitative survey data which helps to highlight areas for further analysis but does not capture the nuances of their lived experience in math classrooms. The lack of qualitative studies in this area is likely perpetuated by the heteronormative pressures we have discussed that cast queer identities as irrelevant to the pursuit of mathematics. Additionally, research with queer youth requires additional considerations in study design with the need of parental consent. Educational researchers in other fields have addressed this issue by recruiting through Parents, Families and Friends of Lesbians and Gays (PLAG), interviewing principals and teachers, and using online platforms as a window into the experiences of queer youth.

Another area for future research is understanding how teacher relationship and role models can support queer youth in mathematics. Unlike other shared visible identities, queerness, as an “invisible other” manifest itself differently than existing research on gender and racial relationships with teachers and role models. As such there is a need to document the impact of visibility and non-heteronormative performances by teachers in math classrooms. It is especially important to understand what environmental and social features allow queer teachers to “come out” in the classroom without fear of reprisal or accusations of “sexualizing” their classrooms. Additionally, future research is needed to understand the impact of inclusive practices of straight ally teachers, such as using pronouns, confronting microaggressions or displaying ally signs in math settings.

While there are existence proofs of queer inclusive curriculum there are relatively few rigorous or thorough studies to understand the use of these curriculum in classroom settings. Additional research can develop principles for curriculum creation that most appropriately center queer identities in mathematics through a normalized approach. Furthermore, classroom studies and professional development are needed to understand how to enact these curricula in the classroom. It is possible that without careful consideration and guidelines implementing queer inclusive math curriculum may create a less inclusive environment through students or parents marginalizing such ideas when encountered.

Given the under-theorization of sex and gender in research, and the prevalence of binary constructions of gender, there is a dearth of literature examining the experiences and environment for gender non-binary and transgender students in mathematics. For instance, researchers have often conflated notions of sex (a biological characteristic) and gender (related to one's identity; cf. Leyva, 2017). This happens when researchers refer to students as female (their sex) rather than as girls or women (their gender). Thus, there is a need to better disentangle sex and gender (Glasser & Smith, 2008), and theorize them for studies in mathematics education (Esmonde, 2011; McWilliams & Penuel, 2017). In addition, gender is typically presented as a binary construction, which fails to recognize the much broader spectrum of gender identities. For this reason, researchers have drawn attention to the need to deconstruct binary notions (Mendick, 2006a) and develop new conceptual understandings of gender for educational research (Damarin & Erchick, 2010).

Implications for Practice

Given the importance of identity development to academic success, understanding how to promote inclusive math environments for queer youth is a critical area of focus. Our research synthesis highlighted a number of promising practices to promote inclusive math environments for queer students by targeting the curriculum, teacher relationship, role models and policies to combat the heteronormative influence in mathematics. Incorporating queer inclusive curriculum in math can

happen at the classroom level tomorrow through modifications to already adopted curriculum or can be systemic through policy adoptions at the district level. The Gay Lesbian Education Network (GLSEN) has resources available for creating such curriculum (https://www.glsen.org/inclusive-curriculum).

Fostering positive student-teacher relationships and providing role models for queer students means communicating an awareness and openness to queer issues and language. As these issues are constantly evolving and adapting to societal needs a first place to start is through partnerships with gender and sexuality alliances (https://gsanetwork.org/national/), out in STEM student organizations (www.ostem.org), the gay and lesbian education network (www.glsen.org) or through the national gay and lesbian task force (https://www.thetaskforce.org/). These organizations can provide resources that help support students' queer identity formation. Such resources include best practices with the use of pronouns when introducing oneself, supporting gender-nonconforming students, and creating anti-discrimination policies.

In addition, there is a need for larger reforms in the societal systems of oppression that function to marginalize queer individuals. We view the changes in practice outlined above as a necessary, but insufficient step towards this larger change. It is critical that we recognize and build upon the unique strengths of queer students in mathematics, rather than focusing only on the challenges they face. Ultimately, this is a matter of fixing the system, not fixing people. Being queer and in mathematics need not be a disjoint set, and through further research and understanding we can begin to support the next generation of queer mathematicians who will shape and influence the discipline of mathematics.

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