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Teacher Characteristics, Student Beliefs, and the Gender Gap in STEM Fields

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This article uses data from the U.S. High School Longitudinal Study of 2009 to investigate the relationship between high school students' beliefs about female abilities in math and science and their teacher gender, beliefs, and classroom behaviors. Estimates are obtained by comparing the same ninth graders between math and science classes, thus controlling for student fixed effects. Students were less likely to believe that men were better than women in math or science when assigned to female teachers or to teachers who valued and listened to ideas from their students. The empirical analysis also provides evidence suggesting that these gender beliefs were related to the decisions by female students to take advanced math and science classes in high school.

Keywords: *gender gap, high school, STEM, women in science, beliefs, teacher gender*

This article employs U.S. data to investigate one potential determinant of the gender gap in STEM (science, technology, engineering and mathematics) fields. In particular, this work contributes to the extensive literature on the lack of diversity in these sectors by studying how student–teacher interactions in high school shape student beliefs about female abilities in math and science. The empirical analysis shows that female students assigned to same-sex teachers and/or teachers who listened to and valued ideas from their students were less likely to believe that men were better than women in math or science. Furthermore, this study provides suggestive evidence that female students who did not believe that men were better than women in math or science were more likely to enroll in advanced classes in these subjects.

Historically, male students have outperformed their female classmates in math test scores. Although this gender gap is still significant in some academic indicators such as PISA (Program for International Student Assessment; National Center for Education Statistics [NCES], 2016b), other studies have found only small and declining gender gaps (Hyde, Lindberg, Linn, Ellis, & Williams, 2008; NCES, 2013). In addition to this, there is growing evidence that gender differences in math and science are not caused by genetic factors (Fryer & Levitt, 2010; Guiso, Monte, Sapienza, & Zingales, 2008; Joel et al., 2015; Organisation for Economic Co-Operation and Development, 2015). One may argue that men and women approach complex mathematical problems in different ways, but this does not imply that one gender has an intrinsic advantage in learning advanced mathematics (Spelke, 2005). In this context, Leslie, Cimpian, Meyer, and Freeland (2015) noted that gender imbalances were predominant in subjects in which practitioners believed that raw, innate talent was a key element for success in the field.

While in high school, male students are more likely to take advanced courses in mathematics, physics, and computer science (National Science Board, 2014). These trends remain through tertiary education as well: Women are still a minority in engineering, computer science, physics, economics, and mathematics. In some of these fields, like computer science, the proportion of women has actually decreased over time (National Science Foundation, 2015). Attrition rates are also particularly high, thus suggesting that students may not be ready to attend college-level courses in these subjects. These statistics are similar—or worse—at the graduate level (Chen, 2013).

These educational gaps translate in occupational differences: 50% of scientists and engineers are White men. The underrepresentation of women is clear also in academia ("The Thinking Behind Feminist Economics," 2015), as well as in the Silicon Valley (Apple, 2015; Google, 2015). All the above findings have generated a national debate about the lack of women in science (Pollack, 2015) and the overall shortage of STEM workers (Carnevale, Smith, & Melton, 2011; Executive Office of the President, 2012; Sabot & Wakeman-Linn, 1991). Several scholars have highlighted the importance of women in STEM fields (Corbett & Hill, 2015; Page, 2008; Woolley, Chabris, Pentland, Hashmi, & Malone, 2010).[1]

To summarize, the gender gap in test scores has been declining over time and there is empirical evidence that women are not innately inferior to men in math and science. Nevertheless, women tend to choose different courses in high school and to major less frequently in STEM fields, thus decreasing productivity in those sectors and aggravating the lack of STEM workers (as well as perpetuating the wage gender gap). This article investigates whether participation and college readiness in math and science among female students can be improved by changing their beliefs about women's abilities through their high school teachers.

In particular, the specific channel investigated here is the relationship between student beliefs about male and female abilities in math and science and teacher gender, beliefs, and classroom behaviors. A unique feature of the High School Longitudinal Study of 2009 (HSLS:09) is exploited here: Teachers, students, and parents were asked to compare men and women in math and science. The aim of this article is to explore if and how teacher characteristics were related to student responses. If the estimates showed that teacher gender did drive the results, that is, ceteris paribus, students matched with a female teacher were less likely to believe that men were better than women in math or science, the policy implications would be much different than if the estimates indicated that the key drivers were how the teachers behaved in class or the teacher's own beliefs about men's and women's abilities in math and science.

The rapidly growing literature on the effects of teacher gender on student outcomes motivates the main section of the article. Dee (2005) and Carrell, Page, and West (2010) found positive effects of female teachers on female student performance and behavior. Carrell et al. (2010) exploited random student–professor assignments at the U.S. Air Force Academy to show that female professors increased performance and retention in STEM among female students. Economists and educational specialists have conducted similar analyses in primary and secondary schools (Antecol, Ozkan, & Serkan, 2015; Dee, 2007; Holmlund & Sund, 2008; Paredes, 2014; Winters, Haight, Swaim, & Pickering, 2013), as well as universities (Bettinger & Long, 2005; Bottia, Stearns, Mickelson, Moller, & Valentino, 2015; Hoffmann & Oreopoulos, 2009; Price, 2010) and in developing countries (Muralidharan & Sheth, 2016). More generally, researchers have started to analyze the relationship between teacher demographic characteristics and student short- and long-term outcomes (Gershenson, Hart, Lindsay, & Papageorge, 2017)

Within this literature, Egalite and Kisida (2018) emphasized the negative relationship between teacher–student gender mismatch and student self-reported academic perceptions and attitudes such as feeling cared for, interest and enjoyment of classwork, level of happiness in class, and college aspirations. Both Egalite and Kisida (2018) and Papageorge, Gershenson, and Kang (2016) emphasized the role of teacher expectations and how these expectations changed when students and teachers shared the same demographic characteristics.

