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Research Overview: Female Interest in Mathematics

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I. Introduction

Despite comparable performance by women and men in a variety of math subjects such as algebra and geometry (Else-Quest, Hyde, & Linn, 2010) and similar abilities associated with completing math-related tasks (Barnett & Rivers, 2004; Spelke, 2005), female interest in mathematics is markedly lower than male interest (Frenzel, Goetz, Pekrun, & Watt, 2010; Nosek, Banaji, & Greenwald, 2002). At a young age girls and boys express similar interest in and positive attitudes toward math (Linver, Davis-Kean, & Eccles, 2002); however, gender differences in math interest become apparent after elementary school. By eighth grade, boys are more likely than girls to indicate an interest in mathematics (Linver et al., 2002). Between fourth and twelfth grades, the percentage of girls who indicate they are no longer interested in studying math increases from 9% to 50% (Boswell, 1985, p. 91). Reported lack of interest by girls is masked by course-taking patterns: Girls enroll in math-based courses throughout middle and high school at the same rate as boys do and perform as well on math-based standardized performance tests (Freeman, 2004).

These trends present a confusing picture of females and mathematics. Competing statistics have been reported, and research has focused on identifying experiences that might explain the lack of interest among females despite the fact that they and males demonstrate equal aptitude for math (Spelke, 2005). To that end, Spelke (2005) found that sociocultural factors play a major role in students' perceptions about the degree to which females and males are good at math and the utility of studying the subject. Negative views held by influential individuals such as parents and teachers underscore these messages and are internalized by girls, negating their interest in mathematics. When considering the long-term impact, lack of interest in mathematics among girls is directly related to fewer women pursuing degrees in math-related careers, including science, technology, and engineering (Linver et al., 2002; Spelke, 2005; Watt, 2006).

This overview reviews studies of extrinsic (e.g., outside, external) and intrinsic (e.g., internal) factors that affect female interest in math and suggests interventions and strategies for parents and practitioners to improve math interest among girls (Tobias, 1989). In this literature overview, interest is defined as expressed curiosity in or attitudes toward mathematics as a subject for study and a career choice.

II. Concise Overview

The degree to which interest is shaped by views related to the source of mathematical ability, sociocultural factors, and previous experiences with mathematics has been studied to explain why females report less interest in the subject. Identifying and studying these interrelated factors can support systematic change within organizations and institutions, potentially improving female representation in math-related fields (Dweck, 2007; Spelke, 2005).

Math performance: Innate ability or product of hard work

Whether students view their math performance as a gift or something that can be developed by hard work can influence their interest in the subject (Dweck, 1999). If students view math ability as a fixed ability that they either possess (i.e., were born with) or do not possess, they are more likely to lose interest when they encounter difficulty with math. If students view math ability as something that can be developed through study and by seeking additional resources and assistance when they feel challenged, they maintain an interest in mathematics despite difficulties or obstacles (Dweck, 1999). Views related to the source of math ability influence interest in the subject, especially among females (Dweck, 2007). While this same pattern may occur in relation to other subjects, Dweck (2007) believes that negative gender stereotypes about female interest in math work in tandem to diminish pursuit of math skills among females.

Female views of mathematics are shaped in part by gender-based stereotypes that convey misconceptions that differential innate mathematical abilities exist between males and females. Research that focuses on cognitive development among students of various ages documents that mathematical reasoning among females and males develops from a shared set of biologically-based capabilities that lead both genders to develop an equal aptitude for mathematics (Spelke, 2005). In general, both girls and boys have the same innate ability to learn math skills and are born interested in a variety of objects and ideas (Spelke, 2005; Spelke & Grace, 2007).

