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REVIEW ARTICLE

Gender Gap in Science, Technology, Engineering, and Mathematics (STEM): Current Knowledge, Implications for Practice, Policy, and Future Directions

Ming-Te Wang[1] · Jessica L. Degol[1,2]

Abstract Although the gender gap in math course-taking and performance has narrowed in recent decades, females continue to be underrepresented in math-intensive fields of Science, Technology, Engineering, and Mathematics (STEM). Career pathways encompass the ability to pursue a career as well as the motivation to employ that ability. Individual differences in cognitive capacity and motivation are also influenced by broader sociocultural factors. After reviewing research from the fields of psychology, sociology, economics, and education over the past 30 years, we summarize six explanations for US women's underrepresentation in math-intensive STEM fields: (a) cognitive ability, (b) relative cognitive strengths, (c) occupational interests or preferences, (d) lifestyle values or work-family balance preferences, (e) field-specific ability beliefs, and (f) gender-related stereotypes and biases. We then describe the potential biological and sociocultural explanations for observed gender differences on cognitive and motivational factors and demonstrate the developmental period(s) during which each factor becomes most relevant. We then propose evidence-based recommendations for policy and practice to improve STEM diversity and recommendations for future research directions.

Keywords Gender gap · STEM · Career preference · Lifestyle value · Relative cognitive strength · Motivation

Although women comprised the majority of medical and health science degrees and occupations in recent decades in the USA (U.S. Department of Eduation, NCES 2012), they continue to be underrepresented in the most mathematically intensive fields in Science, Technology,

✉ Ming-Te Wang
mtwang@pitt.edu

Jessica L. Degol
jld467@psu.edu

1 University of Pittsburgh, 230 South Bouquet Street, Pittsburgh, PA 15260, USA

2 Penn State Altoona, 3000 Ivyside Park, Altoona, PA 16601, USA

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Engineering, and Mathematics (STEM) (National Science Foundation 2011). For example, statistics on earned bachelor's degrees in 2012 show that women were awarded 59 % of degrees in the biological/biomedical sciences but in math-intensive fields made up only 43 % of degrees in mathematics and statistics, 18 % of degrees in computer and information sciences, 19 % of degrees in engineering, and 38 % of degrees in the physical and technological sciences (U.S. Department of Education, NCES 2014). Women are also underrepresented at the graduate level, receiving only 29, 19, 23, and 34 % of doctorates in mathematics and statistics, computer and information sciences, engineering, and physical and technological sciences, respectively (U.S. Department of Education, NCES 2014). On the other hand, women represent 54 % of all earned doctorates in the biological and biomedical sciences and 48 % of all earned medical degrees (M.D.) since 2012 (U.S. Department of Education, NCES 2014). These statistics demonstrate that math-intensive fields are among the only STEM fields in which women have not yet reached parity with men. This issue has received widespread attention in the USA, with social cognitive researchers offering up and debating theories to explain and address the persistent dearth of women in math-intensive fields. For instance, expectancy-value theory asserts that women are less likely to pursue math-intensive fields due to their relatively lower math and science expectancies and values in comparison with men, whereas mindset theory suggests that females are more susceptible to reduced math performance in the context of endorsing a fixed mindset in math ability (Wang and Degol 2014a). In this review article, we acknowledge the inherent value of using multiple theoretical orientations to explain male/female differences in career choices and, therefore, adopt a more global social cognitive approach to explaining women's underrepresentation in math-intensive fields.

Drawing on a broader social cognitive perspective, career pathways encompass the *ability* to pursue a career and the *motivation* to employ that ability (e.g., Dweck 2002; Eccles 2009; Lubinski et al. 2006). Without being good at math and science, it is probably difficult to pursue a STEM-related job. However, being capable in math and science does not necessarily mean that an individual will enjoy STEM-related activities or even pursue a STEM career. Therefore, in addition to cognitive ability, the competence beliefs, interests, and value that one attaches to relevant subject domains play a key role in career decision making. When individuals feel capable *and* interested in math and science, they are more likely to pursue STEM occupations (Su et al. 2009; Wang et al. 2015). Moreover, individual differences in cognitive capacity, competence beliefs, and motivation can be linked to biological processes and experiences in broader sociocultural contexts (Wang and Degol 2014a). Experiences and interactions in these contexts illuminate individuals' personal values, goals, social identities, competence to succeed, and connection to others. Over time, these sociocultural experiences accumulate to inform the development of cognitive ability and motivation, which in turn influence career choices.

The first goal of this article is to summarize the cognitive and motivational factors that affect women's decisions to opt out of math-intensive STEM fields. We then describe the potential biological and sociocultural explanations for observed gender differences in cognitive and motivational factors and discuss the developmental period(s) during which each factor becomes most relevant. We next propose evidence-based policy and practice recommendations, each supported by empirical research, to improve and increase female perceptions and interest in STEM and to retain and accommodate a larger female workforce by incorporating more flexible, family-oriented programs and policies in the workplace. The last is to offer suggestions for future research to expand our current understanding of gender issues in STEM.

Current Evidenced-Based Explanations for Gender Gap in STEM

Using a social cognitive perspective as our theoretical guide, we identify six empirically supported factors as the leading causes of female underrepresentation in STEM fields: (a) cognitive ability, (b) relative cognitive strengths, (c) career preferences, (d) lifestyle values, (e) field-specific ability beliefs, and (f) gender-related stereotypes and biases. Cognitive ability and relative cognitive strengths are cognitive factors indicating performance in quantitative and verbal reasoning, while career preferences, lifestyle choices, and field-specific ability beliefs are motivational factors reflecting personal interests, mindsets, goals, and values. Stereotypes and biases are sociocultural factors that potentially affect these cognitive and motivational factors.