Although most of these studies have found positive effects of female teachers on female student achievements, the overall mixed results indicate that the issue may be more complex. Female teachers represent a highly heterogeneous group, so it is not surprising that the empirical conclusions have not been clear-cut. For instance, Dee (2007) argued that switching from a male teacher to a female teacher would halve the gender gap in science among eighth graders. In contrast, Antecol et al. (2015) used a randomized experiment to show that female teachers had a negative impact on math test scores of female students in primary schools located in disadvantaged U.S. neighborhoods. The authors suggested that their results could be driven by math anxiety in those teachers and gender stereotypes instilled in their students. In addition to this, Holmlund and Sund (2008) did not find strong evidence of a causal effect of teacher gender on student grades in Swedish high schools.

This article contributes to this literature by differentiating between several teacher characteristics. In fact, the detailed information in the HSLS:09 makes it possible to understand whether female students were more influenced by their female teachers because of their gender per se, or rather what really mattered were the teachers' gender attitudes or how they treated their students and managed the classroom. Using a between-subject student fixed effects, that is, by comparing how math and science teacher characteristics were related to student beliefs in these two subjects, this study shows that teacher gender was indeed pivotal. For instance, if a (female or male) student had a female teacher in ninth grade math and a male teacher in science, she was less likely to believe that men were better than women in math, compared with how that same student felt about men being better than women in science. A similar result for female student beliefs is found when teachers listened and valued ideas from their students. On the contrary, this study cannot reject the null hypothesis that teacher beliefs had no relation with student beliefs.

To further motivate the article, the second part of the empirical analysis focuses on the relationship between gender beliefs among female students and their decision to take advanced math and science classes in high school. Using a between-subject student fixed effects model, this analysis shows that female students who believed that men were better than women in math or science were less willing to take advanced classes in these subject while in high school. This result suggests that policymakers may improve college readiness among female students by increasing their confidence in women's math abilities through their teachers in high school, thus potentially increasing persistence of women in STEM during college.

Changing gender beliefs is not the only pathway through which the gap in STEM fields may be reduced. As argued by Speer (2017), precollege factors contribute substantially to the gender gap in math-intensive fields. Beliefs can be particularly important in high school: Whether a female student in ninth grade plans to enroll in advanced math or science classes may depend not only on her expected earnings in or out of science field after 10 years, but also on how she compares males and females in math and science, that is, on her confidence in women's abilities and on her expectation about the learning environment.

However, even if high school teachers can play an important role in shaping the career choices of their students, this does not rule out that female students take into account other variables when deciding their future employment paths. The goal here is to offer an explanation that is a complement rather than a substitute to those already emphasized in the previous literature. As summarized in Ceci, Ginther, Kahn, and Williams (2014) and Altonji, Arcidiacono, and Maurel (2016), several authors have looked at the characteristics of the labor markets, as well as at individual preferences, to explain gender differences in major and occupational choices (Goldin, 2014; Reuben, Sapienza, & Zingales, 2014; Turner & Bowen, 1999; Zafar, 2013). Goldin (2014) highlighted the role played by higher demand for flexible working hours among women. Similarly, Zafar (2013) argued that preferences and tastes were the main explanations for the gender gap in the selection of a college major.

This article argues that one of the reasons women are underrepresented in STEM is the negative beliefs about women's abilities in these fields. Lack of role models and adverse classroom and work environments, as well as different expectations for girls and boys, can lead more female students to believe that men are better than women in math and science. This may affect their choices about coursework in high school, thus causing fewer women to select a career in STEM. Those who do choose this path are typically unprepared because they took fewer advanced math and science classes than their male classmates in high school. The final result is a shortage of highly qualified women in STEM, which confirms the lower expectations held for women and lead to even worse conditions in term of role models and work environment. This article investigates whether it is possible to break this vicious circle, or "self-fulfilling prophecy" (Coate & Loury, 1993) by improving teacher–student interactions in high school.[2]

Data

The HSLS:09 is a nationally representative panel micro dataset. These data include approximately 21,440 students in ninth grade from about 940 schools. The survey design has two levels: First, schools were selected at the national level (both private and public). Second, around 20 to 30 students in each school were randomly selected among ninth grades.

In the first round, the selected ninth graders, their parents, math and science teachers, school administrators, and lead school counselors completed a survey. The parent or guardian most familiar with the ninth grader's school situation and experience filled in the parent questionnaire. If the ninth grader had more than one science or math teacher, one teacher per subject was randomly selected among those provided. Students were interviewed between September 2009 and April 2010. The first follow-up was in the spring of 2012, while a brief update was conducted in 2013 (summer and fall) to record students' postsecondary plans. The 2012 follow-up interviews included students, parent, school administrators, and counselors. This wave did not include a questionnaire for teachers. Finally, only students and parents were interviewed in 2013.

Students completed a math assessment in 9th grade (2009) and in 11th grade (2012). Academic transcripts included student GPA, AP class grades, SAT scores, and the number of credits taken in each subject during high school. Additional documentation about the HSLS:09 can be found in the online training modules (NCES, 2016a) and in Ingels et al. (2011), Ingels et al. (2014), and Ingels et al. (2015).

