Journal of Urban Mathematics Education
May 2020, Vol. 13, No. 1, pp. 1–14
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Gender and Mathematics: What Can Other Disciplines Tell Us? What is Our Role?

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In this article, we begin by taking stock of broad trends related to gender and mathematics, focusing primarily on patterns within the United States and considering how these patterns may vary by social class and race. This article is not a traditional, empirical piece but instead pulls together evidence from quantitative and qualitative studies to argue that gender remains an issue worthy of our attention within mathematics education. Given that much recent work on gender and mathematics has been situated outside of traditional mathematics education frames, we consider how ongoing work in psychology and gender studies can contribute to our understanding, and we use this work in conjunction with interview data from a study of women's experiences in a mathematics Ph.D. program. Ultimately, we argue that mathematics education researchers bring unique expertise to the table and have a particular role to play in building upon findings in other fields to further the work on gender and mathematics.

KEYWORDS: gender, psychology, race, socio-economic status

Gender—Still an Issue Within Mathematics Education?

Several decades ago there were marked disparities between women and men in key metrics of concern to the mathematics education community, such as completion of high school mathematics courses and bachelor's degrees in mathematics, but these disparities ultimately narrowed (Dalton et al., 2007; Perez-Felkner et al., 2014). Perhaps because of this, gender has received less attention since the turn of the century within the mathematics education community than it did in the 1970s–1990s (Grevholm, 2011); however, work has continued in other fields, such as psychology and sociology, with dedicated journals such as *Psychology of Women Quarterly* and *Sex Roles* (Lubienski & Ganley, 2017).

Moreover, the idea of gender itself has been challenged. We use the term "gender" throughout this article to reflect our primary focus on socially constructed norms associated with being a woman or man in our society as opposed to a focus on fixed

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biological traits (Hall, 2014). We acknowledge the limits of our use of binary categories, but we find these categories useful for taking stock of equity concerns for our purposes here; as discussed below, this very conversation is something that gender scholars have grappled with in recent decades as well. Overall, with the advances in equity in gender and mathematics, along with the deconstruction of gender as a concept, it is not surprising that attention to gender has declined within the mathematics education community (Grevholm, 2011; Lubienski & Ganley, 2017). Still, our aim in this paper is to argue that mathematics educators have a responsibility to attend to gender and mathematics education and that, despite the contributions of scholars in other fields, we have particular expertise to contribute.

According to some key metrics, progress toward gender equity in mathematics has stalled. For example, in the United States gender disparities in performance among K–12 students continue to favor boys, who are substantially overrepresented at the top of the mathematics achievement distribution (Cimpian et al., 2016). With some exceptions, significant gender differences also tend to favor boys internationally, with boys in Organisation for Economic Co-Operation and Development (OECD) member countries outscoring girls by an average equivalent of 5 months of schooling (OECD, 2015). Although gender gaps in performance are often viewed as relatively small, gaps in mathematical confidence are larger, both in the U.S. (Ganley & Lubienski, 2016) and among other OECD countries (OECD, 2014). Major gender disparities in mathematics persist beyond K–12 schooling as well, and the collegiate and professional mathematics settings have in fact experienced some regression in women's representation since the turn of the century.

Although U.S. women are more likely than men to attend college, the percentage of bachelor's degrees in mathematics earned by women was 46% in 1997 and only 42% two decades later; additionally, women earn less than 29% of mathematics doctoral degrees and only 19% of bachelors' degrees in computer science, down from 27% in 1997 (National Center for Science and Engineering Statistics, 2019). Furthermore, the median salary for women who are college graduates and employed full-time is only 74% of the median salary of men with a similar education level (American Association of University Women [AAUW], 2018), and a substantial portion of this disparity is attributable to men's overrepresentation in mathematics-intensive professions (Corbett & Hill, 2012; Ryan, 2012). This imbalance in mathematics-intensive fields diminishes women's pay and status as well as the pool of skilled professionals contributing to these fields.

Hence, despite some progress toward gender equity in the field of mathematics, concerns remain. Gender differences in mathematics outcomes are specific to our field, as they do not occur in reading or even in science majors that are not mathematics intensive. Additionally, although differences in mathematics outcomes by race and social class tend to be at least partially attributable to differences in schools attended (Fryer & Levitt, 2004), gender differences appear among boys and girls learning within the same mathematics classrooms. Because of this, mathematics educators arguably have a particular responsibility to examine and address issues of gender equity.