Cognitive Ability Level

Research demonstrates that although girls earn higher grades in math than boys (American Association of University Women Educational Foundation 2008; Voyer and Voyer 2014), boys outscore girls on high-stakes standardized assessments. However, recent meta-analyses have revealed that gender differences in math ability on many standardized assessments are negligible with small average effect sizes ($d < 0.15$), ranging considerably by sample, testing source, grade level, and year the study was conducted (Hyde et al. 2008; Lindberg et al. 2010). Likewise, although males tend to outscore females on tests of spatial relations involving mental rotation tasks, these gender differences have been moderated by the use of time constraints and cross-national differences in gender equality (Lippa et al. 2010; Maeda and Yoon 2013; Voyer 2011). A female advantage even exists on other spatial relation tasks such as object identity memory and object location memory (Voyer et al. 2007).

Extending research beyond average differences in male/female performance on standardized tests, studies have found a disproportionately higher number of males scoring in the extreme right tail of the distribution, from which many talented STEM professionals are sourced (Wai et al. 2010, 2012). Between the years 2006 and 2010, boys outnumbered girls approximately 4:1 and 3:1 in the top 0.01 % of the distribution for the math subtests of the SAT and ACT, respectively. If cognitive ability levels were a primary cause for women's underrepresentation in math-intensive fields, we could expect to see proportions of male and female STEM workers comparable to these ratios. However, even with smaller proportions of females relative to males in these extreme scores (e.g., 4:1 or 25 % women), we see smaller percentages of women majoring and working in math-intensive fields.

Relative Cognitive Strengths

Meanwhile, recent evidence is converging toward the notion that gender differences in STEM are not reflected by differences in absolute cognitive ability but rather by differences in the breadth of cognitive ability (Valla and Ceci 2014). That is to say, relative cognitive strengths provide a stronger explanation for gender differences in STEM career choices than cognitive ability levels alone. Research demonstrates that gifted individuals are more likely than the general population to have uneven ability profiles (Lohman et al. 2008), which may affect career choices. When comparing mathematically gifted individuals, those with higher math skills relative to verbal skills are more likely to pursue STEM careers, while individuals with comparably high math and verbal ability are more likely to pursue non-STEM careers (Wang et al. 2013). Similarly, relative math and verbal performance among mathematically gifted individuals is strongly predictive of the field in which substantial career accomplishments are likely to occur; individuals with higher math ability relative to verbal ability are more likely to obtain a tenure-track position in a STEM field and to secure a patent, while individuals with higher verbal relative to math ability are more likely to secure a tenure-track position in the humanities (Park et al. 2007). Even among mathematically talented individuals, women are more likely than men to pursue non-STEM careers and are more likely than men to make notable career accomplishments in non-STEM fields than in STEM fields (Park et al. 2007). These ability patterns are divided along gender lines, with girls more likely to possess both high math and verbal ability and boys more likely to demonstrate higher math relative to verbal ability (Wang et al. 2013). As women are more likely than men to be highly skilled in verbal and math domains, they are potentially afforded a greater variety of career options.

Having one dominant cognitive aptitude is likely to reinforce a higher self-concept in that domain and an unequivocal goal of investing time, effort, and energy into pursuing that domain as a future career. Having multiple cognitive strengths, on the other hand, is likely to lead to more ambiguous expectancies and self-concepts and, therefore, less specific career goals (Valla and Ceci 2014). When individuals have stronger math skills relative to verbal skills, they may be more likely to use these ability differences as a guide toward pursuing a math-intensive career in order to maximize their potential for success. When individuals, on the other hand, have equally strong math and verbal skills (and women tend to have more balanced math and verbal abilities than men), their abilities are likely to take a backseat to their interests and values, which may explain why math-talented women are more likely to choose challenging non-STEM fields that are more practical or applied, as opposed to math-intensive STEM fields that are more theoretical or mechanical. As such, relative cognitive strengths appear to drive STEM career choices more than absolute cognitive ability and to be a primary factor explaining the dearth of women pursuing math-intensive careers.

Developmental Period It is difficult to pinpoint the specific age at which gender differences in cognitive abilities emerge. Research suggests that gender differences in average math ability are minimal throughout childhood and do not emerge consistently until mid-to-late adolescence, although right-tail differences favoring males are present as early as kindergarten and girls do lose some ground as they progress through elementary school (Lindberg et al. 2010; Robinson and Lubienski 2011). Research also shows that while gender gaps in verbal ability narrow over time, differences in average verbal ability favoring females are present at the start of kindergarten and remain throughout childhood (Robinson and Lubienski 2011). The emergence of gender differences in spatial orientation is also somewhat unclear (Miller and Halpern 2014). While some research has detected male advantages in spatial orientation tests as early as infancy and preschool (Moore and Johnson 2008; Quinn and Liben 2008), others have found no differences in performance (Frick and Wang 2014; Möhring and Frick 2013). Regardless of inconsistencies in research, evidence seems to point to the notion that gender gaps in cognitive abilities, no matter how stable or minimal, emerge in early and late childhood, which may have serious consequences given that this time period coincides with the beginning of formal schooling. Throughout childhood and adolescence, students' educational experiences may serve to reinforce these gender gaps in cognitive performance over time.

Biological and Sociocultural Explanations In an attempt to explain the link between gender and cognitive performance, research has examined the potential contributions of biology and environment. Although studies have examined whether biological factors such as testosterone exposure and greater brain lateralization are linked to superior mathematical reasoning and reduced verbal ability among males, findings have been inconclusive (Miller and Halpern 2014; Valla and Ceci 2011). Contrasting this are the more consistent findings of the sociocultural impact on gender differences in quantitative and verbal reasoning. Enriched STEM-related learning experiences predict notable STEM accomplishments even among mathematically gifted individuals (Wai et al. 2010). Additionally, parents may shape children's math expectancies and performance by communicating their own gender-biased beliefs about how girls and boys should perform in math. For example, research has found that parents with stronger gender-math stereotype beliefs (e.g., beliefs that boys are better at math than girls and find math more useful and more important than girls) had higher perceptions of math ability for their sons and lower perceptions of math ability for their daughters. These parental beliefs, in turn, were positively associated with children's own math ability beliefs (Jacobs and Eccles 1992; Tiedemann 2000a; b).