Descriptive Statistics

Table 1 provides some initial summary statistics. The key variables in the empirical analysis are the respondents' beliefs about female and male abilities in math and science.[3] Students in 9th and 11th grades, as well as their parents, 9th-grade math and science teachers, were asked to compare men and women in math and science. The original question was the following:

How would you compare males and females in each of the following subjects? [math or science]

1. Females are much better
2. Females are somewhat better
3. Females and males are the same
4. Males are somewhat better
5. Males are much better

Most of the 9th and 11th graders believed that males and females were the same in math and science (see also Appendix Table A2 in the online version of the journal). The percentage of those who believed that men and women were the same was constant over time in science (around 64%), while it slightly decreased in math (from 60% to 56%).

The first three options and the last two have been combined in the empirical analysis as the goal of the article is to analyze how teachers can influence negative beliefs about women's abilities. Therefore, this gender comparison variable has been set equal to 1 if the respondent believed that men were (much or somewhat) better than women in a given subject, 0 otherwise. This has been done not only to simplify the analysis but also to consistently compare responses across individuals. If one imagines that each individual had a continuous latent variable which measured how much males were better than females, it was likely that each respondent had a different threshold which allowed her to say that "Males are much better" instead of "Males are somewhat better" (Peracchi & Rossetti, 2012). Instead, it is easier to justify a common threshold for this indicator variable. For instance, one may imagine that respondents compared math abilities among the men and women they knew, and declared that males were better if more men than women were above average.[4]

Around 20% of the students in 9th grade and 27% in 11th grade thought that men were better than women in math. There was a similar increase over time in science: from 20% to 24%. It is even more striking to note that the proportion of female students thinking that men were better than women in math jumped from 15% to 25%. When looking at the relationship between

9th-grade teacher gender and student beliefs, 14% of female students who had a female math teacher deemed men superior in math, while 16% held such opinion among female students assigned to male math teachers. Similarly, 14% of female students who had a female science teacher deemed men superior in science, while 19% held such opinion among female students assigned to male science teachers. The two percentage point mean difference in math and the five percentage point mean difference in science are both statistically significant.

For high school teachers, around 11% of the math teachers believed that men were (somewhat or much) better than women in math. Furthermore, this opinion was more common among male math teachers (14%). Nevertheless, it is remarkable that 8% of female math teachers believed that men were better in math. In science, around 9% of the science teachers believed that men were better in their field. Male science teachers were more likely to hold such beliefs (11%) as compared with female teachers (7%). It is also important to highlight that around 61% of math teachers and 56% of science teachers in the sample were female. For parents, around 30% of them believed that men were better than women in math, while 21% supported this idea in science.

Beliefs tended to be persistent: More than 80% (84% among girls) of the students who did not believe that men were better than women in science in 9th grade had the same opinion in 11th grade. This fact provides an additional incentive to find a way to change these beliefs early on: Given that relatively few students switched between 9th and 11th grade from thinking that men were not better than women in math or science to the opposite, it seems worth trying to convince students at the beginning of high school that indeed men are not better than women in these subjects. This may also push female students to take advanced classes in math and science during the first years of high school.

In fact, looking at how many students planned to take advanced math and science classes in high school, around 39% of students intended to enroll in an AP calculus or science course. This figure was similar in math and science and for boys and girls, with a small difference between the two genders in math. However, it seems that more female students were unsure about their future plans: 42% of female students had not decided yet whether to take an AP calculus course, compared with 37% of male students. Among girls, 41% of those who did not believe that men were better than women in science intended to enroll in an AP or IB science class, while this was true only for 31% of the female students in the sample who had the opposite belief.

These stylized facts are simple descriptive statistics and could actually reflect spurious relationships due to omitted variables. Therefore, the rest of the article uses several econometric techniques to test the robustness of the link between teacher characteristics and student beliefs.

Econometric Framework

Main Specification

This article employs an econometric technique pioneered by Dee (2005) and implemented for a binary dependent variable by Gershenson, Holt, and Papageorge (2016). Male and female students are considered separately. The identification strategy exploits the fact that for each interviewed student in ninth grade, it was possible to obtain information about her math (*M*) and science (*N*) teachers. The estimated specification is the following:

$$b_{is} = z'_{is}\beta_1 + \mu_i + \alpha_s + \varepsilon_{is},$$

where the dependent variable (b_{is}) indicates whether or not student i thought in ninth grade that males were better than females in subject s ($s \in \{M, N\}$), 0 otherwise. This belief depended on the math/science teacher characteristics for student i (z'_{is}), student fixed effects (μ_i), a subject fixed effect (α_s), and the error terms (ε_{is}).

The matrix Z contains the regressors of interest, that is, teacher gender, beliefs, and behaviors in class. One issue is omitted variable bias: Other teacher characteristics may affect student beliefs and be correlated with those regressors. To address this concern, the set of controls incorporates additional teacher information. The main specification includes dummy variables reporting whether the teacher had a graduate degree, whether the teacher majored in a STEM field, as well as the number of years (and its squared term) of teaching experience in the subject.

