K-8 Teachers' Overall and Gender-Specific Beliefs About Mathematical Aptitude

Article *in* International Journal of Science and Mathematics Education · June 2020

DOI: 10.1007/s10763-020-10104-7

Yasemin Copur-Gencturk
University of Southern California

Ian Thacker
University of Southern California

David M. Quinn
University of Southern California

Abstract

Teachers' beliefs play a significant role in students' academic attainment and career choices. Despite comparable attainment levels between genders, persistent stereotypes and beliefs that certain disciplines require innate ability and that men and women have different ability levels impede students' academic career paths. In this study, we examined the prevalence of U.S. mathematics teachers' explicit general and gender-specific beliefs about mathematical ability and identified which teacher characteristics were associated with these beliefs. An analysis of data from 382 K-8 teachers in the USA indicated that overall, teachers disagreed with the idea that general and gender-specific mathematical ability is innate, and agreed with the idea that hard work and dedication are required for success in mathematics. However, our findings indicate that those who believed mathematics requires brilliance also tended to think girls lacked this ability. We also found that teachers who were teaching mathematics to 11- to 14-year old students seemed to believe that mathematics requires innate ability compared with teachers who were teaching mathematics to 5- to 10-year-old students. In addition, more experienced teachers and teachers who worked with special education students seemed to believe less in the role of hard work in success in mathematics, which could have serious consequences for shaping their students' beliefs about their academic self-concept and future career-related decisions.

Keywords: gender-specific ability beliefs, mathematics-specific ability beliefs, teachers' beliefs

A widespread belief exists in many societies that some people are born with mathematics *ability*, which is regarded as an innate aptitude or the potential to perform well in mathematics. Historical and psychological research supports the existence of prevalent stereotypes and beliefs associating men more than women with mathematical ability (e.g., Bennett, 2011; Furnham, Hosoe, & Tang, 2002; Lecklider, 2013; Tiedemann, 2000).[1] In fact, the lower representation of women in disciplines whose experts report that innate ability is the main requirement for success suggests that such beliefs may deter women from entering Science, Technology, Engineering, and Mathematics (STEM) fields, in which inherent ability is perceived to be the key to success (Leslie, Cimpian, Meyer, & Freeland, 2015). Prior work indeed provides evidence that widely held stereotypical beliefs and biases communicated to girls through their social environments partly harm their self-perceptions and academic performance (e.g., Ambady, Shih, Kim, & Pittinsky, 2001; Nosek et al., 2009; Rosenthal & Jacobson, 1968; Steele & Aronson, 1995; see also Bennett, 2011; Ceci, Williams, & Barnett, 2009; Steele, Spencer, & Aronson, 2002; Wang & Degol, 2017, for reviews). However, little is known about the relationship between general and gender-specific beliefs about mathematical ability and the extent to which teachers working with different student populations may hold such beliefs. Thus, the purpose of this study is to explore general and gender-specific beliefs held by teachers that may lead to gender disparities in mathematics attainment.[2]

Gender Differences, Self-Concept, and the Influence of Stereotypes

[1] We use the term "ability" to be consistent with the literature on "field-specific ability beliefs" (see, e.g., Leslie et al., 2015) which uses the term "ability" synonymously with terms such as "natural gift," "talent," or "brilliance."
[2] The term *attainment* refers to education levels that are reached as set by given standard benchmarks (e.g., grades, standardized test scores, educational credentials), a concept that differs notably from the nebulous idea of innate mathematical ability.

Why might women be underrepresented in fields that are perceived as requiring innate ability, such as mathematics? Some have argued that gender-based gaps in mathematical attainment can be explained by biological differences (e.g., Geary, 1996; Geary, Saults, Liu, & Hoard, 2000). However, research has shown that gender differences in mathematics attainment appear and develop while students are in elementary school, suggesting that attainment differences are not genetic (Cimpian, Lubienski, Timmer, Makowski, & Miller, 2016; Husain & Millimet, 2009; Lubienski, McGraw, & Strutchens, 2004; Robinson & Lubienski, 2011). Although the magnitude and statistical significance of gender gaps in mathematics vary from elementary to secondary education and from country to country, the gender gap in mathematics attainment is still a concern for many countries. For instance, according to the Trends in International Mathematics and Science Study (TIMSS) 2015 at the fourth-grade level, boys outperformed girls in 18 out of 49 countries, and the opposite pattern was observed in only 8 countries. At the TIMSS eighth-grade level, boys outperformed girls in 6 out of 39 countries, whereas in 7 countries, girls outperformed boys (Mullis, Martin, Foy, & Hooper; 2016). However, results of another international study with students of similar ages showed more disconcerting results. Specifically, in the Programme for International Student Assessment (PISA) 2018, 15-year-old boys significantly outperformed girls in mathematics in 31 countries and economies, whereas in only 12 countries and economies was the opposite observed (Organisation for Economic Co-operation and Development [OECD], 2019). Furthermore, on average across OECD countries and economies, as well as in more than 30 individual countries and economies, a statistically significant difference was found in self-reports of the top-performing boys and girls in science or mathematics who expect to be working as science and engineering professionals when they are 30, with the results favoring boys. In alignment with these self-reports, bachelor's, master's, and doctoral degrees in STEM fields are increasingly and disproportionately being awarded to men compared with women in the United States (National Science Foundation [NSF], 2015) and internationally (see United Nations Educational, Scientific and Cultural Organization [UNESCO], n.d.).[3] Taken together, the evidence of growing gender disparities from elementary to secondary to postsecondary school suggests that gender differences in mathematics attainment in some countries, including the United States, are not inborn, but rather develop and widen over time.

Female students' decisions not to take advanced-level mathematics courses or choose STEM fields could be critically linked to their *academic self-concept*—their self-evaluation of their mathematical competence and ability (e.g., Bong & Skaalvik, 2003; Oysermann, Elmore, & Smith, 2012). Self-concept is an important aspect of people's mathematical identity and is expected to guide behavior such that people are more driven to behave in ways that are congruent with their self-perceptions (Oysermann et al., 2012). Female students' mathematics self-concept in high school is critically linked to their mathematics course-taking patterns as well as their STEM career aspirations and choices (e.g., Niepel, Stadler, & Greiff, 2019; Schoon & Eccles, 2014; Watt & Eccles, 2008). In some countries, self-concept is actually more strongly associated with their choice of a STEM major than is their attainment level (Ercikian, McCrieth, & Lapointe, 2005).

In developing self-concept, students draw from the messages they receive from their social environment. Exposure to gender-biased messages is hypothesized to reinforce stereotypes that affect women's feelings of competency in a specific domain (Correll, 2001; Greenwald et al., 2002). Gender biases—discriminatory beliefs and behaviors—can be either *explicit*, in that

[3] This evidence is based on graduation data from the UNESCO website (http://data.uis.unesco.org) under "Distribution of Tertiary Graduates."

individuals are consciously aware of them, or *implicit*, in that they are outside the conscious awareness of the individual and are expressed through subtle associations and micro-behaviors (Bargh, 1994; Greenwald & Banaji, 1995; Strack & Deutsch, 2004). Earlier research has shown that teachers and parents sometimes hold explicit gendered and stereotypical beliefs that mathematics is a male-dominated domain (see Li, 1999, for a review). Furthermore, research has documented that such explicit and stereotypical beliefs held by the teachers and parents of female students could affect the students' reported interest in mathematics and mathematics-intensive STEM fields, their intent to pursue mathematics-intensive STEM careers, their self-concept and achievement (see Kim, Sinatra, & Seyranian, 2018, for a review), and ultimately their long-term participation in mathematics and mathematics-intensive STEM fields (Good, Rattan, & Dweck, 2012; Lavy & Sand, 2015).