In addition, several cross-national studies indicate that greater cultural inequities between males and females are associated with larger gaps in mathematical performance favoring males (Else-Quest et al. 2010). Specifically, nations with higher proportions of women enrolled in postsecondary science courses and employed in science careers are less likely to explicitly endorse the stereotype that science is a masculine profession (Miller et al. 2015). These cultural values and beliefs about male/female abilities and roles are communicated to children through prominent adult figures. For example, a meta-analysis found that parental gender stereotypes reflecting male/female roles, interests, and abilities were linked to children's gender schemas about others and their attitudes about gender occupational roles (Tenenbaum and Leaper 2002). Similar to the sex differences in math performance favoring boys, sex differences in verbal performance favoring girls may be partially derived from parental socialization at young ages. For example, research found that mothers talked more and used more supportive speech with their daughters than their sons (Leaper et al. 1998). In another study using nationally representative data, parents spent more time teaching girls verbal activities, such as reading and storytelling (Baker and Milligan 2013): some of these differences emerged in early childhood and persisted into elementary school. Although these studies did not link these socialization differences directly to cognitive performance, these differential experiences for boys and girls may partially explain why girls are more likely to outperform boys on standardized tests of verbal ability. Therefore, while biological factors cannot be definitively dismissed, sociocultural influences appear more likely to impact gender differences in cognitive ability.

In summary, individuals with more symmetrical cognitive profiles in verbal and math domains are more likely to choose non-STEM professions as a result of the greater number of career options available to them, and because symmetrical profiles are more often found in women, they are also more likely to pursue other occupations. However, if women have more varied career options available to them, why are they opting out of math-intensive fields at such high rates? Relative cognitive strengths still cannot fully explain this phenomenon; otherwise, high math and verbal ability women would be equally likely to pursue both STEM and non-STEM fields. There appears to be additional motivators and selection factors that operate in career decisions. These main factors, which will be discussed in further detail below, are gender differences in occupational preferences, family obligations/lifestyle values, and field-specific ability beliefs.

Career Preferences

Gender differences in career interests also contribute to women's underrepresentation in math-intensive fields. A meta-analysis showed that males prefer working with objects, whereas females prefer working with other people (Su et al. 2009). The magnitude of these gender differences was large ($d = 0.93$). Additionally, considerable effect sizes were found for men's greater interest in STEM (e.g., engineering, $d = 1.11$, and mathematics, $d = 0.34$) and women's greater preferences for socially oriented occupations ($d = 0.68$). Women's preferences for socially oriented occupations may be motivated by altruism, as women report a greater desire than men to help others and benefit society (Freund et al. 2012): STEM careers are often considered incongruous with communal goals, leading many women to overlook STEM careers (Diekman et al. 2010; Diekman et al. 2011). Even within STEM fields, women are more likely to choose degrees that emphasize community or are people-oriented. Women, for example, obtain degrees in biomedical and environmental engineering at higher rates than in mechanical or electrical engineering (Ceci and Williams 2011). This evidence suggests that preferences may outweigh ability, even among women who select careers in STEM (Tai et al. 2006).

Developmental Period Gender differences in work preferences and occupational aspirations are well established by late adolescence (Correll 2001), but some research suggests that science career interests may be established in middle school (Maltese and Tai 2010). This research has important ramifications for the selection of STEM careers. High school is a crucial period for establishing math-intensive career trajectories, particularly since youth have more freedom to choose courses that are of interest to them, and advanced math courses in high school are often a prerequisite for enrolling in a math-intensive STEM major (Correll 2001). However, despite students having little choice in the courses they take before high school, their educational and career interests may still impact their selection of activities that further enhance, nurture, and develop these career interests. Interests in math and science prior to high school may set the tone for future STEM career selection, and over time, the choices youth make, as well as the educational experiences they elect to have in high school and college, can serve to reinforce these interests (Maltese and Tai 2010, 2011). Indeed, gender differences in STEM careers that reflect differences in interests reach back as far as early adolescence and are reinforced through a continual process of decision making, experiential outcomes, and expectations of others.

Biological and Sociocultural Explanations Researchers have long examined the contribution of biological and sociocultural factors to gender differences in interests and behaviors (Alexander et al. 2009). For example, one study found that girls with congenital adrenal hyperplasia (CAH), a condition resulting in abnormally high exposure to prenatal androgens, played with masculine toys more often than control girls (Wong et al. 2012). However, this association was mediated by parents' encouragement to play with non-feminine toys, suggesting that socialization influences are still largely at play. In fact, overall findings conclude that although androgen exposure may influence sex differences in preferences, the impact of socialization on sex-typed interests and behavior cannot be overlooked (Spelke 2005).

Abundant cultural stereotypes lead many women to believe that math-intensive careers are inconsistent with their desire to work with people, which may explain their decreased interest in these careers (Diekman et al. 2011).

Family-Work Balance and Lifestyle Values

The fourth factor concerns gender differences in lifestyle preferences or the priorities that females and males place on family versus career (Hill et al. 2010). Women are not only more willing than men to make occupational sacrifices for the sake of their families (Eccles et al. 1999), they also prefer work-centered lifestyles at lower rates than their male counterparts (Hakim 2006). When women make plans to have children, the overlap between their optimal years of fertility and tenure pursuits result in many viewing STEM careers, or tenure-track academic careers in general, as unsuited to achieving their familial goals (Mason and Goulden 2004; Williams and Ceci 2012). In academia, for instance, women seem to be vacating tenure-track positions or seeking out more flexible part-time academic positions at higher rates than men, resulting in women becoming overrepresented in part-time or full-time instructor and lecturer positions and underrepresented among full-time associate professor and full professor faculty positions (Kena et al. 2015). Even among men and women who were equally matched in both high mathematical ability and STEM interest, differences in lifestyle values emerged as individuals entered their mid-30s (Ferriman et al. 2009). While women with children placed higher value on work flexibility, the preferences of men with families did not markedly differ from those without children. These findings suggest that highly talented women's lifestyle priorities can shift to family-centered goals as they become parents.