Gender Patterns by SES and Race

Although national data provide overall averages by gender, they can also mask the ways in which patterns vary across contexts. Hence, it is important to examine gender issues with an intersectional lens.

Gender and SES

Gender disparities in mathematics are larger in high-socioeconomic status (SES) schools (Reardon et al., 2018). Given that higher SES students tend to have higher achievement than their less advantaged peers (Reardon, 2011), this SES pattern is consistent with gender gaps being larger at the top of the distribution (Cimpian et al., 2016). These patterns may seem surprising given that high-SES parents have been found to espouse more egalitarian views than do lower SES parents (Marks et al., 2009). An explanation for this pattern may be found in a study that used national data from the Early Childhood Longitudinal Study, which found that high-SES children were more likely than their low-SES peers to participate in parent-initiated activities falling along traditional gendered lines, such as dance lessons for girls and organized sports for boys (Lubienski et al., 2013). Although these differences in activities themselves did not explain emerging gender differences in mathematics performance, the study suggests that high-SES children may experience other gendered parenting practices that could contribute to the early gender gaps we see among high mathematics achievers.

Ellison and Swanson's (2010, 2018) analyses of American Mathematics Competitions (AMC) data provide a different look at girls' opportunities to excel in mathematics within varied SES contexts. The AMC is a series of competitions held at over 3,000 U.S. high schools. Although 43% of the AMC test takers examined were girls, boys were six times as likely to score among the top 1% (n=1,200) of AMC scorers. Ellison and Swanson (2010) observed fairly consistent gender gaps in scores across most high schools but found that while high-scoring boys came from a wide variety of schools, high-scoring girls were concentrated in a very small number of elite, high-SES schools. It is important to note that although gender disparities might be larger among high-SES students, girls who do excel tend to come from high-SES contexts. These results highlight both the importance and possibility of schools doing more to nurture all girls' mathematical talents. Specific to considerations of urban education (the focus of this journal), these results also raise questions about the resources teachers and schools need in order to foster all students' talents, and how schools' geographic contexts may affect teachers' and students' access to such resources.

Gender and Race

Just as students' gendered experiences and outcomes can vary by SES contexts, they also have been found to vary by race. For example, McGraw et al. (2006) found that Black girls tended to score higher than Black boys on the National Assessment of Educational Progress (NAEP). The most recent data from NAEP, from 2015 and 2017, confirm this pattern. Specifically, small gender differences among Black students tend to favor girls across the 4th, 8th, and 12th grades, and there are reverse patterns among Asian, Hispanic, and White students (data pulled from the NAEP Data Explorer at https://www.nationsreportcard.gov/ndecore/xplore/NDE). This trend among Black students in grade school does not mirror the trend of Black students in college pursuing science, technology, engineering, and mathematics (STEM) majors however.

Riegle-Crumb and King (2010) analyzed Educational Longitudinal Study data and found that among U.S. students who attended a four-year college, Black and White men were far more likely to pursue physical science and engineering majors than both Black and White women. Moreover, Black men were more likely to pursue such a major than White men when academic preparation was accounted for. It is critically important to remember that these numbers are restricted to those in four-year colleges and also do not consider the relatively high departure rate of Black students in STEM majors (Riegle-Crumb et al., 2019). Still, the data support Gholson's (2016) argument that intersectionality is important and that Black women should not be overlooked by mathematics education researchers and support programs.

Interpreting Women's Experiences in Graduate Mathematics

Decades ago, Fennema and colleagues (1998) published a small-scale study in which elementary school girls were found to approach problems with more taught strategies while boys more often used invented strategies. The researchers then opened the work up to consideration by scholars in other fields to interpret the findings. We think much can be gained by such an interdisciplinary approach, and so we embark on a small version of multi-disciplinary conversation here, highlighting how recent work in psychology and gender studies can complement—but not replace the need for—mathematics education research on gender and mathematics. We use these two fields as examples because our own thinking about gender and mathematics has recently been informed by these fields. We do not mean to suggest that other fields are any less important for informing such work or that gender-related work at the intersection of these fields and mathematics education has not been done before.