Despite the conclusions drawn from this research, sociocultural forces impart false beliefs that boys are born with a greater aptitude for math. Environments such as mathematics classrooms and households that are heavily influenced by beliefs that girls may be disadvantaged genetically when it comes to math ability can have a serious negative effect on math interest among girls (Dweck, 2007). In particular, parents play an integral role in shaping how students view math ability and related performance. If parents believe that math ability is genetic and success reflects genetic predisposition, students who receive such messages and then encounter difficulty see those challenges as proof that they lack natural mathematic ability (Dweck & Leggett, 1988). In turn, this fixed-ability mindset results in decreased confidence and interest in math (Dweck, 2007). At the same time, girls who view math ability as a gift lose interest in mathematics more readily than do girls who view math ability as something that can be developed or cultivated (Dweck, 2007; Mueller & Dweck, 1998).

Overall, female success in mathematics is more likely to be attributed to hard work than to innate ability. In a study among eighth graders, parents and teachers cited conscientiousness in mathematics as playing an integral role in female math performance and attributed male performance to innate ability (Usher, 2009). This type of behavior can communicate to girls that they do not have the ability to perform math and must make up for that with hard work. This negatively impacts female attitudes because girls see math as something in which they will experience little success and consequently disengage from further study of the subject (Usher, 2009).

Learned preferences: Cultural influences

While views on the source of math ability can have negative consequences for female interest, environmental factors, including social expectations conveyed primarily through stereotypes, work to diffuse girls' interest in math as well (Barnett & Rivers, 2004; Eccles, Jacobs, & Harold, 1990). Pervasive social, cultural, and historical messages that math is not useful to women, math careers are masculine, and women are more interested in social fields (Barnett & Rivers, 2004) are communicated explicitly and implicitly to girls from a very young age. For instance, parents tend to view math as a more masculine field and buy more math-related products for their sons than for their daughters (Bleeker & Jacobs, 2004; Nosek et al., 2002). These messages, although unfounded scientifically, start with influential adults such as parents and teachers, are picked up and furthered by peers (Barnett & Rivers, 2004), and are reinforced by media, including magazines, television, and textbooks used in schools.

The effect of stereotypes on math performance has been well researched (Brown & Josephs, 1999; Good, Aronson, & Harder, 2008; Lesko & Corpus, 2006), but the degree to which stereotypes affect math interest has been examined less thoroughly (Marx & Roman, 2002). Nosek et al. (2002) revealed that gender identity (i.e., seeing oneself as female) has a direct and negative effect on math interest. The more gender math stereotypes that girls possessed, the less likely they were to indicate an interest in mathematics. This finding held true even among women who were pursuing a math or math-related career. Similar studies have shown that the more girls see math as a male-oriented field, the less likely they are to indicate an interest in mathematics (Boswell, 1985). Female students have attributed their lack of interest in math to not wanting to be seen as "weird" or "strange," given the associations that students make that math is a field heavily dominated by men and that women "don't belong in" math-related careers (Barnet & Rivers, 2004).

Conversely, in the absence of math-related stereotypes, girls show a greater interest in mathematics and math-related careers. Women who successfully attained an engineering degree reported that they grew up in households with few gender-based stereotypes, more parental support for their career choice, and more parental involvement in their schooling (Mau, 2003).

Math anxiety

For certain disciplines, the more anxious students are when faced with new material, the less likely they are to express interest in those fields (Ackerman, Bowen, Beier, & Kanfer, 2001). This trend is especially applicable to female interest in mathematics. How students navigate difficulty associated with learning mathematical concepts has direct implications for student interest. As student performance in math decreases, so does interest in studying math as a subject or in pursing a career in math or related disciplines (Wells, Sanchez, & Attridge, 2009; Thorndike-Christ, 1991).

Students are likely to experience anxiety when they are faced with tasks that challenge their ability. They are more likely to become confused and anxious when learning new material in mathematics than when learning new verbal content because if prior mathematical concepts are not learned and mastered, students can become easily confused as new content and conceptual systems are introduced. This is further compounded because mathematics is often taught in isolation as a stand-alone subject, preventing students from practicing or applying math skills in the context of more familiar subjects and making relationships that can assist in learning (Hiebert & Grouws, 2007; Licht & Dweck, 1984). Among college students, math anxiety is more likely to occur among students with weaker high school math preparation, with anxiety occurring more frequently among females than males (Betz, 1978).