TABLE 1
Summary Statistics

	All	Male	Female	Difference
Students				
Men better than women in math (9th grade)	0.197	0.243	0.151	0.093***
Men better than women in science (9th grade)	0.202	0.240	0.164	0.075***
Men better than women in math (11th grade)	0.274	0.295	0.253	0.042***
Men better than women in science (11th grade)	0.240	0.284	0.196	0.088***
Intend to take AP/IB math	0.392	0.400	0.384	0.016**
Intend to take AP/IB science	0.388	0.384	0.391	−0.007
A in eighth-grade math	0.371	0.338	0.406	−0.068***
A in eighth-grade science	0.412	0.386	0.439	−0.054***
Friends taking more math course	0.054	0.059	0.050	0.009***
Friends taking more science course	0.056	0.063	0.050	0.012***
Enjoyed ninth-grade math course	0.665	0.668	0.661	0.007
Enjoyed ninth-grade science course	0.681	0.700	0.662	0.039***
Math self-efficacy	0.042	0.135	−0.052	0.187***
Science self-efficacy	0.037	0.157	−0.082	0.238***
Observations	20,720	10,440	10,280	
Math teachers				
Men better than women in math	0.106	0.143	0.082	0.061***
Teacher listens student ideas	0.856	0.866	0.856	0.010*
More than bachelor's degree	0.507	0.488	0.520	−0.032***
Bachelor's with STEM major	0.402	0.424	0.387	0.037***
Experience teaching math	10.33	10.96	9.92	1.034***
Observations	16,000	6,180	9,820	
Science teachers				
Men better than women in science	0.090	0.109	0.075	0.034***
Teacher listens student ideas	0.860	0.879	0.859	0.020***
More than bachelor's degree	0.566	0.580	0.555	0.024***
Bachelor's with STEM major	0.578	0.550	0.600	−0.049***
Experience teaching science	10.87	12.18	9.85	2.327***
Observations	14,510	6,430	8,080	
Parents				
Men better than women in math	0.300	0.312	0.296	0.015*
Men better than women in science	0.215	0.229	0.210	0.018**
Observations	14,920	3,470	11,450	

Note. All sample size numbers have been rounded to the nearest 10 for security reason. The number of observations for each category refers to the first variable (Men better than women in math). Unweighted means. STEM = science, technology, engineering, and mathematics.
*$p < .10$. **$p < .05$. ***$p < .01$.

The key point is that each student is observed twice—once in math and once in science—making it possible to control for all observable and unobservable variables that affect student beliefs and that are constant across subjects. In other words, the main advantage of this econometric model is the inclusion of student fixed effects (μ_i). These fixed effects take into account not only student individual characteristics (such as race or cognitive and noncognitive skills), but also school characteristics (such as whether the school is private or its gender composition) and family background (e.g., income, parental education, household demographics). In particular, the student fixed effect holds the student's general attitudes toward men and women constant, as well as the student's assessment criteria.

The parameter of interest (β_1) is then identified by measuring how having different teachers in math and science—such as a male teacher in math and a female teacher in science—was related to their students' comparison of men and women in these two subjects. It is worth emphasizing that there is no need to impose that the impacts of math and science teachers were the same: Additional heterogeneity can be included by interacting teacher characteristics with the subject fixed effect. In other words, it is possible to obtain estimates of β_{1s} rather than just β_1, as done in the "Student–Teacher Interaction" section.

Additional Considerations

To be more confident in the results from the above specification, it is also possible to add one variable that changes across individuals and subjects at the household level: how parents compared men and women in math and science. In other words, the following equation has been estimated, where x'_{is} includes parent beliefs:

$$b_{is} = z'_{is}\beta_1 + x'_{is}\beta_2 + \mu_i + \alpha_s + \varepsilon_{is}.$$

Another concern is that part of the unobservable student characteristics (μ_i) may actually be subject specific (i.e., $\mu_i + \delta_{is}$), thus the fixed effects would not control for such subject-specific student unobservables. First, it is possible to argue that, while these subject-specific components may be important when comparing hard science with humanities as in Dee (2005), the difference between math and science might be smaller. Indeed, as reported in Patterson and Kobrin (2012), there is a high correlation between the SAT scores in math and chemistry (0.756) or physics (0.755). Second, these between-subject differences can be taken into account by controlling for student grades in math and science in the previous academic year, that is, eighth grade. However, these controls are potentially endogenous as they depend on eighth-grade teacher characteristics, which may affect student beliefs in ninth grade as well. Therefore, such a specification is not presented as the main equation of interest, but is added as a robustness check.

Around one fourth of the students in the sample provided different answers about male and female abilities in math and science; thus, there is enough variation to obtain within-individual estimates. Moreover, the fact that there is such variation provides additional evidence supporting the empirical strategy of separating math and science beliefs. In other words, people provided different answers when they were asked to compare men and women in math or science, so it would not be appropriate to combine beliefs.

The empirical analysis takes into account the complex survey design described in the "Data" section by clustering the standard errors at the school level. The dataset also includes the student analytic weights for the base year survey and the longitudinal study. Following Solon, Haider, and Wooldridge (2015), in this study the sampling is independent of the dependent variables conditional on the explanatory variables, so using weights to correct for endogenous sampling is not appropriate here. Moreover, using weights to estimate average partial effects in case of heterogeneous effects is usually insufficient. Therefore, rather than weighting, the analysis has been extended by adding interaction terms or by focusing the estimation on a particular subsample. Finally, the general view is that it is more conservative to report heteroscedasticity-robust standard errors rather than using weights to obtain more precise estimates under heteroscedasticity. To conclude, there are no reasons in this analysis to justify weighting when estimating average effects.

Empirical Results

Student–Teacher Interaction

The results from the student fixed effects model described in the "Main Specification" section are presented in Table 2 for female and male students separately. Column 1 (for female students) and column 5 (for male students) include the basic regressors. Additional teacher characteristics are added in columns 2 and 6, parental beliefs and student grades in previous courses are taken into account in columns 3 and 7, while additional interaction terms are included in columns 4 and 8.

The main result, which holds across all specifications, is that teacher gender was strongly related to student beliefs. On average, having a female teacher reduced the probability of believing that men were better than women in math/science by almost six percentage points for female students (column 3). For example, if a female ninth grader had a female teacher in math, and a male teacher in science, she was less likely to believe that men were better than women in math, compared with how that same student deemed men and women in science. A symmetric effect is found for students who had a male teacher in math and a female teacher in science. Indeed, there is no evidence of heterogeneity between subjects: The coefficient of teacher gender is similar in math and science (column 4).

