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FEMINIST FORUM

The Role of Parents and Teachers in the Development of Gender-Related Math Attitudes

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Abstract Girls tend to have more negative math attitudes, including gender stereotypes, anxieties, and self-concepts, than boys. These attitudes play a critical role in math performance, math course-taking, and the pursuit of math-related career paths. We review existing research, primarily from U.S. samples, showing that parents' and teachers' expectancies for children's math competence are often gender-biased and can influence children's math attitudes and performance. We then propose three new directions for future research on the social transmission of gender-related math attitudes. First, parents' and teachers' own math anxieties and their beliefs about whether math ability is a stable trait may prove to be significant influences on children's math attitudes. Second, a developmental perspective that investigates math attitudes at younger ages and in relation to other aspects of gender development, such as gender rigidity, may yield new insights into the development of math attitudes. Third, investigating the specific behaviors and mannerisms that form the causal links between parents' and teachers' beliefs and children's math attitudes may lead to effective interventions to improve children's math attitudes from a young age. Such work will not only further our understanding of the relations between attitudes and performance, but will lead to the development of practical interventions for the home and classroom that ensure that all students are provided with opportunities to excel in math.

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Introduction

Issues of gender equity in math achievement, course-taking, and careers have been of concern at least since the 1970s (e.g., Fennema and Sherman 1977; Jacobs 2005; Perl 1982). Historically, males have been reported to have higher levels of math achievement than females, but results of achievement tests given to elementary and high school students in the United States indicate that this gender gap has closed in recent years (Hyde et al. 2008). Nevertheless, gender differences persist in the number of students who take advanced math courses (Eccles 2007) and who pursue math-related careers (Jacobs 2005). Thus, despite similar math achievement test scores for girls and boys, fewer girls choose to pursue math coursework or quantitative career paths.

This disconnect raises the possibility that factors other than gender differences in math achievement play an important role in influencing the choices that males and females make about math-related careers. While many such factors have been proposed, including women's belief that successful STEM careers are incompatible with raising children and the possibility of hiring and promotion discrimination against women in STEM fields (for a recent review, see Ceci et al. 2009), we focus our review on early-developing math attitudes. In this review, we conceptualize math attitudes as a cluster of beliefs and affective orientations related to mathematics, such as math anxiety, math-gender stereotypes, math self-concepts, and attributions and expectations for success and failure in math. These math attitudes have all been shown to contribute to individuals' choices to pursue math-related courses and careers (Cheryan and Plaut 2010; Hembree 1990; Schmader et al. 2004; Seegers and Boekaerts 1996; Simpkins et al. 2006). Further, girls tend to have more negative attitudes about math than boys (Hyde et al. 1990). Since math attitudes vary by gender and influence important outcomes such as entry into math-related careers, we focus our review on environmental factors that impact the development of gender-related math attitudes.

We focus specifically on parents and teachers, as they represent two major environmental influences on children's development and are particularly important for the formation of academic attitudes (Tiedemann 2000b; Yee and Eccles 1988). While peers' attitudes and behaviors may also exert an influence on children's math attitudes (e.g., Ryan and Patrick 2001), we chose to focus on adults' attitudes and behaviors since they are likely to influence both children and their peers, thus forming the primary means for the intergenerational transmission of math attitudes. While peers may be especially important for the development of math attitudes during adolescence when peer effects tend to be greatest (e.g., Berndt 1979), these effects are beyond the scope of this paper and its focus on the development of math attitudes in children.

A great deal of research has explored the impact of parents' and teachers' expectancies and attributions on children's math attitudes and achievement (Eccles and Jacobs 1986; Eccles et al. 1990; Jacobs 1991; Jacobs et al. 2005; Jacobs and Eccles 1992; Midgley et al. 1989; Yee and Eccles 1988). This work provides valuable insights, showing that adults' math-gender stereotypes influence their expectations and attributions for boys' and girls' math achievement, which in turn can affect children's own math attitudes and achievement.

We propose that future research expand on these insights in three ways. First, we argue that adults' expectancies and attributions are not the only attitudes and behaviors that contribute to children's development of gender-related math attitudes. Rather, adults' own math anxieties (Beilock et al. 2010) and their beliefs that math ability is a stable trait (Mueller and Dweck 1998) may have significant impacts on children's development of math attitudes. Second, we argue that future work investigating adults' influences on gender-related math attitudes take a developmental approach in which children's attitudes are investigated at much younger ages and across levels of schooling. We propose that the development of negative math attitudes in young children, especially girls, sets the stage for lifelong behavioral and attitudinal patterns, such as math anxiety and math avoidance, which can eventually lead to lower levels of STEM course-taking and career choices among women versus men. Recent work has shown that children as young as preschool are susceptible to gender stereotypes in math (Ambady et al. 2001) and that anxiety about spatial activities, which are highly relevant to math achievement, is more prevalent among girls than boys in first and second grades (Casey et al. 1995; Ramirez et al. 2011). However, little work has investigated the sources of children's math stereotypes and anxieties in preschool or early elementary school. In addition, such a developmental approach predicts potential interactions between children's rapidly developing gender cognitions and adults' messages about gender and math. For example, children may be especially likely to internalize math-gender stereotypes when they reach the peak stage of gender rigidity, believing that certain traits and activities are appropriate only for girls or only for boys, which typically occurs in early elementary school.

Third, we argue that researchers should examine the behavioral mechanisms through which adults' own attitudes impact children's attitudes, and look beyond one-to-one mappings between adults' and children's math attitudes. For example, recent research has shown that female teachers' math anxiety is related to female students' greater math-gender stereotypes rather than to female students' general math anxieties (Beilock et al. 2010). There are likely to be various complex ways in which adults' attitudes can affect children's attitudes and achievement, depending on the child's developmental stage as well as the specific adult behaviors that mediate the relation between adults' and children's math attitudes. Finally, it should be noted the research reviewed here is based on U.S. samples unless otherwise stated, and it is possible that the effects discussed may differ in other cultures.