Developmental Period Gender differences in lifestyle preferences usually emerge in adulthood as men and women experience important life transitions (e.g., marriage, parenthood) that enable them to reassess how their careers align with their lifestyle goals (Ferriman et al. 2009). As women begin to focus on familial obligations, new obstacles to their STEM achievement arise. STEM fields are rapidly changing and require a substantial time commitment and continuous development of expertise to remain both productive and competitive (Lubinski and Benbow 2006). Women with children, due to the increased number of hours they devote to housework and caretaking, work far fewer hours than men with or without children and women without children (Jacobs and Winslow 2004). Furthermore, the nature of STEM careers makes it difficult for women to take maternity leave and maintains the productivity levels of their male and childless female peers (Ceci and Williams 2011). These findings, therefore, may explain why women are not only less likely to select math-intensive careers but are also more likely to leave them.

Biological and Sociocultural Explanations It is difficult to discern the relative contribution of biological factors from sociocultural factors that influence male/female differences in family lifestyle preferences. Although most cultures reflect women's reproductive capacity in how they split work roles by gender, the extent of this division varies by culture and degree of patriarchy present therein (Wood and Eagly 2002). In the USA, women's decisions to spend more time caring for their families and less time in the workplace may reflect their personal choices, but despite progress made by the women's rights movements of the 1970s, American cultural norms and stereotypes still dictate that women are primarily responsible for childcare and housework. These added responsibilities, due to cultural pressures and personal choices, make it difficult for women in math-intensive STEM fields to allocate the time necessary to keep up with the latest innovations and remain competitive within the field.

Field-Specific Ability Beliefs

Field-specific ability beliefs have also emerged as a potential explanation for the underrepresentation of women in math-intensive fields. Recent research has shown that individuals are more likely to rate male-dominated fields as requiring innate intelligence or brilliance compared to fields with a larger proportion of women (Leslie et al. 2015; Meyer et al. 2015). These findings were upheld regardless of whether the field in question was STEM or non-STEM (Meyer et al. 2015), indicating that gender distributions across disciplines are not only influenced by STEM interests and beliefs but also by the extent to which innate intelligence is believed to be needed for success in a career. The importance of effort versus intelligence in shaping women's motivation has been widely researched. Individuals with a fixed mindset believe that intelligence is a static trait or an innate ability, while individuals with a growth mindset believe that intelligence is malleable and that effort, practice, and persistence can enhance ability over time. Decades of research has found support for differences in academic outcomes for individuals with fixed versus growth mindsets. For instance, studies have shown that youth with growth mindsets had higher academic performance and higher completion rates of challenging math courses than youth with fixed mindsets (Blackwell, Trzesniewski, & Dweck 2007; Yeager and Dweck 2012). Individuals with a growth mindset are also more likely to persist in the face of a challenge, while individuals with fixed mindsets are more likely to give up for fear of failure. Fixed mindsets can be problematic, particularly for girls and women who believe that math ability is due to innate intelligence. After conducting several decades of research on this topic, Dweck et al. found that girls cope less well than boys when confronted with difficult math material and are more susceptible than boys to experiencing reduced math performance when they endorse a fixed mindset (Dweck 2007). These findings suggest that women may be avoiding challenging careers in STEM not only because they erroneously believe that innate intelligence is needed for success in these fields but also because they erroneously believe that they belong to a group that is less likely to possess the qualities needed for success in these fields.

Developmental Period Research on mindset has been examined from elementary to post-secondary school environments. However, mindset may emerge as a more prominent factor in children's academic performance during transitions from elementary to secondary school. During middle school and high school, the learning environment is more likely to emphasize performance goals, which stands in contrast to the more mastery-oriented approach of elementary schools (Eccles et al. 1993). Likewise, middle and high school environments are more likely to emphasize competition and comparison, to rely upon pre-established benchmark levels to rate student performance, and to highlight high-stakes standardized testing (Eccles et al. 1993). These changes are believed to contribute to the reduced motivation and academic performance of youth following the transition to secondary school.

Biological and Sociocultural Explanations Mindset and learning goals do not exist in a vacuum. Research has shown that mindset is malleable and can be shaped by social forces. For example, classrooms in which teachers emphasize mastery of material rather than relative performance have students with greater interest in challenging themselves, greater interest in increasing their understanding, and higher achievement (Friedel et al. 2007; Meece et al. 2006; Roseth et al. 2008). Meanwhile, students in classrooms that emphasize performance goals are more likely to avoid challenging material and give up more easily (Turner and Patrick 2004; Wolters 2004). This research suggests that teachers' own goals and mindsets about learning may be powerful influences over students' own mindset and subsequent academic performance. In fact, experimental work has shown that when experimenters praised children's effort rather than ability, participants were more likely to persist through challenging tasks, displayed more task enjoyment, had higher task performance, and were more likely to endorse learning goals rather than performance goals (Mueller and Dweck 1998). Additionally, interventions promoting a growth mindset administered in junior high school led to increased student endorsement of a growth mindset, motivation in math, and math achievement relative to that of a control group (Blackwell et al. 2007): intervention effects in math achievement trajectories were stronger for youth who originally endorsed a fixed mindset. Using this same sample, Dweck (2007) further found that girls benefited more than boys from growth mindset training, which eliminated the discernible gender gaps in math performance favoring boys found in the control group. This research demonstrates that women may be more likely to pursue math-intensive STEM fields if greater emphasis is placed on the importance of effort and practice in math achievement.