In addition to explicit beliefs, implicit biases have an impact on students' academic achievement and self-concept. For instance, country-level implicit gender stereotypes associating males with science were found to predict gender gaps on international mathematics and science tests (Nosek et al., 2009), and mathematics-specific implicit biases were negatively associated with girls' self-concept and engagement in mathematics but positively associated with boys' (Nosek & Smyth, 2011). Lavy and Sand (2015) found that Israeli elementary teachers' gender-related grading biases predicted their students' mathematics achievement and course enrollment in advanced mathematics in middle school and high school. German pre-service teachers' implicit and explicit gender-stereotypical beliefs about students' ability in mathematics have also been linked to their tracking decisions when placing hypothetical students into advanced mathematics classes (Nurnberger, Nerb, Schmitz, Keller, and Sutterlin, 2016). And while it is possible that teachers' perceptions of gender differences in the USA may be grounded in actual attainment differences (OECD, 2015), recent research shows that U.S. elementary and middle school mathematics teachers demonstrate gender-based implicit biases even in decontextualized experimental settings (Authors, 2019).

Taken together, this research suggests that implicit and explicit gender biases present in the environment can negatively affect girls' self-concept and their overall participation in mathematics and mathematics-intensive STEM fields. We thus draw from research on mathematics teachers' beliefs as well as on theories hypothesizing that these beliefs are implicitly or explicitly communicated and internalized by students.

Mathematics Teachers' Beliefs

Research on mathematics teachers' beliefs spans more than three decades (for reviews, see Leder, Pehkonen, & Törner, 2003; Phillip, 2007). Foundational studies by Cooney (1985), Ernest (1989), and Thompson (1984) have suggested that mathematics teachers' conceptions may play an important role in shaping their actions. Beliefs are thought of as implicit or explicit behavioral dispositions (Eynde, de Corte, & Verschaffel, 2003; Wilson & Cooney, 2003) that are inextricably intertwined with affect (Debellis & Goldin, 2006; Hannula, 2012; Zan, Brown, Evans, & Hannula, 2006) and attitudes (Di Martino & Zan, 2015; Leder & Forgasz, 2003) and are somewhat stable (see, e.g., Liljedahl, Oesterle, & Berneche, 2012, for a systematic comparison of definitions). Although there is no consensus on how to define mathematics teachers' beliefs, we have adopted the definition of Philipp (2007):

> "[Beliefs are] psychologically held understandings, premises, or propositions about the world that are thought to be true. Beliefs are more cognitive, are felt less intensely, and are harder to change than attitudes. Beliefs might be thought of as lenses that affect one's view of some aspect of the world or as dispositions toward action. Beliefs, unlike

knowledge, may be held with varying degrees of conviction and are not consensual. Beliefs are more cognitive than emotions and attitudes." (p. 259)

Thus, teachers' beliefs have important implications for students given that teachers' beliefs about mathematical ability (1) can be subtle dispositions that potentially influence action; (2) are related to but discernible from knowledge, attitudes, and emotion; and (3) are relatively (but not ultimately) stable. In this study, we focus on teachers' beliefs about mathematical ability which pertain to the nature of mathematics, mathematical knowledge, or mathematics teaching and learning. Such beliefs cut across all topics and situations in mathematics; thus, have a potential to impact teachers' actions in mathematics teaching (Dweck, 1986; Stipek, Givvin, Salmon, & MacGyvers, 2001). Furthermore, prior work has also documented that teachers' explicit beliefs in fixed mathematical ability are also related to their students' de-emphases on hard work and effort (Seals, 2018) and predict teachers' selection of curricular materials and instructional practices (e.g., Handal, 2003).

Beliefs about mathematics can also be gender specific. Gender can be defined broadly as "socially constructed differences between men and women and the beliefs and identities that support difference and inequality" (Acker, 2006, p. 444). Gender-specific beliefs—such as the stereotype that "mathematics is for boys" (Brandell, Leder, & Nyström, 2007)—are thought to be *symbolic* in that they signify to others what is gender normative and what is gender deviant, and they ultimately justify and perpetuate inequitable social structures (e.g., Bjerrum & Nielsen, 2003; Sumpter, 2016). For instance, Keller (2001) found, after adjusting for student achievement, interest, and confidence, that students in Switzerland were more likely to stereotype mathematics as a male domain if their teachers held the same belief. Thus, depending on whether teachers hold genderless mathematical ability beliefs or gender-specific ability beliefs, different groups of students can be impacted by such beliefs. Specifically, while general beliefs could harm all students who were considered as mathematically less able, gender-specific ability beliefs could harm girls even if they were performing similar to boys. In sum, teachers' beliefs send signals to students about who belongs in mathematics and who does not.

Prior Research on Teachers' Beliefs About Mathematical Ability

Prior studies have found that some elementary and middle school mathematics teachers (a) hold beliefs that mathematical ability is a fixed trait, and (b) rate male students' mathematical ability as greater than female students' ability. However, few studies have investigated potential relationships between teachers' general beliefs about mathematical ability and their gender-specific beliefs about mathematical ability, nor has research identified whether working with certain groups of students or possessing certain background characteristics is associated with such beliefs.

General beliefs about mathematical ability. One line of research explores teachers' general beliefs about mathematics and the nature of mathematical ability (e.g., Depaepe, DeCorte, & Verschaffel, 2016). This research often draws a contrast between entity beliefs (i.e., that mathematical ability is fixed and stable) and incremental beliefs (i.e., that mathematical ability is developed through effort; e.g., Dweck, 1986; Stipek et al., 2001). For example, Chrysostomou and Philippou (2010) investigated the extent to which teachers emphasize the requirement of talent and natural ability for success in mathematics. They surveyed 184 in-service and preservice teachers in Cyprus about their mathematical beliefs and found that, on average, they disagreed that ability to learn mathematics is fixed and innate, although about 30% agreed that mathematical ability is an inherent trait. The authors also found that teachers' beliefs that mathematics requires innate ability were linked with other beliefs about mathematics (e.g., that mathematical knowledge is certain, simple, and derived from authority) as well as negative teaching efficacy beliefs. However, the authors of this study did not investigate potential relationships between these beliefs in general ability and gender-specific ability. Additionally, the authors did not report whether teachers' background characteristics were linked to these beliefs, considering that some groups of teachers might be more prone to hold certain beliefs about mathematical ability.

Gender-specific beliefs about mathematical ability. A separate line of research investigates teachers' gender-specific beliefs about mathematical ability and has consistently found that teachers tend to associate natural mathematical ability with boys more often than girls (Tiedemann, 2000; 2002; Fennema, Peterson, Carpenter, & Lubinski, 1990) and explicitly stereotype mathematics as a male domain (Keller, 2001; Leedy, LaLonde, & Runk, 2003, Li, 1999). Tiedemann (2000) surveyed 52 German teachers of Grades 1–5 about their perceptions of boys and girls in their classes. They were asked to choose six of their students, three boys and three girls, from the same performance categories for each gender, one low-performing, one mid-performing, and one high-performing. Teachers then reported on each student's mathematical ability, effort, and potential for success in mathematics and provided their causal attributions for boys' versus girls' successes in mathematics. The author found that teachers viewed boys as more logical thinkers and viewed mathematics as less difficult for boys than girls of the same achievement level, although differences were significant only for mid-performers. Tiedemann also found that teachers believed girls profited less than boys from additional effort and attributed girls' unexpected failure to low ability but attributed boys' failure to effort. However, although this study highlighted teachers' gender-stereotypical evaluations of students' ability in their classrooms, it did not investigate connections between these beliefs and more general beliefs about whether success in mathematics requires innate ability.