Impact of Adults' Gender Stereotypes, Expectancies, and Attributions on Children's Math Attitudes

Parents' Math-Gender Stereotypes and Gender-Biased Math Expectancies

A large body of work has shown that parents' and teachers' gender stereotypes, beliefs, and expectations regarding children's math aptitude affect children's subsequent math attitudes and achievement in a way that perpetuates gender-stereotypical roles (Eccles and Jacobs 1986; Eccles et al. 1990; Jacobs and Eccles 1992; Midgley et al. 1989; Yee and Eccles 1988). In middle school and high school, parents of boys tend to believe that their child has higher math ability and expect their child to achieve more in math than parents of girls (Eccles et al. 1990; Yee and Eccles 1988). By sixth grade, parents believe that boys have more natural talent in math, anticipate that boys will have greater future success in careers requiring math skills, rate the importance of math as greater for boys than for girls, and rate math as more difficult for girls than for boys (Eccles et al. 1990). Mothers of boys also tend to believe that their child has more talent in math and has to try less hard than mothers of girls, and fathers set much higher minimum standards for math grades for average-ability boys than for average-ability girls (there was no difference in fathers' minimum standards for high-ability boys and high-ability girls; Yee and Eccles 1988). Importantly parents have gender-stereotyped beliefs about their boys' and girls' math abilities even when boys' and girls' math achievement levels do not differ according to objective measures (Yee and Eccles 1988).

Additional studies have established that parents' gender-stereotyped beliefs about their children's abilities influence their children's perceptions of their own math ability (Jacobs 1991; Parsons et al. 1982). Among parents of 6th to 11th grade students, parents of girls hold stronger gender stereotypes favoring boys in math than parents of boys (Jacobs 1991). Further, parents who hold stronger math-gender stereotypes in general also have more gender-stereotyped beliefs about their own child's math ability, controlling for the child's previous year's math grade (Jacobs 1991). In other words, parents who believe that boys are better at math than girls also apply this stereotype to the abilities of their own children, despite their access to a great deal of information about their child's actual math achievement, which should moderate these views. Notably, parents' beliefs about their children's math ability predict children's self-perceptions in math even more strongly than children's own past math achievement; further, children's self-perceptions about math affect their subsequent math achievement (Jacobs 1991; Parsonset al. 1982). Taken together, these results suggest a causal model in which parents' gender stereotypes bias their beliefs about their own child's math ability and these beliefs affect children's own self-perceptions about math, which in turn affect children's subsequent math achievement.

The effects of parents' expectancies on children's math attitudes are less well studied in younger children, although some studies have found that parents' gender biases are present and impact their children in early elementary school as well. One study found that parents' perceptions of kindergarten through 3rd grade children's math competence did not differ by gender (Eccles et al. 1990). However, these parents believed that math was more important for boys than for girls, and those who held stronger math-gender stereotypes were more likely to have gender-biased perceptions of their children's math ability (Eccles et al. 1990). A study of 3rd and 4th grade students in Germany found that parents of boys believed that their children were more competent in math than parents of girls; again, this effect was strongest among parents who endorsed math-gender stereotypes in general (Tiedemann 2000b). In addition, a cross-cultural study of parents and children in Taiwan, Japan, and the U.S. found that mothers of kindergarten children in all three cultures believed that boys were better at math and girls were better at reading (Lummis and Stevenson 1990). In the same sample, boys had higher expectations for success in math than girls by fifth grade (Lummis and Stevenson 1990). These studies of elementary school parents and children suggest that parents' math-gender stereotypes can affect their perceptions of their own children's math ability even in early elementary school. Moreover, these parental perceptions appear to have an impact on children's achievement expectations.

Teachers' Math-Gender Stereotypes and Gender-Biased Math Expectancies

Teachers also show gender-stereotyped beliefs about their students' math abilities (for a review, see Li 1999). For example, first-grade teachers in the U.S. perceive their best male students as being more logical, more competitive, more independent in math, and liking math more than their best female students (Fennema et al. 1990). Similarly, 3rd through 5th grade teachers in Germany believe that boys have greater math ability than girls, that boys are more capable of logical thought than girls, and that math is a more difficult subject for girls than for boys (Tiedemann 2000a, b, 2002). These teachers show the greatest gender biases for students who are middle-achieving based on course grades, which may be because the performance of these students is more ambiguous than that of higher- or lower-achieving students. In the same way as parents, teachers who endorse math-gender stereotypes are more likely to have greater gender-stereotyped views of their students' math ability, at least in German samples (Tiedemann 2000a, b, 2002), perhaps because teachers with stereotyped attitudes are more likely to judge others on categorical traits (e.g., gender, race) rather than on an individual basis (Fiske and Neuberg 1989). Further, teachers' gender stereotypes about their students' math ability can lead students to endorse math-gender stereotypes themselves, as shown by a study of middle-school teachers and their students in Switzerland (Keller 2001). These studies suggest that, for both parents and teachers, adults' own gender stereotypes influence their expectancies for their offspring and students, respectively, which in turn influence those children's gendered math attitudes.