Gender-Based Stereotypes and Bias

An often disputed factor within this field is the extent to which discrimination and prejudice contribute to the underrepresentation of women in math-intensive fields. Ceci et al. recently reviewed the literature for consistent or discernible favoritism of males across various STEM academic fields (Ceci et al. 2014; Ceci et al. 2009). They were unable to find any convincing pattern of discrimination against women entering or progressing through their scientific careers, leading to their conclusion that prejudice and discrimination are a historical rather than current cause of women's underrepresentation in STEM fields. They added that bias and discriminatory behaviors are more likely to occur at younger ages when boys and girls are starting to develop their career interests. However, their work narrowly defined gender discrimination as recent hiring and promoting practices, mainly across major research universities. As a result, they failed to distinguish between the prevalence of overt and covert forms of discrimination, ignored the extent to which sexism and gender bias exist on a daily basis within educational and work settings, and neglected to examine how gendered messages about math and science manifest throughout the lifespan.

Discrimination researchers have long distinguished between overt or intentional forms of gender discrimination and covert or subtle forms of gender discrimination, which include denial that discrimination exists, antagonism toward women who make demands for equality, and resentment about special favors provided for women to enhance equality (Swim et al. 1995; Swim and Cohen 1997). Additionally, discrimination researchers have established the differences between hostile and benevolent forms of sexism. Both include beliefs that men should be dominant over women, but while hostile forms include derogatory and exploitative views and behaviors toward women, benevolent includes affectionate views and behaviors toward women (e.g., men as the provider and protector, women as the nurturer). Both forms of sexism serve to keep women out of positions of power and to keep patriarchy firmly in place; however, benevolent forms are often overlooked as forms of sexism and may not even be perceived as detrimental to women (Glick and Fiske 1997; Swim et al. 2005).

Although overt or deliberate practices of discrimination may no longer be as prevalent as they were decades ago, covert and benevolent forms of sexism still exist and occur throughout the lifespan, undoubtedly shaping male/female career trajectories. For example, a number of studies have shown that parents and teachers underestimate girls' math ability relative to boys' despite having similar grades (Bleeker and Jacobs 2004; Lubienski et al. 2013; Tiedemann 2000b), encourage boys more often in math and science pursuits (Tenenbaum 2009), and attribute boys' successes in math more to ability and failures in math more to lack of effort, while the opposite is believed to be true for girls (Tiedemann 2000a). In fact, the stereotype in Western culture that math and science are male domains is so pervasive that children as young as six subscribe to it (Miller et al. 2015). For example, a US sample of first and second graders found that boys and girls exhibited implicit and explicit gender-math stereotypes, in which males were more likely to associate math with their own gender than were girls (Cvencek et al. 2011). Likewise, differences in parental support for math and science occur at very young ages, with parents discussing and explaining science content more frequently to young boys than girls despite a lack of gender differences in the number of child-initiated science prompts (Crowley et al. 2001). Although parents and teachers may not be consciously or intentionally perpetuating stereotypes, the gender experiences that girls have with math and science are likely sending the message that math and science are male domains.

As children age, peers are also likely to become important influences of STEM course and career selection. Research shows that youth with peer groups who encourage, endorse, or exemplify high math and science achievement are more likely to take more math courses (Crosnoe et al. 2008), have higher math and science motivation (Leaper et al. 2012), and are more likely to see themselves as future scientists (Stake and Nickens 2005). While these relationships are rather consistent for boys and girls, a slightly stronger association between peer relationships and girls' math and science behaviors and beliefs tends to be found (Crosnoe et al. 2008; Stake and Nickens 2005). In other words, due to the pervasive nature of gender stereotypes in STEM, girls may be more susceptible to peer social influences in these areas, which may be detrimental if peers are not supporting girls' math/science interests.

Additionally, there is evidence that a subconscious or implicit bias against women scientists exists in higher education settings. For instance, college students were more likely to rate the same conference abstracts as lower in scientific quality if the author's name was female instead of male, particularly if these topics had traditional masculine themes (Knobloch-Westerwick et al. 2013). Other recent experiments have also shown that faculty are implicitly biased in favor of hiring males in academic positions. For example, science faculty rated female student applicants for a laboratory manager position as less competent and hirable than males, despite having the same application materials (Moss-Racusin et al. 2012). In another study, when female and male applicants with equal performance on an arithmetic task applied for a hypothetical job, male candidates were twice as likely to be hired as females (Reuben et al. 2014). Although this research does not unequivocally demonstrate the extent to which these biases actually lead to discriminatory practices, research shows that stereotyping and implicit biases do influence females' interest in science. For example, it has been demonstrated that male-dominated fields such as computer science may deter females due to a lack of perceived similarity and belonging (Cheryan and Plaut 2010) and that removing stereotypically masculine objects from computer science classrooms can actually increase female interest in these courses (Cheryan et al. 2011a; Cheryan et al. 2009). Cumulatively, while there may not be a preponderance of evidence that covert discrimination is occurring in the hiring and promoting practices of women in major research universities, gender stereotypes and implicit bias may dissuade many girls from even pursuing STEM fields in the first place, thereby effectively keeping male-dominated fields "male-dominated."

Summary

Female underrepresentation in math-intensive STEM fields is a cultural phenomenon brought about by the complex interaction of six underlying factors: (a) absolute ability differences, (b) relative ability strengths, (c) career preferences, (d) lifestyle preferences, (e) field-specific ability beliefs, and (f) gender stereotypes and bias. Absolute ability differences, relative ability strengths, career preferences, and lifestyle preferences have all been considered to have their roots in biology, stemming mainly from sex differences in prenatal androgen exposure. However, sociocultural factors, such as societal beliefs and expectations of male/female differences in ability (e.g., men are analytical and logical, women are emotional and hysterical) and cultural pressures to pursue traditionally masculine or feminine interests (e.g., "boys don't play with dolls"), are far more likely than biology alone to impact career decisions. While these findings may seem discouraging, as they highlight the continued existence of rigid, flawed, and narrow views of what it means to be male or female in our society, as with most research there is a silver lining. The fact that sociocultural factors have such a strong influence over individual career decisions also means that we may intervene to alter these outcomes. Strategies for intervention will be addressed more fully in the following section.