To illustrate how frames from different disciplines can enrich our thinking about gender and mathematics, we use data from an ongoing study of how women who are Ph.D. students in mathematics perceive themselves in *mathematical spaces*. We see these spaces as "sites where mathematics knowledge is developed, where induction into a particular community of mathematics doers occurs, and where relationships or interactions contribute to the development of a mathematics identity" (Walker, 2012, p. 67). Using a "life story interview approach" (McAdams, 2008), the second author of this article interviewed six women in mathematics Ph.D. programs at a large Midwestern university in fall 2019. These students were contacted via email, and they completed an online survey providing information about their demographics and mathematical background. Intentionally, the researcher chose two students in the beginning of their studies, two in the middle, and two close to the end. This strategy was used to examine students' experiences throughout different phases of doctoral study (Pinheiro, 2019). Only students who identified as women and who had exemplary grades in high-level graduate mathematics courses were chosen to participate in the project. Among these six students, four identified as White women, one identified as an Asian American woman, and one identified as a Latina from Ecuador. Each woman was interviewed twice for a total period of two hours. Each person was interviewed on two consecutive days.

Overall, the women tended to report that they (1) had more interest in teaching than doing research, (2) considered family-related concerns when making career plans, and (3) had lost confidence in their mathematical abilities as they reached higher-level mathematics. These findings are not new; earlier studies found that women often decide to study a Ph.D. in mathematics because of their love of teaching (Herzig, 2010), their departure from mathematical studies can be connected to a variety of family responsibilities (Herzig, 2004b; Lovitts, 2001; Sonnert & Holton, 1995), and women tend to be less confident in mathematics than men (Etzkowitz et al., 2000; Herzig, 2004a). The current study suggests that women's experiences and the way they feel in mathematical spaces may remain similar to what they were a generation ago. Because of space limitations, we focus specifically on Kelly's[1] experiences, as quotes from her interview succinctly convey these themes.

Kelly is a White 5th-year student who decided to pursue a Ph.D. in mathematics because of her interest in teaching mathematics:

> When I was in, you know, middle school, I wanted to teach middle school math. When I was in high school I wanted to teach high school math, and then in college I was like, no this is way better, I want to teach college math. And then I knew I needed a Ph.D. in order to do that.

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[1] Kelly is a pseudonym.

Although Kelly had worked for years toward her goal of becoming a college mathematics teacher, she expressed a willingness to compromise her desired career path for the sake of her family:

> I consider myself a feminist, but as much as I really do want to teach at a small school, my career is not the most important thing to me. I am much more family oriented. And so I would be much more willing to give up that career in order to have a job close to a city that works well for my husband. And so sometimes I feel odd about vocalizing that to people, because I don't want to be perceived as not empowering to women.

Despite the mathematical accomplishments of the six women in the study, each of the participants, including Kelly, said that their mathematical confidence in graduate school was lower than it was in elementary/middle school, high school, and college. For example, Kelly said she was "definitely less confident in math" in graduate school than she was previously. When asked to describe her confidence on a scale of 1–10, she explained that it started high in graduate school, but fell by her second year:

> Kelly: Started off at 9 or 10. And then by year 2, five maybe.
> Interviewer: Why is that?
> Kelly: I think a variety of reasons. I think part of it was suddenly it got way harder. Part of it, too, was not being sure that I wanted to finish the program. And… those moments, when I felt like I didn't belong as much, was sort of a similar thing, where there are some people in this program who just, they read something and they remember it, they can rattle off a theorem. Like it's nothing. And I, I always thought that I had a really good memory, up until I came here. And all of a sudden, I, I don't have a memory like theirs.

Kelly also talked about her desire to have children, along with her questions about timing:

> … my husband and I have thought about kids more, because we both do want kids. But… I don't know if I can handle that during grad school. But also they say it doesn't get easier. So that's kind of where I'm at right now.

How might we make sense of Kelly's statements? We turn now to consider how work in psychology and gender studies might inform our interpretations. We then close by considering what mathematics education researchers might see in these quotes that others do not and argue that mathematics education research is needed to complement research on gender and mathematics in other fields.

Perspectives from Psychology and Gender Studies

Psychology

Kelly pursued a Ph.D. because she wanted to teach college mathematics. However, when the math became "way harder" in doctoral study, she lost confidence and considered leaving the program. She continues to grapple with how to reconcile her prioritization of family with her feminist identity.