Parents' and Teachers' Gender-Biased Attributions for Math Success and Failure

In addition to believing that boys have greater math ability than girls, parents and teachers also make attributions about children's success and failure in math in ways that privilege boys' math talent over girls' (e.g., Fennema et al. 1990;

Tiedemann 2000a; Yee and Eccles 1988). According to Weiner (1974), individuals attempt to create causal explanations for others' behaviors, and in the domain of achievement, the most prevalent attributions for success or failure are ability, effort, task difficulty, and luck. Attributions affect how individuals react to events. For example, a student who attributes successes to high ability and failures to lack of effort is likely to remain motivated regardless of success or failure experiences because successes reinforce their belief in their ability and failures can be explained by a controllable cause (effort) that can be improved in the future (e.g., Diener and Dweck 1978). With regard to gender differences, when asked to rate the importance of several factors on their middle-school children's math successes and failures, mothers are more likely to attribute boys' math success to natural talent and girls' math success to effort (Yee and Eccles 1988). In addition, parents believe that girls have to work harder to succeed in math than boys (Parsons et al. 1982). This helps to explain how parents come to believe that boys have greater math ability than girls, despite objectively equal performance; parents believe that boys' math success comes to them more naturally than girls' math success. Supporting this explanation, mothers' attributions for children's success mediate the relation between child gender and mothers' perceptions of their child's ability (Eccles et al. 1990). This is consistent with a causal model in which the child's gender creates gender-related success attributions by parents (ability for boys, effort for girls), which in turn leads parents to believe that their male children are better at math than their female children even when both genders are equally successful according to objective measures.

Teachers also show gender biases in their attributions of math success (Fennema et al. 1990; Tiedemann 2000a). Elementary school teachers attribute boys' math successes predominately to ability, while they attribute girls' math successes equally to ability and effort (Fennema et al. 1990). Conversely, teachers are more likely to attribute girls' failures to lack of ability and boys' failures to lack of effort (Fennema et al. 1990; Tiedemann 2000a).

Gender Differences in Children's Own Attributions for Math Success and Failure

Parents' and teachers' causal attributions for children's math successes and failures help to explain gender differences in their perceptions of children's abilities (Eccles 2007). These patterns of attribution are of concern because they may affect children's own attributions for success or failure, which are important to their math attitudes and achievement (Diener and Dweck 1978; Seegers and Boekaerts 1996; Stipek 1984). Indeed, at least as early as 5th and 6th grades, boys are more likely than girls to attribute success in math to ability and are less likely than girls to attribute failure in math to lack of ability (Stipek 1984). Among 8th graders in the Netherlands, girls continue to attribute math failure to lack of ability more often than boys do, and these attributions are correlated with fear of making mistakes and motivation to hide mistakes among girls but not boys (Seegers and Boekaerts 1996). In addition, by 8th grade, attributing math failure to lack of ability predicts lower beliefs in one's math competence, which in turn predicts lower math performance (Seegers and Boekaerts 1996).

In sum, the bulk of previous research on the social transmission of math attitudes from adults to children has focused on parents' and teachers' math-gender stereotypes, perceptions of children's math ability, and attributions about math success and failure (e.g., Fennema et al. 1990; Seegers and Boekaerts 1996; Yee and Eccles 1988). Out of this research, a coherent picture has emerged, in which adults' own gender stereotypes about math ability are reflected in their perceptions that boys have higher ability in math than girls. These perceptions are influenced by adults' gender-stereotyped attributions for math success and failure, where girls are thought to succeed because of effort and fail because of lack of ability, whereas boys are thought to succeed because of ability and fail because of lack of effort. Adults' perceptions of children's math abilities are also related to children's beliefs about their own math ability and to children's later math achievement. These effects are most well-established in middle and high school, although studies with elementary school children and their parents and teachers show similar patterns.

Impact of Adults' Math Anxieties and Implicit Theories of Intelligence on Children's Math Attitudes

Adults' expectancies and attributions are clearly an important source of gender differences in children's math attitudes (e.g., Fennema et al. 1990; Seegers and Boekaerts 1996; Yee and Eccles 1988). Yet these may not be the only factors that impact children's math attitudes. We propose that existing literatures on math anxiety and on implicit theories of intelligence generate strong predictions about additional sources of adult influences on gender differences in children's math attitudes.

Teachers' and Parents' Own Math Anxieties

In addition to their expectancies and attributions about their children's math abilities, parents' and teachers' own personal feelings about math are likely to influence the messages they convey about math to their children. In particular, adults' own math attitudes, including math anxiety, math self-concept, and math teaching self-efficacy, may be important factors in the adult-to-child transmission of math attitudes. Although anxiety, self-concept, and self-efficacy are distinct constructs (e.g., Pajares and Miller 1994), in this review, we treat them as a class that reflects adults' personal attitudes toward math. Math anxiety can be thought of as a negative emotional reaction to the prospect of doing math (Ashcraft 2002). These emotional reactions can occur in academic situations such as taking a math test as well as in everyday situations such as calculating a tip (Ashcraft 2002). Even when individuals have the same level of prior math knowledge, those with high math anxiety perform worse than those with low math anxiety in situations requiring them to do math (Ashcraft 2002). Individuals who are high in math anxiety tend to avoid taking math-related courses and pursuing math-related careers (Hembree 1990). Further, women tend to have higher levels of math anxiety than men, which may account for some of the gender gaps in math-related professions (Hembree 1990).

Teachers' attitudes towards mathematics have long been recognized as an important influence on students' math attitudes (Aiken 1970). Studies in both the U.S. and Canada have found that elementary school teachers tend to have high levels of math anxiety (Brady and Bowd 2005; Bursal and Paznokas 2006; Hembree 1990). Teachers' attitudes toward the subject matter have been shown to influence their instructional techniques, the way they organize the content to be taught, and eventually, their students' attitudes toward the subject (Fennema et al. 1990; Nespor 1987; Pajares 1992). For example, using a case study approach involving in-depth interviews with Austrian teachers who were high and low in math self-concept (which is related to anxiety about math), Relich (1996) found that teachers with low math self-concepts were more likely to report using traditional approaches to teaching, such as lecturing and use of textbooks, and to express a lack of time, interest or motivation to try new teaching strategies in math. In addition, female elementary school teachers with low math self-concepts explicitly endorsed stereotypical gender roles during their interviews, saying that boys are better at math and science and that girls are better at reading (Relich 1996).