Despite recognition that intervention is crucial, the salient time points for intervention vary across each of these six factors. Ability differences emerge in early childhood, as discernible gender gaps in verbal ability and spatial relations are evident before kindergarten, and right-tail differences in math ability favoring males are also prevalent during this period. Likewise, gender stereotypes and bias emerge early, starting when the sex of a fetus is identified (e.g., pink for girls, blue for boys) and affecting parental behavior ranging from wardrobe selection to toy purchases (e.g., cars and blocks for boys; dolls, and easy-bake ovens for girls). Parents' own stereotype endorsements, beliefs and expectancies, and behaviors may have an impact on their daughters' identification with math and nascent gender identity in girls as young as six. Therefore, stereotypes emerge early and continue to be salient throughout the lifespan. Career preferences and field-specific ability beliefs, on the other hand, although potentially emerging in early childhood as well, seem to come into play more so in middle childhood and adolescence. The older a child becomes, the more likely they are to make realistic connections between their interests and career choices and make deliberate choices to partake in activities that enhance these interests, which may better prepare them for a career in STEM. They are also more vulnerable to changes in school contexts during these time periods, during which schools become more performance-oriented and less mastery-oriented. As such, career interests and field-specific ability beliefs are more prevalent during middle childhood and adolescence, although they remain important throughout postsecondary education as well. Finally, lifestyle preferences do not seem to emerge as a leading factor in the underrepresentation of women until adulthood, after women have already chosen a career in STEM, and when their work in STEM begins to collide with family formation and child rearing responsibilities. Women's experiences in postsecondary education (e.g., during their graduate and postdoctoral work) and in the workplace (e.g., as faculty members striving for tenure) will become crucial deciding factors over whether they consider their careers in STEM to be compatible with their lifestyle values and goals.

Recommendations for Policy, Practice, and Future Research

In order to address the main causes of women's underrepresentation in math-intensive STEM, we provide practical suggestions for addressing the pervasive gender imbalance in STEM fields. The first seven can be implemented to promote increased female interest in pursuing STEM occupations. The last five recommendations suggest future research directions to improve intervention efforts and provide a better understanding of how best to intervene to improve female outcomes.

Recommendations for Policy and Practice

Focus on Ability Enhancement but Also Interest Enhancement Research shows that aptitude and interest are equally crucial to determining the career paths that individuals choose. Girls with high math achievement and little interest or motivation in pursuing a STEM occupation are far less likely to obtain a science degree than individuals with average math skills and high interest in science (Tai et al. 2006). Therefore, although it is still important to promote achievement in math and science, cultivating interest in these subjects should produce more female scientists in the long run. In particular, it is critical to cultivate the interest of females who are equally good at math and verbal domains, as they have the talent to succeed in STEM but do not seem to have the interest (Wang et al. 2013). Furthermore, since females are more likely to prefer careers that allow them to work with people and make positive contributions to society, occupations in math and science should be promoted as compatible with these career goals by stressing the more communal and altruistic aspects of the job (Su et al. 2009). Practitioners and policymakers, for instance, can play up how advancements in areas such as computer science and engineering—which are not viewed as highly people-oriented professions—can improve the overall quality of life and require extensive collaboration with other researchers and colleagues. The optimal time for intervention would be during middle childhood and adolescence, before youth lose the opportunity to enroll in the advanced math and science courses that will best prepare them for a major in STEM.

Intervene Early to Cultivate Interest in Math and Science Research shows that most people make their future career decisions before entering college and that interests in math and science develop as early as middle school (Maltese and Tai 2011; Tai et al. 2006). Therefore, the earlier we intervene to cultivate interests the better. This could be particularly crucial during late childhood and early adolescence when children are better able to make domain-specific interest/ability connections to actual career choices. Additionally, since women scientists report that school experiences were crucial to the development of their interest and curiosity in science, providing and sustaining positive classroom experiences for girls from elementary through secondary school is a pivotal goal (Maltese and Tai 2010). Some examples include smaller classroom sizes to promote more positive interactions among students and teachers (Deutsch 2003; Haughey et al. 2001; Stecher and Bohrnstedt 2002), cooperative learning environments that enhance confidence in math abilities (Wang 2012), providing clear expectations for grades and feedback on how to improve work (Hill et al. 2010), and providing hands-on science and math activities that students can relate to real-life situations.

Break Down Stereotypes About Women and STEM Stereotypes are pervasive throughout society and can influence beliefs about an individual's strengths and shortcomings, even when evidence of their skill level indicates otherwise. These beliefs can influence the way in which individuals think, behave, and feel about their own abilities, in addition to the way in which they view others. Therefore, we need to combat negative stereotypes by highlighting the achievements of women and girls in STEM areas. For example, as the school and home environments are important sources for sparking science interest in girls, teachers and parents can communicate that men and women are receiving equivalent achievement in nearly every STEM subject and that greater numbers of women have been entering and succeeding in STEM fields in recent years. Eliminating stereotypically "masculine" objects from STEM classrooms may also increase women's interest in those fields by removing perceptions that these fields are not for women (Cheryan et al. 2011a; Cheryan et al. 2009). Finally, the media should strive to create more positive portrayals of female professionals in STEM fields, so that girls and women encounter well-rounded and realistic images of successful women scientists. An example of this is the recent NSF-funded "SciGirls" television series, which features young girls performing science experiments with the help of a female scientist mentor, and Project Scientist, which includes a summer camp where girls spend 5 weeks studying different scientific topics, conducting hands-on experiments, and working with female STEM role models. Intervening to reduce gender-stereotyped beliefs and behaviors should occur throughout the lifespan, as differential treatment of males and females begins early in a child's life and continues into adulthood.