Similarly, Fennema and colleagues (1990) conducted a study in the United States that investigated gender differences in first-grade teachers' attributions of the success of students in their own classrooms. Thirty-eight teachers reported characteristics of their most and least successful boy and girl students in mathematics and were interviewed about whether they attributed the successes and failures of their students to the students' ability or effort. These attributions of selected students were also compared with the students' mathematics test scores. The authors found that teachers rated high-performing boys as more competitive, logical, enjoying mathematics more, being more independent, and volunteering answers more often than they did their top-performing girls. However, teachers in this study evaluated students in their own classes, and teachers' overrating or underrating of students' performance was measured by the inconsistencies between teachers' ratings and the students' standardized test scores (used as a proxy for ability) in mathematics. As such, there was no way to know whether teachers' overrating of male students was mainly due to gender-related beliefs or to actual differences in their students' personal characteristics. Moreover, like other studies of teachers' beliefs about ability, this research did not investigate relationships between teachers' gender-specific beliefs about mathematical ability and their general beliefs about mathematical ability, nor did it investigate whether teachers working with certain student populations or possessing certain background characteristics might predict these beliefs.

Given that inherent ability and gender-specific ability beliefs are sending somewhat different messages to students, it is important to investigate the relationship between them. Specifically, espousal of the former implies a stronger conviction that if a student does not have a mathematical brain, he or she will not able to succeed, whereas espousing the latter sends a message only to girls that they do not have mathematical ability. Furthermore, as reported in earlier work, teacher characteristics were not included in these studies. We argue that it is important to understand whether teachers working with different student populations hold different beliefs regarding general and gender-specific ability because it will help us better understand how students with different backgrounds (e.g., ELLs [i.e., students who are not currently proficient as English Language speakers and are in the process of learning English] and special education students [i.e., students with identified health impairments and learning, emotional, and behavioral disorders]) develop their academic self-concept and their perseverance in mathematics, which has important implications for teachers, teacher educators, and researchers.

Present Study

As summarized above, prior research has mainly focused on teachers' gender-related beliefs about and biases pertaining to mathematical abilities. However, to our knowledge, none has explored the relationship between teachers' beliefs regarding mathematical ability as a fixed trait and boys being considered mathematically more gifted. This study attempted to address this gap in the literature and explore whether certain groups of teachers could be identified as espousing such beliefs. In the present study, we examined the relationship between teachers' beliefs regarding mathematical ability and their gender-specific beliefs regarding students' ability, as well as which teacher background characteristics were associated with these beliefs. We aimed to answer the following two research questions based on data collected from 382 teachers in the USA who taught mathematics in Grades K-8 in one of the largest school districts in the United States:

1. To what extent do K-8 teachers hold beliefs that: (a) mathematics requires innate mathematical ability and that (b) boys have higher mathematical ability compared with girls? To what extent are these beliefs related?
2. Which teacher background characteristics are associated with these beliefs?

Method

Study Context

Data for this study were collected as part of a collaboration with (blinded) center, which was conducting an ongoing research study of professional development for teachers in Grades K-8 in a large-sized school district in the United States. The center included our scales capturing teachers' beliefs in their web-based survey. The survey was sent out to teachers who had signed up for summer training as well as teachers who did not sign up for the training. Teachers completed the survey before the summer institute along with an instrument to capture their baseline understanding of mathematical concepts and pedagogical knowledge. The teachers responded to our items in a randomized order before providing their background information. All teachers were offered a $25 Amazon gift card for completing the survey. Nonrespondents were sent additional e-mail reminders over a period of 6 weeks.

Study Sample

We restricted our analysis to teachers who completed all our items and who reported teaching mathematics (N = 382)[4]. As shown in Table 1, the analytical sample had similar levels of teaching experience as a nationwide sample of U.S. teachers in public elementary schools (Snyder, Brey, & Dillow, 2019). Table 2 provides background information on the study sample. The results for the full sample are similar to those reported for this study (see Appendix A).

[4] In total, 664 teachers received an email for the survey and 434 completed our items.

Table 1
Background Characteristics of Teachers in the Present Sample Compared with a Nationwide Sample

	Study sample of U.S. teachers teaching 5- to 13-year-old students (%)	Nationwide sample of U.S. teachers teaching 4- to 11-year-old students (2015–2016) (%)
Female	89.3	89.3
Years of teaching experience		
Less than 3	8.6	10.1
3 to 9	29.8	28.3
10 to 20	40.8	39.3
More than 20	20.7	22.3

Note. Data for nationwide sample of U.S. teachers from Snyder, de Brey, and Dillow (2019).

Measures

Teachers' beliefs regarding mathematical ability. We used four items created by Leslie and colleagues (2015) to create two subcomposites capturing beliefs in mathematics-specific ability. We decided to use these items because this prominent study had found that beliefs captured by these items were highly correlated with the representation of females in STEM fields in the United States. On these items, teachers rated their agreement with four statements on a 7-point scale ranging from 1 = *strongly disagree* to 7 = *strongly agree*.

Innate mathematical ability. These items captured the extent to which teachers believed that mathematical ability was innate, or something that could not be taught:

1. Being a top student of mathematics requires a special aptitude that can't be taught.
2. If you want to succeed in mathematics, hard work alone won't cut it; you need to have an innate gift or talent.

We created the composite variable "Innate" by taking the means of these two items ($\alpha =$ .66 for the analytical sample).[5] Higher values on this composite indicated that teachers agreed more that mathematical ability is innate; lower values indicated that teachers did not believe that mathematical ability is innate.

Malleable mathematical ability. These items captured the extent to which teachers believed that students could improve their mathematics performance by working hard:

1. With the right amount of effort and dedication, anyone can become a top student in mathematics.
2. When it comes to mathematics, the most important factors for success are motivation and sustained effort; raw ability is secondary.

We created the composite variable "Malleable" by taking the means of these two items ($\alpha = .64$ for the analytical sample). On this composite, higher values indicated that teachers agreed more that mathematical ability is malleable and lower values meant that teachers disagreed that mathematical ability is malleable.

Teachers' beliefs regarding gender-specific mathematical ability. To capture teachers' explicit beliefs regarding female students' mathematical ability, we asked teachers to state their agreement with the following three statements by using the same 7-point agree/disagree scale:

1. Even though it's not politically correct to say it, boys are often better at mathematics than girls.
2. Although there are exceptions, boys are usually smarter in mathematics than girls.

[5] Note that coefficients of internal consistency tend to increase as the number of items goes up, thus our scales consisting of two items might be expected to have a lower value for alpha than what is conventionally accepted (e.g., Nunnally & Bernstein, 1994).