Although many educators agree that teachers' math attitudes can affect their students' math attitudes and achievement (e.g., Gresham 2007; Hembree 1990; Jackson and Leffingwell 1999), only a few empirical studies have directly tested this relation (Beilock et al. 2010; Midgley et al. 1989). One study found that teachers' math teaching self-efficacy was positively related to students' own math attitudes in late elementary and middle school (Midgley et al. 1989). Compared to students whose teachers had low math teaching self-efficacy, students whose teachers had higher math teaching self-efficacy believed math was less difficult, believed they were doing better in math, and expected to do better in math in the future (Midgley et al. 1989). Further, the impact of teachers' math teaching self-efficacy was most pronounced for students who were lower-achieving in math (Midgley et al. 1989).

More recent research has investigated the impact of teachers' math anxiety on students' math attitudes and achievement in early elementary school (Beilock et al. 2010). Since elementary school teachers are more than 90% female (National Education Association 2003), this study asked whether female teachers' math anxiety affected students' achievement in 1st and 2nd grades, and whether this effect was related to student gender. Moreover, the study investigated whether the relation of teachers' math anxiety to students' math achievement was mediated by students' gender stereotypes about math. Findings showed that female teachers' math anxiety was related to students' math achievement, but that this was only true for female students. Girls who had a higher-math-anxious teacher had lower math achievement at the end of the year than girls who had a lower-math-anxious teacher, even after controlling for girls' beginning-of-year math achievement. Importantly, this relation was mediated by girls' endorsement of traditional gender stereotypes. In classrooms where teachers had higher math anxiety, by the end of the school year, girls were more likely to endorse the stereotype that boys are good at math and girls are good at reading. In addition, at the end of the year, those girls who endorsed traditional math-gender stereotypes performed more poorly on a standardized test of math achievement than girls who did not endorse these stereotypes and more poorly than boys in general. Female teachers' math anxiety was not related to boys' math-gender stereotypes or to boys' math achievement. Although teachers were not observed during math lessons, these findings suggest that teachers may be demonstrating their dislike of math, thereby confirming the societally-prevalent stereotype that math is for boys and not girls. Indeed, teachers who are high in math anxiety tend to be low in math teaching self-efficacy, indicating that their general discomfort with math is likely to be revealed in their teaching (Swars et al. 2010). Girls may be particularly prone to notice and be influenced by their female teachers' math attitudes because of their identification with their teacher as a role model of the same gender (Bussey and Bandura 1984).

These studies represent a first step toward establishing the role that teachers' own feelings about math—including math anxiety, math self-concept, and math teaching self-efficacy—play in the formation of children's math attitudes and level of achievement. The fact that female teachers' math anxiety affects girls' math-gender stereotypes and achievement indicates that teachers who are math-anxious tend to perpetuate math-gender stereotypes among their students. On the other hand, teachers who are low in math anxiety and high in math teaching self-efficacy may have the ability to break these societal stereotypes and encourage positive math attitudes. This may be especially true for female teachers and their female students, consistent with research showing that competent female role models can encourage high levels of math achievement among female students (Marx and Roman 2002).

Although the studies mentioned above lay the groundwork by establishing that teachers' math attitudes are related to students' math attitudes and achievement, there is a need for additional research on these effects. Are the impacts of teachers' math anxiety, math teaching self-efficacy, and math self-concept on students' attitudes and achievement similar or distinct? How do male teachers' math attitudes affect their male and female students? And, critical for our understanding of these relations, what teaching practices and behaviors occur as a result of teachers' math attitudes, and how do students interpret and react to these behaviors? Answering these questions across grade levels, from early elementary school to high school, can help to shed light on possible routes through which students' gendered math attitudes are perpetuated through the impact of teachers' own math anxieties. On the flip side, these studies can also provide information about how students' gendered math attitudes can be alleviated by positive experiences with math-confident teachers.

Parents' math anxieties and self-concepts may also play a role in their children's developing math attitudes. However, little research has addressed this issue. This may be at least partially because of the implicit belief that math learning is primarily the function of schooling, and that parents' role in promoting math learning is not as important as their role in promoting learning in other domains such as reading (Cannon and Ginsburg 2008). Yet, in the same way that a female teacher can serve as a salient role model for her female students, mothers' and fathers' own attitudes toward math are likely to impact their children's math attitudes. This is especially the case since parents are generally a long-term, consistent force in their children's life, as opposed to teachers who frequently change. More research is needed in this area, not only because parents' math attitudes are likely to be an important influence on children's math attitudes, but also because the nature of these relations is not obvious.

For example, children learn gender-appropriate behaviors from same-gender adults and tend to distance themselves from the behaviors of opposite-gender adults (Bussey and Bandura 1984). Therefore, one might predict that a girl whose mother is math-anxious and whose father has positive math attitudes may develop very strong math-gender stereotypes and affiliate with her mother, who fears math. However, one could also predict that having a parent of either gender who has positive math self-concepts and low math anxiety would be helpful to both male and female children, if that parent promotes enjoyment of math, integrates math into everyday life, and provides positive and challenging math experiences. The paucity of research about parents' and teachers' math attitudes, and the complexity of the potential effects on children, represent a significant opportunity to improve our understanding of the transmission of gendered math attitudes from adults to children and to improve math achievement in all children.

Adults' Influence on Children's Implicit Theories of Intelligence

Research on the formation of implicit theories of intelligence is a second area in which existing findings can generate new predictions about the development of gendered math attitudes (Blackwell et al. 2007; Hong et al. 1999; Mueller and Dweck 1998). Children and adults can ascribe to two different theories of intelligence that are associated with a constellation of attitudes and behaviors (Blackwell et al. 2007). Those who believe that intelligence is fixed (an entity theory) also tend to believe that working hard means you aren't very smart, are motivated by performance goals that emphasize displaying their high level of ability, and tend to disengage from difficult tasks that call their ability into question (Blackwell et al. 2007; Hong et al. 1999). On the other hand, those who believe that intelligence is malleable (an incremental theory) tend to believe that working hard can help you improve at a task, are motivated by learning goals that emphasize gaining new knowledge and skills, and tend to embrace difficult tasks that provide an opportunity for learning. Incremental theories are more adaptive for academic achievement because they promote motivation to persist even after failure (Hong et al. 1999). In fact, promoting incremental theories through school-based interventions that emphasize the malleability of intelligence (e.g., lessons explaining that "the mind is a muscle") can significantly improve students' performance (Aronson et al. 2002; Blackwell et al. 2007; Good et al. 2003).