Emphasize Effort and Hard Work Instead of Talent A leading factor in women's underrepresentation in math-intensive fields is the fact that women are less likely to select careers that are perceived to require innate intelligence, which are likely to include math-intensive careers. To counter this, educators must stress the importance of effort and hard work in achieving success in math-intensive careers. They should also reinforce a growth mindset in girls to increase their understanding that math ability is cultivated through effort and persistence and is not a static or immovable trait (Dweck 2007). Specifically, research has demonstrated that praising children's effort and not their ability will encourage greater persistence and achievement (Mueller and Dweck 1998). Classrooms that emphasize learning and improvement over performance are also associated with more positive academic outcomes for youth (Leslie et al. 2015; Meece et al. 2006; Meyer et al. 2015). Therefore, downplaying the role of innate intelligence in these fields should hopefully encourage more women to pursue STEM careers. As growth versus fixed mindsets seem to emerge during late elementary school, emphases on effort, persistence, and hard work should begin as early as possible to enhance academic performance.

Add More Storytelling to STEM Learning Given that girls are more likely than boys to have high verbal and math skills, girls may get more out of science and math lessons if they are taught through the lens of a story. This educational strategy might enable girls and women to retain interest in STEM subjects by capitalizing on the strengths of their verbal skills. Learning through storytelling may also increase interest and engagement with math and science by making these subjects appear more hands-on and relatable (Kelleher et al. 2007; Sadik 2008). For example, instead of solely relying on textbooks that dryly transmit concepts, functions, and formulas, science teachers could incorporate novels and writing assignments into their teaching material (Allen 2004). Many scientific achievements and well-developed theories have compelling stories embedded within rich cultural and historical contexts that can teach students a great deal about how scientific ideas unfold, evolve, and impact society. Scientific narratives provide students with memorable real-life applications for the subject matter that can increase both male and female interest in identifying as future scientists or mathematicians.

Communicate the Relevance of a STEM Degree to Real-World Applications Many individuals may not truly understand what it means to obtain a degree in STEM. Introducing youth to the different majors they can pursue in STEM and the careers that these degrees will prepare them for can provide adolescents with a better understanding of the nature of these occupations. For instance, what does an engineer do? What kind of jobs can an engineer obtain? What training and coursework is necessary to receive a degree in engineering? Describing how STEM fields can be collaborative, innovative, and beneficial to society as a whole (i.e., altruistic) and making careers in STEM more relatable and accessible to girls in everyday life should increase women's interest in pursuing these careers (Diekman et al. 2011). For example, it is important to convey to young people, particularly females, that although careers within engineering or computer science may not involve direct patient care, such careers have a beneficial impact on society and do allow individuals to collaborate with other people. Ensuring that women are well informed of the full diversity of options available in STEM will enable math-competent females to better evaluate both the utility and cost of different STEM career possibilities. When promoting STEM careers, professionals may also want to balance the difficulty of obtaining a STEM degree with the level of enjoyment, creativity, and innovation it can bring. This is also where emphasizing a growth mindset in girls is important; we do not want girls to give up simply because a field is difficult or challenging. These promotional practices are relevant beginning in late elementary school when children have more realistic career expectations.

Providing More Female Role Models for Girls and Women Research has shown that female role models are important for increasing positive female attitudes toward STEM careers (Cheryan et al. 2011b; Stout et al. 2011). As they are the minority in STEM fields, women may be reluctant to pursue these careers due to a lack of female mentors, colleagues, and peers through which they can establish a support system and a sense of connectedness. This creates an unending cycle in which women cannot be recruited into a field, due to the initial problem that there are not enough female STEM professionals in these fields. However, broader exposure to successful female role models in STEM might encourage girls to reject the stereotype that math and science careers are for men. This can be accomplished through career fairs and inviting successful female STEM scientists and professionals to visit schools on career days. In addition, STEM departments in universities should provide and encourage networking opportunities for women to establish a peer support system. Ideally, this process would introduce girls to STEM role models in elementary school, so that they begin to associate "girls" with "math" and "science" as early as possible.

Accommodate Women's Familial Obligations in the Workplace Among both academic and non-academic positions, women's professional responsibilities come into direct conflict with their familial obligations. The workplace is often lacking in support for women with young children and other caretaking responsibilities. The result is not just that women decide against pursuing STEM careers but that they also vacate STEM positions at greater rates than men do, particularly after taking a leave of absence following the birth of a child. The result is fewer and fewer women at the top positions in their fields. Solutions to this problem include providing paid maternity leave and medical benefits, stoppage of tenure clocks for maternity leave, and on-site high-quality and affordable child care for female graduate students, postdoctoral fellows, faculty members, and professionals. Although these recommendations would mainly be targeted at female professionals, similar opportunities should be provided for fathers so that they can be more supportive and readily available to their spouses and children.

Future Research Directions

Address Gender Differences Within STEM Choices Much research has been dedicated to studying gender differences *between* math-intensive STEM and non-STEM careers, but few studies address the gender gap *within* STEM careers and investigate why females are more drawn to less math-intensive STEM careers. Women are not underrepresented in all STEM fields, but the extent of their underrepresentation varies by domains within STEM. Women now account for nearly half of medical doctor degrees and 44 % of PhD degrees in the life sciences, but they persist to be underrepresented in the most math-intensive STEM fields. It is informative to examine factors that determine entry into less math-intensive STEM occupations versus math-intensive STEM occupations. For example, are women with equally high math and verbal ability more likely to enter medicine than engineering? Do gender differences persist because women equate less math-intensive STEM with achieving communal goals and more math-intensive STEM with achieving agentic goals? Efforts to increase female participation in STEM should differentiate the factors leading to specific STEM disciplines, especially those with the lowest overall participation of women.