High-performing females have been shown to experience a loss of confidence and effectiveness when they have difficulty performing a task despite the fact that they perform as well or better than their male peers do on other tasks (Licht, Linden, Brown, & Sexton, 1984; Licht & Shapiro, 1982). One study revealed that when high-performing females were presented with new, confusing material, they were less likely to cope well when compared to males. Further, the higher the IQ for females, the worse they performed as the anxiety associated with new material increased. On the other hand, among males, the higher their IQ, the better they performed when new material was presented (Licht & Dweck, 1984). Licht and Dweck posit that gender differences in math interest are related to gender differences in coping with anxiety-producing situations, including setbacks and confusion. Among girls, this confusion is believed to reinforce gender-based stereotypes that they are not or should not be "good at math," leading girls to report a decreased interest in mathematics after anxiety-producing situations.

In part, some of girls' math anxiety can be attributed to female elementary school teachers. A recent study demonstrated that having a female teacher who says she is anxious about math leads girls in her class to share that attitude and score lower on tests (Beilock, Gunderson, Ramirez, & Levine, 2010). While girls were more likely to adopt their teacher's math anxiety following one year of exposure, this trend was not seen among males. Following exposure to math-anxious teachers, girls were more likely than boys to endorse the stereotype that "boys are good at math, and girls are good at reading." While it is unclear what exactly conveys the transmission of anxiety from female teacher to female student (Beilock et al., 2010), similar trends have been seen in relation to students whose mothers experience math anxiety. A mother's interest and perceived ability to perform mathematical tasks have been shown to influence her child's confidence and interest in mathematics among both girls and boys (Usher, 2009). Conversely, strong female role models have been shown to validate girls' interest in math, and girls with such role models subsequently perform as well as boys on math-related tasks (Marx & Roman, 2002).

III. Synthesis of Findings

Impact and effects of math interest on individual performance

Lack of interest in mathematics has direct implications for student involvement in areas that require a strong math background, including science, technology, engineering and mathematics (STEM) disciplines and careers, particularly for females. Lower interest is closely related to lower performance on math-related achievement tests and lower grades in math (Betz, 1978; Singh, Granville, & Dika, 2002; Uerz, Dekkers, & Beguin, 2004), less interest in taking challenging mathematics curricula prior to enrolling in college (Nosek et al., 2002), and less interest in pursuing a career in STEM disciplines (Usher, 2009). Females express less interest in mathematics than male peers and some studies link that lower interest to fewer females pursuing careers in STEM fields (Betz, 1978; Usher, 2009).

Implications for practitioners: Importance of addressing gender differences as they relate to female interest in math

Practitioners play a critical role in formulating interest in mathematics as well as combating societal influences that negate female interest in this area. Teachers and parents can help improve students' math interest and performance by encouraging students and helping them believe that mathematical competencies can be improved through consistent effort (Schunk & Zimmerman, 2007).

While overall student interest in math is low with only one third of middle school students indicating that they like math (Wells et al., 2009), research underscores the need to make math more interesting for girls (Linver et al., 2002). Furthermore, interventions that increase female interest in math also increase male interest (Tobias, 1989). Overall, this can lead to more balanced gender representation among individuals pursuing careers that require adequate math preparation, such as those in STEM fields (Barnett & Rivers, 2004; National Academy of Engineering, 2008).

Research-tested remedies or interventions

- Tobias (1989) shows that girls may have less interest in math than boys do because of the ways teachers communicate with students, often interacting more with boys than with girls during math lessons. When girls ask for help, the teacher is more likely to solve the issue at hand, leaving girls to learn by watching rather than by doing. Conversely, teachers explain to boys how to do math and guide them through the learning experience. Teachers should involve all students in hands-on, inquiry-based activities to increase math interest, which could motivate both male and female students to pursue STEM-based activities and additional education and careers in these areas (Tobias, 1989).