There are gender differences in these theories of intelligence, with boys being more likely to endorse the more adaptive incremental theory of intelligence than girls (Dweck et al. 1978; Gunderson et al. 2011). As young as 8 years of age, boys hold stronger incremental theories than girls in the sociomoral and academic domains (Gunderson et al. 2011). These gender differences persist through later ages as well (Dweck et al. 1978). Further, parents and teachers seem to differ in the messages they give to boys and girls about whether intelligence is a stable or malleable attribute, although it is not clear whether these differences are intentional or related to adults' own implicit theories of intelligence (Dweck et al. 1978; Gunderson et al. 2011). One route through which parents and teachers can convey messages about trait stability is through the types of praise they use with their children (Cimpian et al. 2007; Gunderson et al. 2011; Mueller and Dweck 1998). In controlled experimental settings, children given person-directed praise (e.g., “you must be really smart”) are more likely to endorse an entity theory and engage in theory-consistent behaviors such as disengaging from a task after failure, while children given process-directed praise (e.g., “you must have worked really hard”) are more likely to endorse an incremental theory and to show more persistence after failure (Cimpian et al. 2007; Mueller and Dweck 1998). In other words, the type of praise used sends a message about whether the child’s intelligence is fixed or malleable. These types of messages may contribute to gender differences in implicit theories of intelligence, especially since girls are more strongly influenced than boys by the effects of different types of praise (Corpus and Lepper 2007).

Recent work has shown that the effects of person and process praise are not confined to laboratory studies (Gunderson et al. 2011). A longitudinal study that measured parents’ use of person- and process-directed praise during naturalistic home interactions found that parents’ use of process-directed praise (e.g., “you did a good job”) when children were 1 to 3 years old was positively related to children’s endorsement of incremental theories in the sociomoral and academic domains at the age of 8 years (Gunderson et al. 2011). Importantly, children’s incremental theories were not related to the amount of praise they received, but were specifically related to the prevalence of process-directed praise relative to other types of praise. This suggests that by using praise that emphasizes the child’s effort, work, and actions, parents can encourage children to adopt adaptive theories of intelligence. However, the same study also found that although boys and girls did not differ in the amount of praise they received from their parents, boys heard significantly more process praise than girls. Unsurprisingly, boys held more incremental theories while girls held more entity theories 5 years later (Gunderson et al. 2011). A number of questions remain, including why parents give more process-directed praise to boys than to girls, whether parents’ own implicit theories drive differences in their praise styles, and whether parents’ praise styles and children’s theories of intelligence differ by academic domain (e.g., math versus other subject areas). Nevertheless, the results suggest that parents’ early behaviors influence their children’s formation of more or less adaptive theories of intelligence, and that these behaviors are gender-biased in such a way that leads girls to form less adaptive theories than boys.

Teachers’ behaviors can also lead to gender differences in children’s formation of entity versus incremental theories (Dweck et al. 1978). Teachers’ feedback, whether positive or negative, tends to be devalued when used indiscriminately (Eisenberger et al. 1974). For example, when a teacher gives a student a great deal of positive feedback about nonintellectual performance, such as neatness, this devalues the positive feedback the teacher gives the student about his or her intellectual performance. In a study of 4th and 5th grade students and their teachers, researchers asked whether the amount and type of feedback students received from their teachers differed by student gender (Dweck et al. 1978). Boys and girls received the same overall amount of positive and negative feedback about the intellectual quality of their work. However, teachers’ feedback on nonintellectual aspects of students’ performance, including behavior, neatness, and speaking clearly, differed markedly by gender. Girls received more positive feedback about their nonintellectual performance than boys, which tended to make girls devalue positive feedback about their intellectual performance more than boys. The difference was even more marked for negative feedback, where boys received much more negative feedback about nonintellectual performance such as behavior and neatness than girls. Because of this, less than one third of the negative feedback that boys received was related to their intellectual performance, while more than two thirds of the negative feedback that girls received was related to their intellectual performance. This pattern tends to make the negative feedback that boys receive more ambiguous and less informative about boys’ intellectual skills and abilities. In other words, by praising girls differentially for nonacademic performance, teachers devalue the academic praise they give to girls. Similarly, by criticizing boys differentially for their nonacademic performance, teachers devalue the academic criticism they give to boys. Dweck et al. (1978) posit that this leads girls to attribute academic failures to lack of ability and boys to attribute academic failures to lack of effort.

An important follow-up study experimentally assigned these patterns of positive and negative feedback to boys and girls. Findings showed that for both genders, the pattern of feedback that was typically used with boys led children to attribute academic failures to lack of effort, while the pattern of feedback that was typically used with girls led children to attribute academic failures to lack of ability (Dweck et al. 1978). As discussed earlier, attributions to ability, which were more common among girls, tend to reflect less adaptive entity theories of intelligence (Hong et al. 1999). These studies establish that the feedback that parents and teachers provide is skewed in a way that promotes more incremental theories of intelligence among boys and more entity theories of intelligence among girls.