From a policy perspective, it is interesting to note that male students were also less likely to hold negative gender attitudes when matched with female teachers. These classmates were going to be future husbands, fathers, and colleagues. Therefore, changing their beliefs may have intergenerational effects and improve the workplace environment which is often reported as an obstacle to female participation in STEM fields (Weinberger & Leggon, 2004).

Female students tended also to be more confident about women's abilities when their teachers listened and valued their students' ideas. However, the coefficient of the interaction between teacher gender and whether the teacher listened to ideas from students is positive and significant when examining female students (while statistically insignificant for male students).

Teacher beliefs do not seem to have a significant relationship with student beliefs. This may be due to the lower variability in teacher beliefs between subjects. Around 46% of the students in the sample had math and science teachers with different gender. Moreover, 22% of the students thought that their math teacher listened to students' ideas but that this was not true for their science teacher (or vice versa). On the contrary, only 17.8% of the students had a math teacher who believed that men were better than women in math and a science teacher who did not believe that men were better in science (or vice versa).

Extensions

Table 3 deepens the above analysis by investigating whether having a female teacher in math or science was associated with more students believing that men and women were equivalent in these subjects, or that women were better than men. To this end, while the dependent variable in Table 2 is equal to 1 if a ninth grader believed that men were better than women in math/science, 0 otherwise, the dependent variable in Table 3, column 1 (for female students) and column 4 (for male students) is set equal to 1 if a ninth grader believed that men and women were equivalent in math/science, 0 if she believed that men were better or that women were better. The dependent variable in columns 2 and 5 is instead set equal to 1 if a ninth grader believed that women were better than men in math/science, 0 if she believed that men were better or that men and women were equivalent.

The econometric framework is the same as described in the "Main Specification" section. After comparing the same student in math and science, the estimated coefficient indicates that having a female teacher increased the probability of a female student believing that women were better than men in these subjects by more than four percentage points (column 2). The effect of having a female teacher on the probability of a female student believing that men and women were equivalent in these subjects was also positive, although not statistically significant (column 1). On the contrary, having a female teacher significantly increased this probability among male students (column 4), while it had a limited and insignificant (positive) effect on the probability that a male student believed that women were better than men in math or science (column 5).

Having a male math/science teacher reduced the probability of a female student believing that women were better than men in math/science (column 3), while it did not affect such probability among male students (column 6). It is therefore possible to conclude that exposing students to both male and female teachers in math and science may lead to more neutral and balanced beliefs about men's and women's abilities in these subjects.

Additional Robustness Checks

Appendix B (in the online version of the journal) includes several sensitivity analyses. Results in Table 2 are robust to further tests to

TABLE 2

Estimates of Teacher Effects on Students' Gendered Math and Science Beliefs

	Female students				Male students			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female teacher	−0.060***	−0.058***	−0.058***	−0.129***	−0.053***	−0.054***	−0.063***	−0.089**
	(0.011)	(0.011)	(0.014)	(0.039)	(0.012)	(0.012)	(0.015)	(0.045)
Men better in math/science	−0.005	−0.005	−0.012	−0.011	−0.006	−0.003	−0.017	−0.015
	(0.019)	(0.019)	(0.022)	(0.022)	(0.020)	(0.019)	(0.025)	(0.025)
Listens student ideas	−0.041**	−0.038**	−0.051***	−0.102***	0.026	0.025	0.024	0.017
	(0.016)	(0.017)	(0.019)	(0.029)	(0.018)	(0.018)	(0.023)	(0.036)
Math	−0.002	−0.006	−0.007	−0.001	0.017**	0.020**	0.023**	0.003
	(0.008)	(0.008)	(0.010)	(0.020)	(0.008)	(0.008)	(0.010)	(0.017)
Female teacher × Math				−0.011				0.036
				(0.028)				(0.026)
Female teacher × Listen				0.087**				0.010
				(0.039)				(0.044)
Teacher controls	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Student controls	No	No	Yes	Yes	No	No	Yes	Yes
Observations	11,940	11,910	8,180	8,180	11,790	11,760	7,810	7,810
Overall R^2	.005	.005	.007	.007	.002	.002	.012	.013
Within R^2	.009	.009	.022	.024	.007	.008	.016	.017

Source. HSLS:09.

Note. This table analyzes the relationship between how students compared men and women in math/science and the characteristics of their teachers in these subjects. The dependent variable is equal to 1 if a student believed that men were better than women in math/science, 0 if she believed that women were better or that men and women were equivalent. Standard errors in parenthesis clustered at school level. The set of teacher controls includes experience teaching math/science (and its squared term), whether the teacher completed post-tertiary education (more than bachelor's degree), and whether the teacher majored in a STEM field. The set of student subject-specific controls includes whether the student got an A in eighth-grade math/science, and whether the interviewed parent believed that men were better than women in math/science. Constant term not shown in table. All sample size numbers have been rounded to the nearest 10 for security reason. HSLS:09 = High School Longitudinal Study of 2009; STEM = science, technology, engineering and mathematics.

*$p < .10$. **$p < .05$. ***$p < .01$.