3. Girls often need to work harder than boys to be good at mathematics.

We took the mean of these items to create the "Smart boys" composite ($\alpha = .86$ for the analytical sample). Higher values on this composite represented more agreement that boys are better at mathematics than girls, whereas lower values represented more disagreement with this notion. (See Appendix B for the correlation matrix including all seven items.)

Teacher background characteristics. Teachers were also asked to report their gender, the grade level they were currently teaching, their years of teaching experience, and whether they taught English language learners (ELLs) or special education (Table 2). The analytical sample was predominantly female (89%) with, on average, 13.8 years of teaching experience. Forty-four and a half percent of the teachers reported teaching mathematics in grades K-2, 38.2% reported teaching mathematics in Grades 3–5, and 17.3% reported teaching middle school mathematics. Approximately 10% of the sample were ELL teachers, and approximately 10% were special education teachers.

Analytical Approach

To answer our first research question, we examined descriptive statistics and intercorrelations for our composite items. To answer our second research question, we fit sets of ordinary least squares regression (OLS) models using each of the three composites as the outcome.

Results

Teachers' Beliefs About Mathematical Ability and Gender-Related Mathematical Ability

Table 2 presents descriptive statistics for the scales and items used in the study as well as for teacher characteristics for the analytical sample. On average, teachers disagreed that boys were innately better at mathematics ("Smart boys" mean = 1.85, 95% CI [1.75, 1.96]), and 85%

of the responses for this scale indicated disagreement with this composite (i.e., 85% of the sample scored a 3 or less on this composite). Eighty-one percent of teachers also appeared to disagree that innate ability was necessary to do well in mathematics ("Innate ability" mean = 2.25, 95% CI [2.14, 2.34]; approximately *disagree*). Similarly, the majority of teachers believed that mathematical ability was malleable, with a sample mean of 5.2 on the "Malleable" composite (95% CI [5.07, 5.34]) and a median of 6 (*agree*).

Table 2

Descriptive Statistics for the Analytical Sample

Item	*M*	%	*SD*	Min	*Mdn*	Max
Teacher characteristic						
Years of teaching experience	13.783		8.772	1	13	42
Gender (female)		89.3				
ELL teacher		10.2				
Special education teacher		9.9				
K-2 teacher		44.5				
3rd- to 5th-grade teacher		38.2				
Middle school teacher		17.3				
Beliefs scales						
Smart boys	1.853		1.074	1	1	6
Innate ability	2.249		1.098	1	2	6
Malleable	5.202		1.344	1	6	7
Individual items						
Even though it’s not politically correct to say it, boys are often better at mathematics than girls.	1.825		1.220	1	1	7
Although there are exceptions, boys are usually smarter in mathematics than girls.	1.880		1.245	1	1	7
Being a top student in mathematics requires a special aptitude that just can’t be taught.	2.374		1.368	1	2	7
If you want to succeed in mathematics, hard work alone just won’t cut it; you need to have an innate gift or talent.	2.123		1.174	1	2	7
With the right amount of effort and dedication, anyone can become a top student in mathematics.	5.594		1.504	1	6	7
Girls often need to work harder than boys to be good at mathematics.	1.853		1.173	1	1	7
When it comes to mathematics, the most important factors for success are motivation and sustained effort; raw ability is secondary.	4.809		1.634	1	5	7

Note. *N* = 382. ELL = English language learner.

In Table 3, we present a correlation matrix for the composites of beliefs. We found a moderately positive correlation between the "Smart boys" and "Innate ability" indices ($r = .414$, $p < .001$) such that teachers who believed that boys were better at mathematics than girls also tended to believe that innate ability was important for success in mathematics. In contrast, the relationship between the "Smart boys" and "Malleable" composites was not significant ($r = -.07$, *n.s.*), suggesting no association with teachers' gender-specific ability beliefs and their beliefs about the role of malleable factors in success. On the other hand, teachers' beliefs about mathematics requiring innate ability were modestly negatively correlated with the belief that mathematical ability was malleable ($r = –.185$, $p < .001$).

Table 3

Intercorrelations for Item Composites Regarding Beliefs About Gender-Specific, Innate, and Malleable Mathematical Ability

	Smart boys	Innate ability	Malleable
Smart boys	1		
Innate ability	0.414***	1	
Malleable	–0.0718	–0.185***	1

Note. *N = 382.*

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Relationships Between Teachers' Beliefs and Characteristics

In Table 4, we present the results of our OLS regression models that used teacher characteristics to predict the scores on each of the belief composites. As reported in column 1, none of the teacher-related composites significantly predicted teachers' gender-specific beliefs about mathematical ability individually (controlling for teacher characteristics in the model), nor did they explain significant variation as a group ($F = 0.782$).

When the outcome composite was teachers' beliefs regarding mathematical ability (column 2), we found that compared with K-2 teachers ($N = 170$), middle school teachers ($N = 66$) tended to disagree less strongly that success in mathematics required innate ability (controlling for everything else in the model). This difference was substantial at *b* = 0.560, or .52 *SD.* The difference in mathematical ability beliefs of K-2 teachers and grades 3-5 teachers was not statistically different; however, a post-hoc test shows that upper elementary school teachers' and middle school teachers' beliefs about mathematical ability differed significantly (*b* = 0.41, *p* = .013, not shown). The variables included in this model also did not help us explain much of the variation in teachers' beliefs. Only 4% of the variation was explained by this model.

Table 4

OLS Regression Models Predicting the Teacher Belief Composites

Item	(1) Smart boys	(2) Innate	(3) Malleable
Female teacher	0.0274	–0.128	0.174
	(0.181)	(0.183)	(0.220)
Experienced teacher	0.104	0.175	**–0.346***
	(0.113)	(0.113)	**(0.137)**
Special education teacher	0.0629	–0.0392	**–1.020*****
	(0.185)	(0.187)	**(0.225)**
ELL teacher	0.215	0.0805	**0.581****
	(0.185)	(0.186)	**(0.224)**
Upper elementary (Grades 3-5)	0.0619	0.154	0.0102
	(0.122)	(0.123)	(0.148)
Middle school (Grades 6-8)	–0.142	**0.560*****	0.0551
	(0.159)	(0.160)	(0.192)
Constant	1.750***	2.117***	5.244***
	(0.192)	(0.193)	(0.232)
N	382	382	382
F	0.782	2.754	5.003
R^2	0.012	0.042	0.074

Note. Standard errors in parentheses. Predictors are 0/1 indicator variables representing the category given by the variable name. "Experienced" is the median split for an experienced teacher (*Mdn* = 13 years). See Table 2 for subgroup sample sizes. Statistically significant predictors are in boldface. ELL = English language learner. For grade-level variables, lower elementary (K-2) teachers are the reference category.