Within psychology, Kelly's statements can be viewed in light of expectancy-value theory, which emphasizes the role of individuals' values and expectations for success when making career choices (Eccles, 2009). Instead of focusing on women's avoidance of mathematics, expectancy-value theory focuses our attention on why women choose the careers they do. For example, Eccles and Wang (2016) found that women's greater prioritization of working with people and meeting family needs helps explain gender disparities in 12th graders' career plans, including why women are more likely than men to pursue non-mathematical careers. Students' mathematical self-concepts and expectation for success in mathematics also predict students' pursuit of math-related careers (Lauermann et al., 2017). Through this lens, we notice that Kelly became unsure of whether to remain in the program once her expectations for success (mathematical self-concept) faltered. Kelly continues to struggle to reconcile her career goals with her family aspirations, particularly because "they say it doesn't get easier," meaning that she is not sure that she can balance motherhood with an academic career in a mathematics department even after graduate school. A lack of role models in her current program (e.g., women professors who are mothers) may exacerbate this sense of conflict in her values as well as diminish her expectancy for success as a mother-mathematician.

Another recent line of research in psychology highlights that mathematics and a few other fields (e.g., philosophy) are associated with innate "brilliance." Consistent with stereotypes about White men being "naturally smart" as opposed to needing to work hard to succeed, the fields associated with brilliance have relatively high percentages of Ph.D.s who are White men (Leslie et al., 2015). With this lens, we might wonder if Kelly has internalized the idea that some students inherently have a greater chance at success as research mathematicians than others (i.e., those who "can rattle off a theorem" are simply more mathematically "brilliant" than she is).

Gender Studies

Whereas psychology helps us understand Kelly's choices as shaped by her individual values and expectations, gender studies helps us focus more on broader societal influences. Gender studies is an interdisciplinary field that has attracted increased attention recently, given evolving views on gender and the ways in which these permeate society and impact people's lives. Here we consider ideas from feminist and queer theories, both of which fall under the umbrella of gender studies and can provide distinct views of Kelly's experiences.

Feminist theorists focus on injustices that have historically shaped women's oppression, striving to understand the subordination of women in order to take action to address it (McCann & Kim, 2013). In looking at Kelly's statements, feminist theories would help us notice ways in which her views and experiences have been shaped by her gender in a male-dominated society. Although Kelly considers herself a feminist, she is willing to prioritize her husband's career over her own. This is consistent with Donovan (2012), who argued that in societies where masculinities are still dominant, women fill the role of caring for men. Additionally, Korth's (2003, 2005) methodological research on caring helps us consider ways in which Kelly's desire to both care for her family and to be a teacher may be connected to her socially constructed gender.

Unlike feminist studies, which is focused on women, queer theory is not attached to any specific gender identity. Instead of a focus on commonalities among women versus men, queer theory deconstructs the ideas of gender normativity and the heteronormative, prompting us to think beyond our current binary notions of gender and to consider gender as a socially constructed, performative attribute of an individual (i.e., it's what you do, not who you are) (Butler, 1993). Amin (2017) and other queer theorists would argue for research from multiple historical perspectives to examine what makes Kelly's current experiences possible. Such examinations could help us consider, for example, how our historical emphasis on women and men as categories have perpetuated gendered patterns in mathematics outcomes.

In summary, psychological research has informed us about factors shaping individuals' career choices and how these can collectively result in the underrepresentation of women in mathematics, while work in gender studies foregrounds considerations of gender within broad historical and social contexts, pushing us to think more deeply about the way in which societal gender norms have shaped gendered role expectations over time. Within gender studies, feminist theorists emphasize the importance of interpreting and improving Kelly's experiences as a woman, whereas queer theory urges us to look beyond current notions of gender and envision what Kelly's experience might be if such notions were dismantled.

What Can Mathematics Education Researchers Add?

After considering Kelly's experiences from the perspectives of psychology and gender studies, one might wonder if there is anything else for mathematics education researchers to add. In particular, how might a more explicit focus on mathematics and mathematics education influence what is noticed and queried about Kelly's experiences?