TABLE 3

Estimates of Teacher Effects on Students' Gendered Math and Science Beliefs: Extensions

	Female students			Male students		
	Men = women	Women > men		Men = women	Women > men	
	(1)	(2)	(3)	(4)	(5)	(6)
Female teacher	0.016	0.043***		0.045***	0.018	
	(0.013)	(0.011)		(0.013)	(0.012)	
Men better in math/science	0.024	−0.013	−0.013	0.036	−0.019	−0.019
	(0.021)	(0.018)	(0.018)	(0.023)	(0.019)	(0.019)
Listens student ideas	0.048**	0.003	0.003	0.026	−0.049**	−0.049**
	(0.020)	(0.018)	(0.018)	(0.022)	(0.020)	(0.020)
Math	−0.040***	0.046***	0.046***	−0.075***	0.052***	0.052***
	(0.010)	(0.008)	(0.008)	(0.010)	(0.008)	(0.008)
Male teacher			−0.043***			−0.018
			(0.011)			(0.012)
Teacher controls	Yes	Yes	Yes	Yes	Yes	Yes
Student controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,180	8,180	8,180	7,810	7,810	7,810
Overall R^2	.004	.007	.007	.006	.030	.030
Within R^2	.012	.024	.024	.026	.029	.029

Source. HSLS:09.
Note. This table analyzes the relationship between how students compared men and women in math/science and the characteristics of their teachers in these subjects. The dependent variables are an indicator equal to 1 if a student believed that men and women were equivalent in math/science, 0 if she believed that men were better or that women were better (columns 1 and 4), and an indicator equal to 1 if a student believed that women were better than men in math/science, 0 if she believed that men were better or that men and women were equivalent (columns 2–3 and 5–6). Standard errors in parenthesis clustered at school level. The set of teacher controls includes experience teaching math/science (and its squared term), whether the teacher completed post-tertiary education (more than bachelor's degree), and whether the teacher majored in a STEM field. The set of student subject-specific controls includes whether the student got an A in eighth-grade math/science, and whether the interviewed parent believed that men were better than women in math/science. Constant term not shown in table. All sample size numbers have been rounded to the nearest 10 for security reason. HSLS:09 = High School Longitudinal Study of 2009.
*$p < .10$. **$p < .05$. ***$p < .01$.

rule out reverse causality (see Section B.1 in the online version of the journal) or spillover effects (see Section B.2 in the online version of the journal). The Appendix also extends the main analysis by investigating additional heterogeneities (see Section B.3 in the online version of the journal), excluding some of the teacher characteristics or including additional controls from eighth grade (see Section B.4 in the online version of the journal), exploiting variation in the time of the interview (see Section B.5 in the online version of the journal), as well as variation between 9th and 11th grade (see Section B.6 in the online version of the journal), and discussing misspecifications of the function form (see Section B.7 in the online version of the journal), misreporting, nonresponse rates, and goodness-of-fit measures (see Section B.8 in the online version of the journal).[5]

In particular, one concern about the variable indicating whether the teacher listened to ideas from students is that it was reported by the student, not the teacher. Therefore, there might have been a latent factor that drove students' responses both when they were asked to compare men and women in math and science, as well as when they were asked whether their teachers valued and listened to ideas from students. If such an unobservable was common in both math and science, it would be captured by the student fixed effect. Moreover, it is reassuring to note that omitting the regressor "Listens student ideas" from Table 2 does not change the estimated coefficient of teacher gender (see Appendix Table B5 in the online version of the journal).

Another key issue is that nonrandom assignment of students to teachers may undermine the above identification strategy if different between math and science. For instance, low-ability female students may be systematically assigned to female teachers in math, but not in science. Section B.9 in the Appendix provides evidence against such an endogenous student–teacher sorting mechanism. This section also rejects the hypothesis of differential sorting based on observables using a test developed by Fairlie, Hoffmann, and Oreopoulos (2014) and Gershenson et al. (2016).

Limitations to Causal Interpretation

The results in Table 2 show that there is a significant relationship between high school teacher characteristics and student beliefs, especially through teacher gender. There are a few factors that may suggest that such a relationship is indeed causal. First, the student fixed effects take into account all the observable and unobservable variables that are constant across subjects. This set includes cognitive and noncognitive skills, self-confidence, and family background. Second, the results are robust to the inclusion of subject-specific past performance, as well as parental gender attitudes in math and science. Third, there is no evidence of nonrandom teacher–student sorting, which has been highlighted in the previous literature as the main threat to an identification strategy that relies on the comparison of the same student between subjects.

Despite this, there are two omitted variables that could bias the estimates. One is the effect of previous teachers. For instance, math and science teachers in eighth grade may have affected student beliefs. Nevertheless, if the same teacher taught in the math and science courses, this was included in the student fixed effects. Moreover, it is difficult to see how the eighth-grade teachers may be correlated with the regressors of interest, that is, ninth-grade teacher gender, attitudes, and behaviors. Although previous teachers may influence students' opinions and encourage students to take more math or science courses, they do not create an omitted variable bias as long as they do not affect the assignment of ninth-grade female teachers across courses. Most students changed school between eighth and ninth grade and, as reported by school counselors in the HSLS:09, middle-school teachers had little or no influence on student–teacher assignment in high school.

The second omitted variable is peer effect: If the best student in the class was a girl, or if the student's best friend was a girl with good grades in math and science, this influenced the student's comparison of men and women in math and science. This dataset does not contain this information. Therefore, this is a clear limitation of this study. However, if the best friend was not a classmate, this peer effect was not correlated with ninth-grade teacher characteristics. Furthermore, if the best friend did not change across subject (and she had similar grades in math and science), then this effect was included in the student fixed effects. The same is true if the top student was a girl in both the math and science classes. In addition to this, even if the top student was a girl only in one class, her teacher probably played an important role in her success. Therefore, controlling for such peer effect may not be desirable as it would underestimate the teacher impact by excluding such an indirect effect.