Expand Focus to Female Racial Minorities Many initiatives have been focusing on closing the gender gap in STEM, yet female diversity is often overlooked. African American and Latina women are underrepresented in STEM relative to White and Asian females (U.S. Department of Education, NCES 2012). Women tend to be viewed as a homogeneous group of individuals with similar needs, experiences, and barriers to social progress. As such, many studies have treated gender and race separately, obscuring their complex intersection in the context of racial minorities' unique social history. As members of two stigmatized groups, African American and Latina women are at risk for additive discrimination, known as "double jeopardy" (King 1992). This especially occurs in STEM fields, where academic stereotypes around both race and gender are salient. Indeed, research documents that although African American undergraduate women maintain interest in science, they often choose not to pursue science careers due to concerns about racism and sexism (Hanson 2004). Although African American and Latina girls may experience "double jeopardy," evidence also shows that gender socialization in many racial minority communities may provide girls with unique resources that support sustained interest and effort in STEM. For instance, research suggests that, compared to their White peers, African American girls are more likely to perceive work as an important dimension of family (Hanson 2007). Consequently, African American girls' gender socialization may protect against the perceived conflict between STEM careers and family that prevents many girls from pursuing STEM occupations (Hanson 2004). Given that racial minority females face unique challenges and protective factors in STEM contexts, future work should examine the interactive roles of gender and race in the underrepresentation of racial minority females in STEM and tailor policy initiatives to address the unique needs of this diverse population.

Translate Research Into Evidence-Based Interventions Several interventions have been found to successfully alter girls' and women's perceptions of STEM (e.g., Diekman et al. 2011; Stake and Nickens 2005; Weisgram and Bigler 2006, 2007). Although the recommendations provided in this paper are corroborated by research, there remains a need to translate research-supported understanding into effective practices (Liben and Coyle 2014). What is the best delivery method for these program initiatives: home, school, peer groups, media, or perhaps some combination of all four? If we intervene early to promote female interest in STEM, how long should program effects last to consider them successful? Many extant studies only examine immediate shifts in individual attitudes and performance following exposure to an intervention. Future research should seek to investigate longitudinal changes and whether they produce meaningful modifications in women's career interests and goals. Additionally, interventions should not focus exclusively on altering girls/women's attitudes about STEM but should also target parents, teachers, STEM faculty, and employers to reduce the implicit bias and stereotypes that individuals have about women scientists. Likewise, Liben and Coyle (2014) also call for more rigorous evaluations of STEM programs, such as the use of comparison groups, long-term follow-ups, and the measurement of unintended consequences (e.g., increased gender-schematic behaviors resulting from exposure to a girls-only STEM program).

The Role of Science, Math, and English A richer understanding is needed of the unique interplay between science, math, English interest, and achievement in determining women's career choices. Studies have explored how relative math versus verbal ability predicts career choice (Chow et al. 2012; Wang et al. 2013). For example, Ackerman et al. identified trait clusters representing a science/math/technology profile (i.e., investigative and realistic interests, high self-concept in science, math, and spatial skills) and a verbal/intellectual profile (i.e., high verbal self-concept, investigative and artistic interests), which differentially predict domain-specific knowledge (Ackerman, Bowen, Beier, and Kanfer 2001). Having a science/math/technology trait profile was associated with greater knowledge in the physical sciences and technology, while having a verbal/intellectual profile was associated with greater knowledge in the humanities, civics, and the biological and psychological sciences. However, little is currently known about the relative impact of science, math, and English interest and ability on men and women's STEM educational and career choices. For example, the practice of combining math and science into a general math-science factor or examining them in separate models (Simpkins et al. 2006) limits the field's ability to compare their influence. Without this specificity, it is difficult to know if high math and science interest are equally important for choosing STEM or if high interest in one domain can offset the effects of low interest in another. Furthermore, since women are more likely to pursue science fields that are less math-intensive, it would be valuable to know whether higher math ability and interest relative to science are more important for math-intensive careers and whether higher science interest and ability relative to math are a factor for less math-intensive STEM careers. Ultimately, additional research is needed to answer questions regarding the relationship between domain-specific ability and motivational factors.

Examine Interplay of Biological, Psychological, and Environmental Factors There is a greater need for collaborative research models that incorporate the complex interplay of biological, psychological, and environmental factors and how they interact to influence female career choices and STEM performance. Although research has focused on identifying biological and sociocultural factors responsible for the divergence in gender abilities, interests, and career choices, separating sociocultural and psychological influences from genetic endowment has proven difficult (Wang and Degol 2015). It is clear that these factors are more than the sum of their parts; they aggregate and interact over time. Integrated developmental models are necessary to describe the complex interactions among biological, sociocultural, and psychological factors and how psychological states and sociocultural contexts may mediate or moderate STEM performance among males and females (Wang and Degol 2014b). Regardless of biological differences, experiences and situations that support or inhibit female success in STEM could be better identified through research that integrates the multiple biological, sociocultural, and psychological contexts that shape career development.

Conclusion

To reduce the gender gap in STEM, attention should be given to address the contributory cognitive, motivational, and sociocultural factors, primarily by maximizing the number of career options that women perceive as attainable and compatible with their abilities, preferences, and goals. Until then, large numbers of mathematically talented females will continue to slip through the cracks when their choices are restricted by cultural barriers, gender stereotypes, or misinformation. Our goal, therefore, is to maximize career options for women by capitalizing on female cognitive strengths, emphasizing hard work and effort instead of talent, cultivating female interest in math and science, and removing masculine stereotypes, misinformation, and obstacles that cloud career decisions. In order to achieve these goals, researchers, practitioners, and policymakers will need to increase their collaboration and communication efforts. Researchers, for instance, can contribute by reviewing existing literature, proposing research questions, models, and theories, performing accompanying testing, and providing empirical evidence to support, revise, or reject these theories. They also need to convey their work to policymakers and practitioners who can put their findings into action by creating initiatives to influence the greater cultural sphere at the macro-level or by working directly with females at the micro-level to increase their interest in STEM. Eliminating non-family-friendly policies in universities and institutional discrimination requires a macro approach, while revising everyday educational experiences in math and science classes to better engage female students necessitates micro-level interventions. The results of policymaker and practitioner actions then feed directly back into research, demonstrating what works and what does not work and inspiring continued efforts by researchers to evaluate and tweak these interventions. Therefore, with greater collaboration among stakeholders in the field, the gender gap in STEM fields should continue to shrink observably, and opportunities for women and girls to realize their full potential in math and science should increase.

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