First, although both gender studies and psychology's expectancy-value theory help us understand that Kelly's desire to care for others is consistent with larger societal gender norms, we, as mathematics educators with a fuller appreciation of the discipline, might question whether Kelly understands how mathematics can be used to help people in a variety of professions beyond teaching. Second, given our primary concern for improving mathematics teaching and learning, mathematics education scholars might wonder how the mathematics instruction that Kelly encountered shaped her mathematical identity and confidence. More specifically, although expectancy-value theory suggests that it makes sense for Kelly to consider exiting a field in which she lacks confidence, mathematics educators might choose to examine whether poor mathematics instruction contributed to her drop in confidence and/or if there may be a way for high-quality mathematics instruction to ameliorate this decline.

Finally, mathematics educators would likely be quite troubled by Kelly's perception that memorization is key to success in higher-level mathematics. This last point returns us to Fennema et al.'s (1998) study. In the two decades since Fennema and colleagues observed a greater tendency among boys to use invented strategies, several studies have found similar patterns (Gallagher et al., 2000; Goodchild & Grevholm, 2009; Lubienski et al. 2018; Zhu, 2007). These studies point to several hypotheses: Are girls socialized to be "good girls" who memorize and implement procedures given by the teacher or text, whereas boys are rewarded for becoming "outside the box" problem solvers? Does a "bolder" approach to problem solving have greater payoff on nonroutine, complex problems, thereby explaining larger gender gaps at the top of the distribution as well as the decline in women's confidence when reaching higher-level mathematics? How can mathematics teachers interrupt these patterns?

Such questions have risks. For example, as Leyva (2017) asks, might the portrayal of mathematics as primarily involving independent problem solving align with norms of middle-class, White men, perhaps thereby perpetuating stereotypes within the field? Gholson (2016) complicates this a bit further in noting that Black girls tend to exhibit some traits associated with mathematical success and masculinity, including confidence and independence. Her work prompts us to ask how the mathematical experiences of women of color might differ from those of Kelly, as well as whether more independent approaches to school mathematics might have more payoff for some students than others.

Musto's (2019) longitudinal study in a public suburban middle school near Los Angeles pertains to the questions of differential payoff and how engagement can be viewed differently in different contexts. Musto found that in higher track classes, which contained more affluent White and Asian American students, teachers allowed boys to break rules in class without consequence. However, in the lower track classes, where lower SES Latinx students were overrepresented, those same teachers tended to punish boys for breaking rules. While boys (especially White boys) in the higher track classes ended up dominating conversation and being perceived as exceptionally smart, the lower tracked boys pulled back from participation and were ultimately seen as less smart than the girls.

Sociological studies such as Musto's raise questions that provide additional opportunities for mathematics education research. For example, Musto's work can help us see how teachers might contribute to conceptions of who should express independence and who is smart in school, but the study does not focus specifically on mathematics. Mathematics education scholars could take such work a step further to examine how the interactions in classrooms affect the ways in which students identify with and engage with mathematics, including how they approach mathematical problems. Mathematics educators would also bring a critical eye to mathematics instruction, looking, for example, at ways in which highly structured instructional approaches may be more or less likely to exacerbate gender- and ethnicity-related patterns.

Still, such studies may be limited by their reliance upon binary gender categories and their focus on differences between these categories rather than their fluidity. Some scholars have begun to discuss how gender research that goes beyond such binaries might contribute to the field (e.g., McGraw et al., 2019; Walshaw et al., 2017). Additional studies might also examine how urban or rural school contexts can shape the gender- and ethnicity-related patterns examined by Musto in suburban schools. We also wonder how theories not focal in this article, such as Black feminist theory (Borum & Walker, 2012; Collins, 1990) and queer crit perspectives (Misawa, 2012), might help us ask new questions and examine data with new lenses.

Conclusion

In this brief essay, we could only scratch the surface of gender issues to be considered. The *Compendium for Research in Mathematics Education* chapter on gender (Lubienski & Ganley, 2017) further discusses evolving perspectives of gender and mathematics, international patterns, and additional potential factors shaping gender differences in mathematics outcomes. Clearly, there is more work to be done, and mathematics education scholars have a role to play in both informing and building from work grounded in other fields. Given the costs of underrepresentation of women in math-intensive careers to both women and those fields, such work merits our efforts.

Acknowledgements

The research reported in this article was supported by the MAXQDA Research Grants under the 2019 #ResearchforChange Grant.

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