While these studies address the formation of beliefs about intelligence in general, additional research suggests that people’s beliefs about whether abilities are fixed or malleable can vary across domains (Dweck et al. 1995). It is likely that math-specific theories of intelligence will have the greatest impact on math attitudes. In fact, college women who believe that math ability is a fixed trait are less highly identified with math, enjoy math less, and report less likelihood of pursuing a math major or career than women who believe that math ability is malleable (Burkley et al. 2010). This finding raises the possibility that gender differences in entity versus incremental theories may be stronger and more influential for math than for other subject areas. For example, adults may be especially likely to use process-directed praise with boys and person-directed praise with girls during math activities. Teachers may also be more likely to praise girls' neatness and criticize their correctness during math than during other lessons. Research has thoroughly established the role of adults' praise and criticism in influencing children's implicit theories of intelligence (Cimpian et al. 2007; Gunderson et al. 2011; Kamins and Dweck 1999; Mueller and Dweck 1998). However, additional research is needed to investigate how gender differences in these theories form and whether these gender differences are stronger in math than in other domains.

Advancing a Developmental Perspective

Young Children's Susceptibility to Gendered Math Attitudes

Much of the research on adults' influences on students' gendered math attitudes has focused on late elementary school through high school grade levels (e.g., Jacobs 1991; Midgley et al. 1989; Simpkins et al. 2006; Yee and Eccles 1988). However, developmental research suggests that children in early elementary school already have the ability to infer broadly held stereotypes, and that this is particularly true of children from academically stigmatized groups (McKown and Weinstein 2003). Hence, it should come as no surprise that studies of preschool and early elementary school children have shown that math attitudes are already gender-differentiated at this age (Ambady et al. 2001; Beilock et al. 2010; Cimpian et al. 2007; Cvencek et al. 2011; Gunderson et al. 2011). As early as second grade, children endorse the societal stereotype that math is for boys and not girls on both implicit and explicit measures (Cvencek et al. 2011). Children not only endorse these stereotypes, but their performance can be affected by making these stereotypes more salient (Ambady et al. 2001; Cimpian 2010). Young children are influenced even by subtle introductions of math-gender stereotypes (Ambady et al. 2001). Five- to seven-year-old girls whose female identity was activated by coloring a picture of a girl holding a doll performed worse on a subsequent math test than girls who colored a picture of a landscape, while boys whose male identity was activated performed better on a math test than boys in the control condition (Ambady et al. 2001). These results show that young children are aware of math-gender stereotypes, at least at an implicit level, and that their performance can be affected by making these stereotypes more salient. While it is important to differentiate between stereotype awareness and stereotype endorsement (e.g., Martinot and Désert 2007), simply being made aware of a negative stereotype may be enough to cause students to perform below their actual ability level. This is because young children's reasoning skills may not be developed enough to challenge these socially communicated messages, particularly if these messages are coming from authority figures such as teachers and parents.

Children in preschool and early elementary school are also susceptible to explicit statements about gender stereotypes (Cimpian 2010). When 4- to 7-year-old girls were shown a novel game and were introduced to a gender stereotype using generic language ("boys are really good at this game") they displayed lower levels of persistence and motivation than children who heard a non-generic statement ("there's a boy who is really good at this game," Cimpian 2010). For the youngest children (age 4-5), motivation decreased only after a failure experience, while for slightly older children (age 6-7), motivation decreased immediately after the presentation of the stereotype—even before the child struggled with the task (Cimpian 2010). These results indicate that children's performance is susceptible to the expression of explicit stereotypes, and that children are already aware of and can be affected by implicit reminders of math-gender stereotypes (Ambady et al. 2001; Cimpian 2010).

Young children are also susceptible to the influences of person- versus process-directed praise (Cimpian et al. 2007; Corpus and Lepper 2007; Gunderson et al. 2011). In experimental situations, preschoolers show less motivation and liking of a task after person-directed praise than after process-directed praise, consistent with activation of an entity theory (Cimpian et al. 2007). Naturalistically, parents' use of process-directed praise with children at ages 1 to 3 is positively related to children's endorsement of incremental theories at age 8 (Gunderson et al. 2011). Although studies have not yet investigated this phenomenon specifically in the domain of math, it seems very likely that children will be susceptible to the influence of adults' praise in a situation that requires math. Moreover, it is possible that these types of praise are highly gender-differentiated in domains such as math where societal gender stereotypes are strong.

Children's own attitudes toward math, including math anxiety and math self-concept, begin to be gender-differentiated in early elementary school as well (Cvencek et al. 2011). In a study of 1st and 2nd grade students, girls reported higher levels of anxiety than boys in the stereotyped domain of spatial reasoning, which is strongly related to math achievement (Casey et al. 1995; Ramirez et al. 2011). Similarly, on an implicit measure of math self-concept where children were asked to associate words representing *math* and *reading* with words representing *me* and *not-me*, 1st and 2nd grade boys associated *math* with *me* more strongly than did girls (Cvencek et al. 2011). Taken together, these studies indicate that in early elementary school, children are aware of and are influenced by math-gender stereotypes; that children's implicit theories of intelligence are influenced by adults' praise and criticism; and that children already show gender differences in their own attitudes toward math.

Although a growing body of research has established that children in preschool and early elementary school are beginning to develop gendered math attitudes, relatively few studies have investigated where these math attitudes come from. Advancing research on the early development of these math attitudes, and especially adults' influences on this development, is important for several reasons. First, understanding the emergence of gendered math attitudes may have great potential for alleviating their negative effects. Interventions that target children in preschool or early elementary school often have larger long-term effects than interventions targeting older children because early interventions take advantage of early malleability and compounding effects that occur over time (Heckman 2006).

Second, studying the development of gendered math attitudes at younger ages allows researchers to investigate how these attitudes form in relation to the development of gender cognitions, including gender identity and endorsement of gender stereotypes, which undergo rapid change in preschool and early elementary school (e.g., Martin and Ruble 2004). Research on gendered math attitudes at these ages should consider whether children's susceptibility to or endorsement of math-gender stereotypes interacts with their development of gender cognitions more generally. In fact, some research suggests that children's math self-concepts may form as a result of their identification with their own gender combined with their math-gender stereotypes (Cvencek et al. 2011).