As a final robustness check, it is possible to test the stability of the estimated coefficients of teacher gender in case of omitted variables by implementing the approach suggested by Altonji, Elder, and Taber (2005) and Oster (2017). Scott-Clayton and Minaya (2016) have also used this procedure with a binary outcome variable. The key assumption is that the bias due to unobservable components is correlated with the observed controls. Focusing on the specifications with the largest set of controls (Table 2, column 3), Oster's method implies that the unobservables should be 2.8 times as important as the observables to produce a zero impact of teacher gender on female students' beliefs. The same ratio is 2.7 for male students (Table 2, column 7). As the heuristic threshold for such ratio is 1, this result attenuates the above concerns regarding potential omitted variable bias.

Advanced Math/Science Courses

Trying to affect students' beliefs about men's and women's ability in math and science would be more relevant from a policy perspective if these beliefs actually influence student decisions during high school and later in life. Therefore, to offer an additional motivation for the main research question, this section provides suggestive evidence that student beliefs were related to the decision to take advanced math or science classes in high school.

As the starting point of this article is the lack of women in STEM fields, the estimation focuses on female students. Students in ninth grade were asked whether they planned to enroll in an AP/IB calculus or science course. Given that each student is observed twice—once in math and once in science—it is possible to estimate the following model:

$$\mathrm{AP}_{is} = \beta_1 b_{is} + z'_{is}\beta_2 + x'_{is}\beta_3 + \mu_i + \alpha_s + \varepsilon_{is}.$$

The dependent variable (AP_{is}) is whether or not student i was planning in ninth grade to enroll in an advance course in subject s ($s \in \{M, N\}$) while in high school. The key regressor of interest is whether student i believed that men were better than women in subject s (b_{is}). However, the enrollment decision also depended on other factors which could be correlated with student beliefs. Therefore, the specification also includes the ninth-grade math/science teacher characteristics (z'_{is}), observable and unobservable student fixed effects (μ_i), and a subject fixed effect (α_s). The set of regressors (x'_{is}) also includes parental beliefs, whether the student enjoyed her math/science course in ninth grade, and whether the student wanted to take additional math/science classes because her friends were enrolled in them.

It is important to emphasize again that even if the above specification includes individual fixed effects and several controls regarding teachers, parents, and peers, it may not be enough to claim that b_{is} is exogenous as the error term could still include factors which determined the student's decision to take AP/IB classes in math or science and were correlated with her beliefs. For instance, friends and classmates could have played an important role in this context, but the HSLS:09 data are not rich enough to fully control for peer effects. Nevertheless, the aim of this section is to show that student beliefs are associated with the decision to take additional courses in math or science, thus further emphasizing the importance of analyzing how students compare men and women in math and science and how these beliefs can be modified.

Indeed, after comparing the same student between subjects, column 1 in Table 4 shows that female students who believed that men were better than women in math (science) were more than seven percentage points less likely to enroll in advanced math (science) courses in high school. It is also possible to investigate potential heterogeneities across subjects in the effect of student beliefs, but the interaction between student beliefs and subject fixed effect is not statistically different from 0 (column 2). The coefficient of student i's opinion does not change substantially after adding whether the student got an A in her eighth-grade math/science course (column 3), or a measure of student self-efficacy in these subjects (column 4).[6] With the exception of whether teachers listened to ideas from students, most of the teacher characteristics were not significantly related to student decisions. Although the "Empirical Results" section shows that teacher gender affected student beliefs, there is no evidence that the relationship between teacher gender and student's intention to take additional math or science classes is statistically significant.[7]

As discussed in the Appendix, these results are robust to alternative ways to construct the gender comparison variable b_{is} (see Section C.1 in the online version of the journal), to limiting the sample to only schools that offered AP classes on-site (see Section C.2 in the online version of the journal), and to control for the average gender beliefs among 9th graders in the school (see Section C.3 in the online version of the journal). Sections C.4 to C.6 (in the online version of the journal) include further descriptive analyses of the relationships among 9th-grade student beliefs, teacher characteristics, and long-term outcomes such as whether the student actually took any math or science advance classes by 11th grade, the overall number of credits taken by the student in math or science, or whether the student was planning to major in a STEM field by the time she started college.

Discussion and Conclusion

This article shows that female students assigned to female instructors in ninth grade were less likely to believe that men were better than women

TABLE 4

Intention to Take AP/IB Courses in Math/Science

Female students

	(1)	(2)	(3)	(4)
Men better in math/science (Student)	−0.074***	−0.084***	−0.087***	−0.076***
	(0.019)	(0.027)	(0.028)	(0.027)
Men better × Math		0.018	0.027	0.026
		(0.035)	(0.036)	(0.034)
Female teacher	−0.005	−0.005	−0.004	−0.003
	(0.015)	(0.015)	(0.015)	(0.015)
Men better in math/science (Teacher)	−0.019	−0.019	−0.023	−0.021
	(0.022)	(0.022)	(0.022)	(0.022)
Listens students ideas	−0.033	−0.033	−0.036*	−0.043**
	(0.021)	(0.021)	(0.021)	(0.021)
Subject math fixed effect	0.006	0.003	0.003	−0.004
	(0.010)	(0.011)	(0.011)	(0.012)
Teacher controls	Yes	Yes	Yes	Yes
Student controls	Yes	Yes	Yes	Yes
Past grade	No	No	Yes	No
Self-efficacy	No	No	No	Yes
Observations	6,130	6,130	6,000	6,050
Overall R^2	.034	.034	.087	.098
Within R^2	.045	.045	.054	.066

Source. HSLS:09.