˜$p < 0.10$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

In column 3, we present the results for the "Malleable" composite. After adjusting for all the teacher characteristics, we found that the more experienced teachers believed less strongly that mathematical ability was malleable (compared with the less experienced teachers, $b = -.346$, or .267 *SD*). Teachers of ELLs ($N = 39$) believed more strongly that students who worked hard could become high achievers in mathematics ($b = .581$, or .446 *SD*), and special education teachers ($N = 38$) believed *less* strongly that students who worked hard could become high achievers in mathematics ($b = -1.02$, or .78 *SD*). This model explained 7% of the variation in teachers' beliefs regarding the role of malleable factors. To investigate this result further, we considered the possibility that special education teachers may have interpreted items differently than general education teachers given that they serve students who may face inordinate challenges in becoming a "top performer" in mathematics. As such, we reran the analyses after dropping items that mention "top students" to check whether the observed pattern was still valid. For both outcomes (effort beliefs and innate beliefs), the overall findings held. Specifically, special education teachers also showed statistically significant disagreement with the statement, "When it comes to mathematics, the most important factors for success are motivation and sustained effort; raw ability is secondary" ($p < .0001$, $b = 1.11$). Similarly, we found that compared with lower elementary school teachers, middle school teachers showed statistically significantly less disagreement with the statement, "If you want to succeed in mathematics, hard work alone won't cut it; you need to have an innate gift or talent" ($p = .002$, $b = .52$). Because both the direction and size of the relationship were similar to the composites in which the "top performer" items were included, we believe that the wording "top performer" was not the main reason for the observed differences in teachers' responses.

We also reconducted the regression analyses reported in Table 5, this time including the remaining two belief composites as predictors along with the teacher characteristic variables to investigate whether the observed relationships among teachers' characteristics and beliefs would be affected after adjusting for teachers' other beliefs. As shown in Table 5, the overall pattern observed between teachers' characteristics and beliefs did not change, with one exception. Middle school teachers, compared with K-2 teachers, believed less strongly in gender-specific ability after controlling for their beliefs about innate mathematical ability and malleable factors (*b* = –0.382, or .393 *SD*). As foreshadowed in Table 3, the models that included teachers' beliefs explained more variation in teachers' responses, especially for the mathematical ability and gender-related beliefs (20% and 24% of the variation in these scales was explained in Models 1 and 2 in Table 5, respectively). However, only 11% of the variation in teachers' beliefs regarding the malleable factors was explained by these variables.

Table 5

OLS Regression Models Predicting Teachers' Belief Composites

Variable	Smart boys	Innate	Malleable
Female teacher	0.0810	–0.117	0.144
	(0.164)	(0.163)	(0.217)
Experienced teacher	0.0312	0.0862	**–0.307***
	(0.103)	(0.102)	**(0.135)**
Special education teacher	0.0864	–0.200	**–1.030*****
	(0.173)	(0.171)	**(0.221)**
ELL teacher	0.177	0.0662	**0.598****
	(0.169)	(0.168)	**(0.221)**
Upper elementary	–0.00433	0.130	0.0453
	(0.111)	(0.110)	(0.146)
Middle school	**–0.382****	**0.627*****	0.186
	(0.146)	**(0.143)**	(0.194)
Smart boys		**0.421*****	0.0113
		(0.0465)	(0.0683)
Innate ability	**0.428*****		**–0.232*****

Variable	Smart boys	Innate	Malleable
	(0.0473)		**(0.0678)**
Malleable	0.00651	**–0.131*** **	
	(0.0393)	**(0.0384)**	
Constant	0.809**	2.068***	5.714***
	(0.301)	(0.281)	(0.269)
N	382	382	382
R^2	0.195	0.243	0.107

Note. Standard errors in parentheses. Predictors are 0/1 indicator variables representing the category given by the variable name. "Experienced" is the median split for experienced teacher (*Mdn* = 13 years). See Table 2 to derive the subgroup sample sizes. ELL = English language learner. For grade-level variables, lower elementary (K-2) teachers are the reference category.
˜$p < 0.10$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Discussion

Before discussing the implications of this study, we would like to note the study limitations. First, although our sample is similar to a nationally representative sample of the target teacher population in the United States in terms of gender and years of teaching experience, there are likely unmeasured factors that influence teacher beliefs, and teachers from different parts of the country might have different sets of beliefs; thus, the generalizability of these findings to US teachers overall is unclear. Second, our standard errors were not adjusted for the clustering of teachers within schools; as such, the standard error estimates across our models may be biased downward. Third, teachers may have felt a social desirability bias when answering these questions, which again may have had the potential to affect these findings. Fourth, our measures of effort and innate ability beliefs consisted of two items each; increasing the number of items to capture each construct might have improved internal consistency coefficients, which were slightly less than adequate at conventional levels. With these caveats in mind, we discuss what our results mean.

Overall, our findings indicate that teachers expressed strong disagreement with statements regarding mathematics requiring innate ability and girls having lower mathematical ability. These findings—that teachers widely do not hold gender-specific ability beliefs—are in conflict with older studies finding that teachers believe that boys have greater innate ability than girls and that teachers tend to stereotype mathematics as a male domain (for a review see Li, 1999). Such disparate evidence over time may indicate a changing tide in cultural values amongst teachers, moving towards equitable perceptions about the potential for girl students to be successful in mathematics (c.f., Bolzendahl & Myers, 2004). When compared with more recent research, our findings are consistent with studies conducted in other countries showing that teachers did not hold strong explicit stereotypical beliefs regarding mathematics being an inherit trait (e.g., Chrysostomou & Philippou, 2010). Furthermore, teachers in our sample seemed to hold more growth mind-sets, agreeing that hard work and effort could lead to success in mathematics.

This finding is important, given that students' self-concept is shaped by the beliefs that are communicated through their environment (e.g., Brophy & Good, 1970; Keller, 2001; Rosenthal, 2002); thus, teachers' explicit disagreement with mathematics requiring innate ability and stereotypical gender-specific beliefs have important implications for students' career choices and course-taking patterns. That being said, teachers' explicit beliefs may not be well aligned with their implicit beliefs (e.g., Greenwald & Banaji, 1995; Nosek & Smyth, 2011); therefore, even though teachers may report that they do not believe in inherent mathematical traits, they may reveal implicit stereotypical beliefs as they interact with their students or make instructional decisions. Implicit gender biases such as these are widespread and are associated with disparities in academic attainment worldwide (Nosek et al., 2009).

Our results also indicated that teachers' beliefs in innate mathematical ability were associated with their beliefs in gender-specific ability. Given that we did not find a significant correlation between teachers' gender-specific ability beliefs and their beliefs about the role of malleable factors in success, our findings somewhat contradict earlier work suggesting that teachers attribute female students' failure to ability and male students' failure to effort (e.g., Fennema et al., 1990; Tiedemann, 2000; 2002). Behavioral differences between male and female students, rather than teachers' stereotypical beliefs, could be the reason teachers associate different attributes to their students' success or failure. More research is needed regarding teachers' explicit beliefs and their perceptions of their students' beliefs to better understand how teachers' explicit and implicit beliefs shape their evaluation of their students' performance and ability.

One of the disconcerting results we found is that middle school teachers seemed to believe more in mathematical traits compared with lower elementary school teachers. This result was also aligned with the strong belief in mathematical traits reported by mathematicians (Leslie et al., 2015). This finding may suggest that when mathematical concepts become more difficult, as in the middle school curricula, teachers may attribute students' struggles to their lack of ability. It could also be the case that elementary teachers, having more time with students to observe students develop and grow, may be less likely to hold fixed ability beliefs compared with middle-school teachers who only experience a snapshot of students' life trajectory, and less exposure to the fruits of students' effort and dedication. Entity beliefs about mathematical ability can make it more difficult for teachers to change their instructional practices because teachers can attribute students' struggles to their lack of ability. Thus, in teacher education and professional development programs, specific attention should be given to emphasizing the role of effort in supporting mathematical learning. This finding also suggests that students may be receiving mixed messages from their environment at different stages of schooling, which could contribute to changes in their mathematics self-concept at different stages of their education (e.g., Robnett, 2016; Sax, 2008; Wigfield et al., 1997).