Potential Interactions Between Gender Rigidity and Gendered Math Attitudes

Another aspect of gender development that is of particular interest is children's tendency to believe that only boys or only girls are associated with certain traits, known as gender rigidity (Martin and Ruble 2004; Trautner et al. 2005). Gender rigidity is typically assessed by asking children to sort household items, occupations, behaviors, and/or personality traits into categories representing "only males", "only females", and "both males and females" (Aubry et al. 1999; Martin and Ruble 2004; Miller et al. 2006; Trautner et al. 2005). Some examples of gender-stereotyped behaviors include "like to play with dolls" (female), "like to play with trucks" (male), "are courageous and self-confident" (male), and "are fearful and afraid of many things" (female) (Trautner et al. 2005). Children begin to show some knowledge of gender stereotypes at age 3, and increase in their rigidity in applying these stereotypes until a peak at ages 5 to 7 (Martin and Ruble 2004; Trautner et al. 2005). Although children's knowledge of gender stereotypes continues to increase throughout elementary school, their rigidity in applying these stereotypes decreases after age 7, after which children begin to say that both males and females can engage in gender-stereotyped behaviors (Martin and Ruble 2004).

Interestingly, the peak level of gender rigidity, at ages 5 to 7, coincides with children's introduction to formal schooling. This raises a number of hypotheses about interactions between children's general gender development and the development of gender-based attitudes and stereotypes about academic subjects such as math. One hypothesis is that children who are at the peak level of gender rigidity may be more likely to learn and be influenced by math-gender stereotypes when adults present them, for instance through modeling from a math-anxious female teacher (Beilock et al. 2010). There is some suggestive evidence that children's math-gender stereotype susceptibility is greater in early elementary school than in later elementary school (Ambady et al. 2001; Cvencek et al. 2011). Girls' math performance is hindered by activation of their gender identity in early elementary school (kindergarten through 2nd grade) but not in later elementary school (3rd through 5th grade) (although the negative effect of gender identity activation returns by middle school; Ambady et al. 2001). Similarly, girls have weaker math self-concepts than boys in 1st through 3rd grades, but these differences are not significant in 4th and 5th grades (Cvencek et al. 2011). Although these studies were not designed to test the influence of gender rigidity on children's gender stereotypes and self-concepts, they nevertheless are consistent with the prediction that gender rigidity, which peaks in early elementary school, may be linked to children's development of gendered math attitudes.

Another intriguing possibility is that stereotypes and anxieties that are developed during this formative period of gender rigidity may be stronger and longer-lasting than stereotypes formed at later ages. Although, as a group, children's math-gender stereotype susceptibility seems to temporarily decline in later elementary school (Ambady et al. 2001), it is possible that individual differences in children's math-gender stereotypes are strongly influenced by input that occurs when children are at a stage of peak rigidity. This is because the environmental messages about math and gender that children receive from parents and teachers are likely to be especially salient during the period when children believe that only boys can do male-stereotyped activities and only girls can do female-stereotyped activities. To our knowledge, no studies have been conducted that relate children's gender-role rigidity, parents' and teachers' gender-biased messages about math, and the formation and persistence of children's gendered math attitudes. While complex, such studies could shed light on the developmental processes involved in the formation of gender stereotypes about math.

Investigating Mechanisms

In addition to expanding research to earlier ages and adopting a developmental perspective, researchers should also consider the mechanisms through which adults' gendered math attitudes are passed on to children. Most previous research has investigated the relations between adults' math attitudes and children's math attitudes and math achievement (Eccles et al. 1990; Jacobs 1991; Midgley et al. 1989; Simpkins et al. 2006; Yee and Eccles 1988). This research establishes that adults' math attitudes can affect children, but does not reveal how this process occurs. Yet any effect of adults' attitudes on children's attitudes and behaviors must be mediated through adults' behaviors and interactions with children. Understanding these behaviors is critical for advancing theoretical knowledge of the social transmission of gendered math attitudes. Moreover, this understanding is crucial for designing interventions that can break the cycle that perpetuates negative attitudes about girls and math. For example, interventions currently exist that target specific behaviors, such as treating children in a gender-neutral way in the classroom (Jones et al. 2000; Lundeberg 1997), or that target underlying attitudes, such as teachers' math anxiety and confidence in math teaching (e.g., Simon and Schifter 1993; Vinson 2001). Although these types of interventions can bring about change in teachers' and students' math attitudes, further elucidation of the mechanisms of math attitude transmission can provide a framework for evaluating existing interventions and developing powerful new interventions for parents and teachers.

Some research has already begun to address specific behaviors that may mediate the relation between adults' math attitudes and children's math attitudes and performance. For example, one major source of parent-child interaction about math among school-age children is children's completion of math homework. Several studies have found that parents' math-gender stereotypes are related to lower expectations for female than male children, which in turn are related to girls' lower perceptions of their own ability (Eccles et al. 1990). A recent study took this research a step further by asking whether the relation between parents' math-gender stereotypes and children's perception of their own math ability is mediated by parents' behaviors while children are completing math homework (Bhanot and Jovanovic 2005). Specifically, the authors examined parents' uninvited help and monitoring while children were completing math homework. Referred to as "intrusive support", this type of uninvited intervention can lead children to doubt their competence (e.g., Pomerantz and Ruble 1998). Parents with stronger math-gender stereotypes provided more intrusive support to girls during math homework, and girls who received more intrusive support had lower perceptions of their own math ability (Bhanot and Jovanovic 2005). Further, the relation between parents' math-gender stereotypes and girls' lower math self-perceptions was accounted for by parents' intrusive support during math homework (Bhanot and Jovanovic 2005). This study is an excellent example of the type of work that can illuminate how parents' and teachers' stereotypes and anxieties about math can impact children.