- While it may seem that praising girls when they perform well in mathematics may help boost confidence and diffuse anxiety, this is not the case. Doing so may convey that their math ability is a gift, making girls less likely to take on challenging tasks and lose confidence when faced with difficulty (Dweck, 2007). Practitioners would do better to address students' beliefs about the nature of ability. Highlighting how intellectual skills critical to math performance as well as how knowledge and ability can be developed has the potential to lead to a sustained interest in math among students, especially girls. Practitioners should praise students for effort given toward a certain task rather than only recognizing a task that has been successfully completed (Dweck, 2007; Good, Aronson, & Inzlicht, 2003).

- Lessons that cover contributions by noteworthy mathematicians can focus on how those mathematicians arrived at their conclusions through hard work rather than emphasizing the idea of "math geniuses" who were born with a gift. Doing so can boost female interest in math (Dweck, 2007).

- Using collaborative pedagogical strategies that allow students to work together on projects or assignments can help increase interest in mathematics as it reduces anxiety among students and provides them with an opportunity to reflect on and process new material (Tobias, 1989).

- Math performance and interest can be improved if students are taught how to study and apply needed skills in math, because not all students have honed the skills necessary for success in this area. As part of these interventions, showing students how to make connections between previous experiences and new material can increase interest and performance (Tobias, 1989).

- Sponsoring events such as the Centre for Education in Mathematics and Computing Think about Math! Conference (www.cemc.uwaterloo.ca/events/tam.html), which is targeted at female students in high school, may encourage female interest in math. The event provides hands-on activities and interactive labs as well as opportunities to network with women who have graduated with a degree in mathematics, allowing students to form more long-term mentoring relationships. The National Girls Collaborative Project (www.ngcproject.org) has a database that includes a list of events such as these that take place across the United States.

- Introducing female students to strong female role models in STEM careers has been shown to increase female interest in mathematics. Doing so indicates to girls that pursuing careers in math, engineering, or other fields that require strong mathematical preparation is a viable path and encourages interest in such disciplines (Marx & Roman, 2002). MentorNet (www.mentornet.net), an online forum, is designed to facilitate connections between mentors and protégés in science, technology, engineering, and math.

- In mathematics classrooms, interest in mathematics may be increased if students see their learning as socially relevant. Providing students with authentic or real-world situations and problem sets that can be examined using mathematical concepts may increase student interest and performance, particularly among girls (Bartell, 2007). The Engaging Students in Engineering program (www.engageengineering.org) provides a research-based framework that mathematics educators can use to design similar products for math classrooms.

IV. Assessment Methodologies

- *Math Anxiety Scale*, part of the Fennema-Sherman Mathematics Attitudes Scales, was part of an effort to study students' attitudes toward math in the 1970s. The scale consists of four subscales: a confidence scale, a usefulness scale, a scale that measures views of mathematics as a male domain, and a teacher perception scale, each of which consists of 12 items. This instrument could be used to give both the teacher and student information about students' interest in math. Caution should be exercised because the instrument was developed more than 30 years ago and word connotations may need to be altered (Fennema & Sherman, 1976).

- *State-Trait Anxiety Inventory* (www.mindgarden.com/products/staisch.htm) is a tool used to assess text anxiety and can be used to assess math anxiety. One version is used among adults, and one is used among elementary and junior high school students.

- *Attitudes Toward Mathematics Inventory* is a 49-item instrument designed for use by researchers and practitioners. The ATMI investigates students' attitudes toward mathematics. Items examine confidence, anxiety, value, enjoyment, motivation, and parent-teacher expectations. Additional information can be found online at www.rapidintellect.com/AEQweb/cho25344l.htm.