Our results also indicated that teachers with more teaching experience seemed to believe less in hard work and effort leading to success in mathematics, whereas teachers who work with ELLs believed students could be successful in mathematics if they worked harder. Teachers' instructional decisions are affected by their perceptions of their students' abilities; thus, expecting teachers to enact high-quality instruction requires them to view their students as able to engage with valuable ideas and succeed by putting in effort. Considering that teachers' instructional decisions are shaped by their perceptions of what their students can or cannot do, it may be necessary to shift their perspectives of their students' abilities regarding what they can do and accomplish. We again encourage teacher educators to pay specific attention to these issues in their courses and professional development programs so that such beliefs can be addressed and improved.

We also found that, compared with general education teachers, teachers who work with special education students tended to disagree that effort is important for success in mathematics. One could argue that special education teachers may hold these beliefs because some of the students they teach who have academic disabilities face extreme challenges that prevent them from becoming "top students" in mathematics, regardless of their effort. However, it is also important to note that special education teachers also showed statistically significant disagreement with the statement that motivation and effort are the most important factors and that raw ability is secondary. Thus, further research is needed to investigate special education teachers' beliefs regarding the role of ability in students' success in mathematics.

In sum, our findings indicate teachers' explicit beliefs about mathematical ability are, on average, gender neutral and malleable. However, the results also highlight differences in beliefs about the growth mindset held by elementary and middle school mathematics teachers (Boaler, 1997; 2013; Dweck, 2006; 2008). Increasing teachers' implicit and explicit beliefs in malleable factors such as hard work and decision-making can support students' perseverance in mathematics and their potential choice of STEM-related careers.

References

Acker, J. (2006). Inequality regimes. Gender, class, and race in organizations. *Gender & Society, 20*(4), 441–464.

Ambady, N., Shih, M., Kim, A., & Pittinsky, T. L. (2001). Stereotype susceptibility in children: Effects of identity activation on quantitative performance. *Psychological Science, 12*, 385–390.

Bargh, J. A. (1994). *The four horsemen of automaticity: Awareness, intention, efficiency, and control in social cognition.* In R. S. Wyer & T. K. Srull (Eds.), Handbook of social cognition. Vol. 1: Basic processes (pp. 1–40). Hillsdale, NJ: Lawrence Erlbaum Associates.

Beasley, M. A., & Fischer, M. J. (2012). Why they leave: The impact of stereotype threat on the attrition of women and minorities from science, math and engineering majors. *Social Psychology of Education*, *15*(4), 427–448.

Beaton, A., Martin, M. O., Mullis, I., Gonzalez, E. J., Smith, T. A., & Kelley, D. L. (1996). *Mathematics achievement in the middle school years: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: Boston College.

Bennett, C. (2011). Beyond the leaky pipeline: Consolidating understanding and incorporating new research about women's science careers in the UK. *Business and Economic Review, 54*, 149–176.

Bjerrum Nielsen, H. (2003). *One of the boys? Doing gender in scouting.* Génève, Sweden: World Organization of the Scout Movement.

Boaler, J. (1997). Reclaiming school mathematics: The girls fight back. *Gender and Education, 9*(3), 285-305.

Boaler, J. (2013). Ability and mathematics: The mindset revolution that is reshaping education. *Forum 55*(1), 143-152.

Bolzendahl, C. I., & Myers, D. J. (2004). Feminist attitudes and support for gender equality: Opinion change in women and men, 1974–1998. *Social Forces, 83*(2), 759-789.

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review, 15*(1), 1-40.

Brandell, G., Leder, G. & Nyström, P. (2007). Gender and mathematics: Recent development from a Swedish perspective. *ZDM, 39*(3), 235–250.

Brophy, J. E., & Good, T. L. (1970). Teachers' communication of differential expectations for children's classroom performance: Some behavioral data. *Journal of Educational Psychology, 61*(5), 365.

Ceci, S. J., Williams, W. M., & Barnett, S. M. (2009). Women's Underrepresentation in Science: Sociocultural and Biological Considerations. *Psychological Bulletin, 135*(2), 218–261.

Chrysostomou, M., & Philippou, G. N. (2010). Teachers’ epistemological beliefs and efficacy beliefs about Mathematics. *Procedia-Social and Behavioral Sciences, 9*, 1509-1515.

Cimpian, J. R., Lubienski, S. T., Timmer, J. D., Makowski, M. B., & Miller, E. K. (2016). Have gender gaps in math closed? Achievement, teacher perceptions, and learning behaviors across two ECLS-K cohorts. *AERA Open, 2*(4), 2332858416673617.

Cooney, T. J. (1985). A beginning teacher‟s view of problem solving. *Journal for Research in Mathematics Education, 16,* 324–336.

Correll, S. J. (2001). Gender and the career choice process: The role of biased self-assessments. *American Journal of Sociology, 106*(6), 1691-1730.

Debellis, V. A., & Goldin, G. A. (2006). Affect and meta-affect in mathematical problem solving: A representational perspective. *Educational Studies in Mathematics, 63*(2), 131–147.

Depaepe, F., DeCorte, E., & Verschaffel, L. (2016). Mathematical epistemological beliefs. In J. A. Greene, W. A. Sandoval, & I. Bråten (Eds.), *Handbook of epistemic cognition* (pp. 147–164). New York, NY: Routledge.

Di Martino, P., & Zan, R. (2015). The construct of attitude in mathematics education. In B. Pepin & B. Roesken-Winter (Eds.), *From beliefs to dynamic affect systems in mathematics education* (pp. 51–72). New York: Springer.

Dweck, C. (1986). Motivational processes affecting learning. *American Psychologist, 41*, 1040-1048.

Dweck, C.S. (2006) Is math a gift? Beliefs that put females at risk, in S.J. Ceci & W. Williams (Eds) *Why Aren’t More Women in Science? Top Researchers Debate the Evidence.* Washington DC: American Psychological Association.

Dweck, C. S. (2008). *Mindsets and math/science achievement.* New York, NY: Carnegie Corp. of New York, Institute for Advanced Study, Commission on Mathematics and Science Education.

Ercikan, K., McCreith, T., & Lapointe, V. (2005). Factors associated with mathematics achievement and participation in advanced mathematics courses: An examination of gender differences from an international perspective. *School Science and Mathematics, 105*(1), 5-14.

Ernest, P. (1989). The impact of beliefs on the teaching of mathematics. In C. Keitel, P. Damerow, A. Bishop, & P. Gerdes (Eds.), *Mathematics, education, and society* (pp. 99-101). Paris: UNESCO.

Eynde, P. O., de Corte, E., & Verschaffel, L. (2003). Framing students’ mathematics-related beliefs. A quest for conceptual clarity and a comprehensive categorization. In G. C. Leder, E. Pehkonen, & G. Torner (Eds.), *Beliefs: A hidden variable in mathematics education?* (pp. 13–38). Dordrecht: Kluwer Academic Publishers.

Fennema, E., Peterson, P. L., Carpenter, T. P., & Lubinski, C. A. (1990). Teachers' attributions and beliefs about girls, boys, and mathematics. *Educational Studies in Mathematics, 21*(1), 55-69.

Furnham, A., Hosoe, T., & Tang, T. (2002). Male hubris and female humility A cross-cultural study of ratings of self, parental, and sibling multiple intelligence in America, Britain, and Japan. *Intelligence, 30*, 101–115.