In investigating adults' influence on children, we must carefully consider the potential mechanisms through which parents' and teachers' attitudes can affect children, and look beyond simple one-to-one mappings between adults' and children's attitudes. For example, in the case described previously, parents' math-gender stereotypes did not lead directly to children's math-gender stereotypes, but rather led to girls' lower math self-perceptions (Bhanot and Jovanovic 2005). While children's stereotypes, self-perceptions, anxieties, and achievement are likely to be interconnected, it is critical to know which component of children's gendered math attitudes is affected by specific behaviors from parents or teachers. This is especially important so that interventions that are designed to improve a specific aspect of children's math attitudes (e.g., to reduce children's gender stereotypes) can target the parent and teacher behaviors that are most relevant to that aspect of math attitudes.

Investigating the mechanisms of transmission between adult and child is a complex task, especially since adults can have a number of different types of math attitudes, including math-gender stereotypes, gender-biased math expectancies, math anxieties, math self-concepts, math self-efficacy, and beliefs about math as a stable trait. Each of these attitudes may lead to several different adult behaviors during interactions with children, which may in turn affect children's stereotypes, anxieties, self-concepts, trait beliefs, and achievement. However, the complexity of these interactions may actually be simplified by considering the possible mechanisms of transmission. We propose that direct teaching, differential treatment of boys and girls, and modeling are three overarching behavioral mechanisms that seem likely to explain many of the established relations between adults' math attitudes and children's math attitudes and achievement.

Direct Teaching

In the simplest case, parents' and teachers' explicit statements about gender and math may influence children through direct teaching (Bigler 1995; Gelman et al. 2004; Patterson and Bigler 2006). For example, when parents talk to their children about gender-appropriate activities, they frequently make gender contrasts (e.g., "that's for boys, not girls") and affirm their children's gender stereotyped statements (e.g., child: "Ballet dancers are girls!", mother: "Mm-hmm") (Gelman et al. 2004). Mothers who hold a stronger female identity are more likely to make statements explicitly contrasting boys and girls (Gelman et al. 2004). Children are also sensitive to teachers' explicit use of gender as a social category, and are more likely to endorse gender-based stereotypes when teachers make explicit use of gender in the classroom (Bigler 1995). When teachers verbally label children according to social categories, the impacts on children's inter-group biases are even more extreme (Patterson and Bigler 2006). Extrapolating from these findings, parents' and teachers' explicit, verbal statements about math-gender stereotypes are likely to influence children's own gender stereotypes and attitudes toward math.

Differential Treatment

In addition, parents and teachers may treat girls and boys differently as a result of their own math-gender stereotypes and gender-biased expectancies. This differential treatment can be either cognitive or social in nature. For example, a parent or teacher who has higher expectancies for boys than girls may give boys more challenging math problems to solve, leading to boys' higher levels of achievement. Some evidence for this mechanism comes from findings that teachers in Austria and in the U.S. interact more with boys than with girls during math classes (Becker 1981; Jungwirth 1991). Differential treatment of boys and girls can also have social and affective components. These may include criticizing or ridiculing female students when they ask for help, or failing to intervene when girls are belittled by their peers, behaviors that college students recall when asked about their math experiences in elementary school (Jackson and Leffingwell 1999). Future research is needed to determine how and at what ages these differences in teachers' treatment of boys and girls are connected to gender differences in students' math attitudes, such as higher levels of math anxiety and lower math self-concepts among girls than boys.

Modeling

Modeling may also prove to be an important mechanism through which adults' math attitudes affect children. Children are particularly sensitive to the behaviors of same-gender adults, and are more likely to model their beliefs and behaviors after same-gender adults while distancing themselves from other-gender adults (Bussey and Bandura 1984). Thus, having a same-gender teacher may make that teacher's behaviors particularly salient. Since most elementary school teachers are female (National Education Association 2003), modeling is likely to affect girls more than boys in early elementary school. Support for this theory comes from the finding that female teachers' math anxiety is related to girls' but not boys' increased math-gender stereotypes and decreased math achievement (Beilock et al. 2010). Girls may see their female teachers as role models for gender-appropriate behaviors; when these teachers dislike and fear math, girls may be likely to interpret that behavior as appropriate for all females (Bussey and Bandura 1984). This may lead girls to adopt stronger math-gender stereotypes and to disengage from and fear math themselves.

Conclusion

Although there is no longer a gap between boys and girls on math achievement tests, negative math attitudes can prevent individuals from performing at their best and can lead girls to pursue math-related courses and career paths at lower rates than boys. Math attitudes begin to form in preschool and early elementary school, with children endorsing gender stereotypes about math, girls displaying lower math self-concepts than boys, and girls being negatively affected by implicit and explicit activation of math-gender stereotypes (Ambady et al. 2001; Beilock et al. 2010). Understanding the math attitudes that eventually lead to gender differences in college and career choices requires understanding the development of these math attitudes from early childhood onward.

Children's math attitudes form as a result of environmental influences, especially those that occur in interactions with parents and teachers. For example, parents' and teachers' expectations for children's success in math are biased by their own gender stereotypes (Eccles et al. 1990). These gender-biased expectations lead to lower achievement and lower math-self concepts among girls than boys (Eccles et al. 1990). However, adults' stereotypes and expectancies are not the only routes through which adults can communicate negative math attitudes to children, especially girls. Drawing upon recent research, we propose that adults' own math anxieties and adults' beliefs and behaviors related to trait stability can also impact children's gendered math attitudes (Beilock et al. 2010; Gunderson et al. 2011). New research is needed to investigate these effects by examining children's interactions with parents and teachers, across age groups, and in math-specific contexts. As this research moves forward, we also propose a deeper consideration of the developmental perspective, which allows us to understand changes in children's susceptibility to adults' messages as a function of age as well as other important developmental processes such as gender rigidity. Finally, close attention should be paid to the behavioral mechanisms that accompany adults' attitudes and impact children's attitudes and achievement. Understanding the behaviors and contexts that form the links between adults' and children's gendered math attitudes is critical for understanding how to minimize negative influences and enhance positive influences on children's math attitudes.

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