V. Recommendations for Practitioners

The literature points to the importance of making sure practices within educational settings are guided by sound research. Educators and practitioners play a critical role in formulating student interest in mathematics, especially among girls, directly through their actions and indirectly as they mitigate potentially negative societal influences.

- Early elementary school teachers in the United States are almost exclusively women. Given research that documents how math anxiety and the subsequent lack of interest in mathematics might be transferred from female teachers to female students, practitioners should examine whether teachers possess math anxiety. Implementing workshops and professional development opportunities that can help teachers gain confidence when teaching students mathematics would be an important first step (Beilock et al., 2010).

- Parental and teacher support is important for fostering female interest in math, science, technology, and engineering. Parents and teachers can introduce girls to a range of careers, demonstrate how such occupations are relevant to society, and encourage interest in the mathematical preparation necessary to pursue them.

- Practitioners who design courses and major requirements within STEM disciplines should be careful about how they emphasize the mathematical skills and abilities needed for success, including de-emphasizing the idea that students need to be a math genius. Instead, practitioners should emphasize the academic preparation and study skills needed to succeed (National Academy of Engineering, 2008).

- Sustained mentoring and other programs that introduce and prepare students for challenging coursework can also serve to counteract misconceptions that students need to be born with an innate aptitude for mathematics to succeed.

- Gender-based stereotypes have made it socially acceptable for females to state that they are not good at math or that they "can't do math." The same level of acceptance does not exist in relation to being dismissive of reading skills. Influential parents and teachers need to be careful about the degree to which they reinforce these stereotypes by allowing females to make disparaging comments in relation to math and their math skills as it further negates interest for the individual and among female peers (Beilock et al., 2010).

VI. Recommendations for Further Research

- Study how the teaching of mathematics is conceptualized and how that influences female interest in the subject. Research shows that educators often conceptualize mathematics as free from cultural influences, viewing mathematics as a less socially derived activity. However, normative practice in math classrooms has cultural implications that can disadvantage certain groups. Groups that do not participate in ways that are deemed competent by social norms established within a classroom may further disengage, losing interest and opportunities to acquire mathematical content. While this has been examined in relation to non-White students' interest in math (Hand, 2010), additional research could look specifically at what teacher-led practices, pedagogy, and peer interactions establish a classroom climate that leads to lack of female interest.

- Examine what social contexts increase math interest. Research has looked at how parents shape female interest in mathematics. Future studies could look at the role of peers and siblings in shaping interest and whether it differs by gender.

- Determine the extent to which women and men perceive math-related careers as conducive to balancing work and family (Spelke, 2005) and the degree to which female and male goals to balance work and family are different .

- Following up on the research done by Beilock et al. (2010), look more closely at math anxiety and its link to math interest as well as what can be done by teachers and parents to counteract negative experiences among girls. Findings would help provide practical advice for practitioners and address a gap in the literature.

- Use relevant frameworks and theories that have looked at female engagement either in STEM generally or in math performance to study female interest in mathematics specifically. For instance, stereotype threat (Singletary, Ruggs, Hebl, & Davies, 2011), attribution theory (Assessing Women and Men in Engineering, 2005), and academic self-concept (Beier & Rittmayer, 2011) could provide interesting insights. Information collected from these studies could be used to shape educational settings so that all students could benefit from positive exposure and involvement in math-related activities leading to more gender-diverse groups pursuing STEM careers. For instance, math anxiety may, to some degree, be driven not only by the fact that girls do not perceive that they have the skills to be successful but also by views on the activities in which they excel. Studies related to academic self-concept have shown that as verbal self-concept increases among girls, math self-concept decreases (Marsh & Hau, 2004). Likewise, reducing stereotype threat has been shown to increase math performance among girls, but the relationship to math interest has not been examined.

- Examine more closely the link that females see between mathematics and careers in related fields, such as science, engineering, and technology. This would help educators consider how to make math more interesting and relevant while increasing interest in these math-related careers.

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