Geary, D. C. (1995). Sexual selection and sex differences in spatial cognition. *Learning and Individual Differences, 7*(4), 289–301.

Geary, D. C., Saults, S. J., Liu, F., & Hoard, M. K. (2000). Sex differences in spatial cognition, computational fluency, and arithmetical reasoning. *Journal of Experimental Child Psychology, 77*(4), 337-353.

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women’s representation in mathematics. *Journal of Personality and Social Psychology, 102*(4), 700–717.

Greenwald, A. G., & Banaji, M. R. (1995). Implicit social cognition: attitudes, self-esteem, and stereotypes. *Psychological Review, 102*(1), 4-27.

Greenwald, A. G., Rudman, L. A., Nosek, B. A., Banaji, M. R., Farnham, S. D., & Mellott, D. S. (2002). A unified theory of implicit attitudes, stereotypes, self-esteem, and self-concept. *Psychological Review, 109*(1), 3–25.

Handal, B. (2003). Teachers' mathematical beliefs: A review. *The Mathematics Educator, 13*(2), 47-57.

Hannula, M. S. (2012). Exploring new dimensions of mathematics-related affect: embodied and social theories. *Research in Mathematics Education, 14*(2), 137-161.

Husain, M., & Millimet, D. L. (2009). The mythical ‘boy crisis’?. *Economics of Education Review, 28*(1), 38-48.

Keller, C. (2001). Effect of teachers’ stereotyping on students’ stereotyping of mathematics as a male domain. *Journal of Social Psychology, 141*(2), 165–173.

Kim, A. Y., Sinatra, G. M., & Seyranian, V. (2018). Developing a STEM identity among young women: a social identity perspective. *Review of Educational Research, 88*(4), 589-625.

Lavy, V., & Sand, E. (2015). On the origins of gender human capital gaps: Short and long term consequences of teachers’ stereotypical biases. National Bureau of Economic Research Working Paper No. w20909.

Lecklider, A. S. (2013). Inventing the egghead: The paradoxes of brainpower in cold war American culture. *Journal of American Studies, 45*(2), 245–265.

Leder, G. C. & Forgasz, J. F. (2003). Measuring mathematical beliefs and their impact on the learning of mathematics: A new approach. In G. C. Leder, E. Pehkonen, & G. Torner (Eds.), *Beliefs: A hidden variable in mathematics education?* (pp. 95-114). Dordrecht: Kluwer Academic Publishers.

Leder, G. C., Pehkonen, E., & Torner, G. (2003). *Beliefs: A hidden variable in mathematics education?* Dordrecht: Kluwer Academic Publishers.

Leedy, M. G., LaLonde, D., & Runk, K. (2003). Gender equity in mathematics: Beliefs of students, parents, and teachers. *School Science and Mathematics, 103*(6), 285-292.

Leslie, S.-J., Cimpian, A., Meyer, M., & Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science, 347*(6219), 23–34.

Li, Q. (1999). Teachers’ beliefs and gender differences in mathematics: A review. *Educational Research, 41*(1), 63–76.

Liljedahl, P., Oesterle, S., & Bernèche, C. (2012). Stability of beliefs in mathematics education: a critical analysis. *Nordic Studies in Mathematics Education, 17*(3–4), 101–118.

Lubienski, S. T., McGraw, R., & Strutchens, M. (2004). NAEP findings regarding gender: Mathematics achievement, student affect, and learning practices. In P. Kloosterman & F. K. Lester Jr. (Eds.), *Results and interpretations of the 1990 through 2000 mathematics assessments of the National Assessment of Educational Progress (pp. 305–336)*. Reston, VA: National Council of Teachers of Mathematics.

Mullis, I. V. S., Martin, M. O., Gonzalez, E. J., Gregory, K. D., Garden, R. A., O'Connor, K. M., Chrostowski, S. J. & Smith, T. A. (2000). *TIMSS 1999 international mathematics report: Findings from IEA's report of the third international mathematics and science study at the eighth grade.* Chestnut Hill, MA: Boston College.

Mullis, I.V.S., Martin, M.O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 international results in mathematics.* Boston: Boston College International Study Center. Online at http://timssandpirls.bc.edu/timss2015/international-results/

National Science Foundation (2015). *Science and engineering degrees, by race/ethnicity of recipients: 2002-12.* Arlington, VA. Retrieved from https://www.nsf.gov/statistics/2017/nsf17310/.

Niepel, C., Stadler, M., & Greiff, S. (2019). Seeing is believing: Gender diversity in STEM is related to mathematics self-concept. *Journal of Educational Psychology, 111*(6), 1119-1130.

Nosek, B. A., Smyth, F. L., Sriram, N., Lindner, N. M., Devos, T., Ayala, A., … Greenwald, A. G. (2009). National differences in gender-science stereotypes predict national sex differences in science and math achievement. *Proceedings of the National Academy of Sciences*, *106*(26), 10593–10597.

Nosek, B. A., & Smyth, F. L. (2011). Implicit social cognitions predict sex differences in math engagement and achievement. *American Educational Research Journal, 48*(5), 1125-1156.

Nunnally, J. C. & Bernstein, I.H. (1994). *Psychometric theory.* (3rd ed). New York: McGraw-Hill.

Nürnberger, M., Nerb, J., Schmitz, F., Keller, J., & Sütterlin, S. (2016). Implicit gender stereotypes and essentialist beliefs predict preservice teachers' tracking recommendations. *The Journal of Experimental Education, 84*(1), 152-174.

OECD (2015). *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence,* PISA, OECD Publishing. http://dx.doi.org/10.1787/9789264229945-en

OECD (2019). *PISA 2018 Results (Volume II): Where All Students Can Succeed*, PISA, OECD Publishing, Paris. https://doi.org/10.1787/b5fd1b8f-en.

Oyserman, D., Elmore, K., & Smith, G. (2012). Self, self-concept, and identity. In M. Leary & J. Tangney (Eds.), *Handbook of Self and Identity* (2nd ed., pp. 69–104). NY: Guilford.

Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. In F. Lester (Ed.), *Second handbook of research in mathematics teaching and learning* (pp. 257–315). New York, NY: Information Age

Robinson, J. P., & Lubienski, S. T. (2011). The development of gender achievement gaps in mathematics and reading during elementary and middle school: Examining direct cognitive assessments and teacher ratings. *American Educational Research Journal, 48*(2), 268–302.

Robnett, R. D. (2016). Gender bias in STEM fields: Variation in prevalence and links to STEM self-concept. *Psychology of Women Quarterly, 40*(1), 65-79.

Rosenthal, R., & Jacobson, L. (1968). Pygmalion in the classroom. *The Urban Review, 3*(1), 16-20.

Rosenthal, R. (2002). Covert communication in classrooms, clinics, courtrooms, and cubicles. *American Psychologist, 57*, 838–849.

Sax, L. J. (2008). *The gender gap in college: Maximizing the developmental potential of women and men.* San Francisco: Jossey-Bass.

Schoon, I., & Eccles, J. S. (2014). *Gender differences in aspirations and attainment: A life course perspective.* Cambridge, UK: Cambridge University Press.

Seals, C. (2018). *Teacher beliefs: Effects of a teacher based mindset intervention on math student motivation and achievement.* Michigan State University, East Lansing MI. Retrieved from http://libproxy.usc.edu/login?url=https://search-proquest-com.libproxy2.usc.edu/docview/2155987278?accountid=14749

Snyder, T.D., de Brey, C., & Dillow, S.A. (2019). Digest of Education Statistics 2017 (NCES 2018-070). *National Center for Education Statistics*, Institute of Education Sciences, U.S. Department of Education. Washington, DC. Retrieved from https://nces.ed.gov/programs/digest/d17/tables/dt17_209.22.asp?current=yes.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69*(5), 797.

Steele, C. M., Spencer, S. J., & Aronson, J. (2002). Contending with group image: The psychology of stereotype and social identity threat. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 34, pp. 379–440). San Diego, CA: Academic Press, Inc.

Stipek, D. J., Givvin, K. B., Salmon, J. M., & MacGyvers, V. L. (2001). Teachers' beliefs and practices related to mathematics instruction. *Teaching and Teacher Education, 17*(2), 213–226.

Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review, 8*, 220–247.

Sumpter, L. (2016). Investigating upper secondary school teachers' conceptions: Is mathematical reasoning considered gendered? *International Journal of Science and Mathematics Education, 14*, 347–362.

Thompson, A. (1984). The relationship of teachers' conceptions of mathematics and mathematics teaching to instructional practice. *Educational Studies in Mathematics, 15*, 105-127.

Tiedemann, J. (2000). Gender-related belief of teachers in elementary school mathematics. *Educational Studies in Mathematics*, *41*(2), 191–207.

Tiedemann, J. (2002). Teachers' gender stereotypes as determinants of teacher perceptions in elementary school mathematics. *Educational Studies in Mathematics*, *50*(1), 49–62.

United Nations Educational, Scientific, and Cultural Organization. (n.d.). Education: Distribution of tertiary graduates by field of study [Data file]. Retrieved April 20, 2020 from http://data.uis.unesco.org.

Wang, M. T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational Psychology Review*, *29*(1), 119-140.

Watt, H. M. G., & Eccles, J. S. (2008). *Gender and occupational outcomes: Longitudinal assessments of individual, social, and cultural influences.* Washington, DC: American Psychological Association.

Wigfield, A., Eccles, J. S., Yoon, K. S., Harold, R. D., Arbreton, A. J., Freedman-Doan, C., & Blumenfeld, P. C. (1997). Change in children's competence beliefs and subjective task values across the elementary school years: A 3-year study. *Journal of Educational Psychology, 89*(3), 451.

Wilson, M., & Cooney, T. J. (2003). Mathematics teacher change and development. In G. C. Leder, E. Pehkonen, & G. Torner (Eds.), *Beliefs: A hidden variable in mathematics education?* (pp. 127–148). Dordrecht: Kluwer Academic Publishers.

Zan, R., Brown, L., Evans, J., & Hannula, M. S. (2006). Affect in mathematics education: An introduction. *Educational Studies in Mathematics*, 63(2), 113-121.

Appendix A. Results with the Full Sample.

Table S1

Descriptive Statistics for the Full Sample

Item	*N*	*M*	%	*SD*	Min	*Mdn*	Max
Teacher characteristic							
Years of teaching experience	434	13.984		8.85	1	13	42
Gender (female)	414		89.4				
ELL teacher	434		11.06				
Special education teacher	431		9.74				
K-2 teacher			41.8				
3rd- to 5th-grade teacher			37.2				
Middle school teacher			17.8				
Beliefs scales							
Smart boys	433	1.862		1.074	1	1.7	6.3
Innate ability	433	2.279		1.121	1	2	6
Malleable	434	5.180		1.176	1	5.5	7
Individual items							
Even though it's not politically correct to say it, boys are often better at mathematics than girls.	434	1.855		1.231	1	1	7
Although there are exceptions, boys are usually smarter in mathematics than girls.	434	1.880		1.225	1	1	7
Being a top student in mathematics requires a special aptitude that just can't be taught.	434	2.422		1.410	1	2	7
If you want to succeed in mathematics, hard work alone just won't cut it; you need to have an innate gift or talent.	433	2.241		1.181	1	2	7
With the right amount of effort and dedication, anyone can become a top student in mathematics.	434	5.542		1.498	1	6	7
Girls often need to work harder than boys to be good at mathematics.	433	1.861		1.172	1	1	7
When it comes to mathematics, the most important factors for success are motivation and sustained effort; raw ability is secondary.	434	4.818		1.599	1	5	7

Note. ELL = English language learner.

Table S2. *Intercorrelations for Item Composites Regarding Beliefs About Gender-Specific, Innate, and Malleable Mathematical Ability for the Full Sample*

	Smart boys	Innate ability	Malleable
Smart boys	1		
Innate ability	0.425***	1	
Malleable	–0.0816	–0.198***	1

Note. *N = 433*. **p* < 0.05, ***p* < 0.01, ****p* < 0.001

Table S3. *OLS Regression Models Predicting the Teacher Belief Composites for the Full Sample*

Item	Smart boys	Innate	Malleable
Female teacher	0.0450	-0.112	0.208
	(0.174)	(0.180)	(0.210)
Experienced teacher	0.129	**0.185**~	**-0.373****
	(0.108)	**(0.112)**	**(0.130)**
Special education teacher	0.125	-0.0137	**-1.011*****
	(0.181)	(0.187)	**(0.219)**
ELL teacher	0.159	0.0708	**0.580****
	(0.174)	(0.180)	**(0.208)**
Upper elementary	0.0684	0.151	0.0426
	(0.120)	(0.124)	(0.144)
Middle school	-0.196	**0.531*****	0.0530
	(0.152)	(0.157)	(0.183)
Constant	1.724***	2.103***	5.214***
	(0.186)	(0.192)	(0.224)
N	409	409	410
R^2	0.0178	0.0410	0.0779

Note. Standard errors in parentheses. Predictors are 0/1 indicator variables representing the category given by the variable name. "Experienced" is the median split for an experienced teacher (*Mdn* = 13 years). Statistically significant predictors are in boldface. ELL = English language learner. ~*p* < 0.10, ***p* < 0.01, ****p* < 0.001.

Appendix B. *Inter-correlations for the items on beliefs about math ability and gender-specific math ability (n=382).*

	Item 1	Item2	Item3	Item4	Item5	Item6	Item7
Item1	1						
Item2	0.748***	1					
Item3	0.659***	0.619***	1				
Item4	0.348***	0.349***	0.352***	1			
Item5	0.286***	0.254***	0.299***	0.489***	1		
Item6	-0.0446	-0.0472	-0.0680	-0.198***	-0.150**	1	
Item7	-0.0787	-0.0720	-0.0147	-0.0794	-0.126*	0.467***	1

Note. Item 1: Even though it's not politically correct to say it, boys are often better at mathematics than girls.; Item 2: Although there are exceptions, boys are usually smarter in mathematics than girls.; Item 3: Girls often need to work harder than boys to be good at mathematics.; Item 4: Being a top student of mathematics requires a special aptitude that can't be taught.; Item 5: If you want to succeed in mathematics, hard work alone won't cut it; you need to have an innate gift or talent: Item 6: With the right amount of effort and dedication, anyone can become a top student in mathematics.: Item 7: When it comes to mathematics, the most important factors for success are motivation and sustained effort; raw ability is secondary. * *p* < 0.05, ** *p* < 0.01, *** *p* < 0.001