Note. This table analyzes the relationship between intention to take advance course in math/science and how students compared men and women in these subjects. Only female students considered. Standard errors in parenthesis clustered at school level. The set of teacher controls includes experience teaching math/science (and its squared term), whether the teacher completed post-tertiary education (more than bachelor's degree), and whether the teacher majored in a STEM field. The set of student subject-specific controls includes whether the student planned to take more math/science courses because her friends were enrolled in them, whether the ninth grader enjoyed her math/science courses very much, and whether the interviewed parent believed that men were better than women in math/science. Constant term not shown in table. All sample size numbers have been rounded to the nearest 10 for security reason. HSLS:09 = High School Longitudinal Study of 2009; STEM = science, technology, engineering and mathematics.

*$p < .10$. **$p < .05$. ***$p < .01$.

in math or science, compared with the other subject where the student had a male teacher. In other words, after observing the same ninth grader in math and science, the estimates indicate that a student was less likely to believe that men were better than women in math (science) when she was matched with a female math (science) teacher and a male science (math) teacher.

The significant relationship between teacher gender and student beliefs is in line with the positive effect of female leaders on female aspirations and educational attainment (Beaman, Duflo, Pande, & Topalova, 2012). Moreover, the fact that such a relationship is found also among male students is an interesting and important result as these high school male students are going to interact with women in college, at work, and within their family as adults. As a result, changing their opinion could help improve the learning and working environment, and it could have a positive intergenerational effect, thus contributing to break the current vicious circle that pushes women out of STEM fields.

From a policy perspective, this study also suggests that changing student beliefs may lead female students to enroll in advanced math and science classes in high school, thus increasing their readiness for STEM majors in college. Some scholars have argued that high school might be already too late to help students, thus advocating for focusing resources on early childhood education (Carniero & Heckman, 2003). However, in line with the findings in this article, recent studies have shown that it is possible to design effective interventions for adolescents (Cook et al., 2014; Cortes, Goodman, & Nomi, 2015; Fryer, 2017; Rodriguez-Planas, 2012).

There is instead no evidence that teacher gender directly affected female students' intention to take additional math and science courses. Even if the analysis of gender achievement gaps is inherently different from the analysis of racial gaps in education (for a start, boys and girls are equally distributed across schools, unlike minority students), it is worth comparing this study with the general literature on teacher diversity. Implicit or explicit biases and lack of role models might spur from both gender and racial teacher–student mismatches. Within this context, the insignificant coefficient of teacher gender is in contrast with the result in Gershenson et al. (2017) that Black elementary school teachers had long-lasting effects on Black male students when examining high school graduation and educational aspirations. Although this difference might be due to the timing of the analyses (primary vs. secondary schools), more research is required to carefully identify any long-run causal effect of teacher gender on female students, especially in relation to the selection of a college major and occupational choices. In particular, the intersection between gender and race should be further investigated.

Another striking result is the statistically insignificant relationship between teachers' and students' beliefs. This is particularly surprising because Papageorge et al. (2016) argued that teacher expectations about students' future educational achievements affected college completion rates. As already discussed, this insignificant result may be due to the low variability in beliefs among male and female teachers. This and the previous point highlight the need of additional research to better understand which factors may lead teachers to have long-lasting effects on students.

When examining teacher behavior, female students were less likely to think that men were better than women in math or science when their teachers listened and valued ideas from their students. In line with the previous literature (Kramer et al., 2016), girls seemed to be more sensitive to the learning environment. This effect was stronger when this strategy was implemented by male teachers (Table 2, column 4). One explanation for this result is that gender stereotypes were reduced when male teachers stimulated class discussion and involved female students. Alternatively, it is possible that students deemed female teachers allowing dialogues as less qualified and knowledgeable, thus decreasing teacher impact. Either way, this result indicates a certain degree of substitutability between a policy that increases the number of female teachers and another which affects teaching strategies among existing instructors.

Nevertheless, when trying to infer implementable strategies for policymakers from the above results, one needs to be cautious. As also stressed by Dee (2007), a positive effect of teacher gender on student outcomes does not support single-sex schools, because that would change the distribution of students, not teachers. It also does not support segregating teacher and students by gender, because this would change the composition of peers, raise ethical issues, and have potential negative impacts on noncognitive abilities and social skills.

Moreover, increasing the percentage of female teachers in STEM subjects may not be optimal. The majority of teachers in these subjects are already women. In addition to this, results from previous studies imply that such a policy would not positively impact all student outcomes. For instance, Sansone (2017) showed that whether teachers treated boys and girls differently, as well as teachers' gender attitudes, mattered more than teachers' own gender per se when examining student interest and self-confidence in math and science. Furthermore, due to the existing general difficulties in recruiting teachers in STEM subjects, limiting searches by gender may not be practical. Last but not least, recruiting more women in lower paid jobs as teachers would further exacerbate the gender wage gap. Following the findings in Table 3, the distribution of existing teachers may instead be modified to assign each student to both male and female teachers during their educational path. This distribution would encourage the dissemination of more neutral beliefs about men's and women's abilities in math and science.

Finally, a note of caution about the magnitude of the findings in this article. This study provides suggestive evidence that changing beliefs may lead more students to take advanced classes in math and science while in high school. However, this would not be enough to fill the gender gap in STEM as female students who believe that men are better than women are a minority (although a substantial one). In other words, this article is not suggesting a panacea, but rather a complementary strategy that could be adopted together with other solutions, such as additional workplace flexibility (Goldin, 2014), to speed up the transition to gender equality in science and math.

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Notes

1. One may argue that a diverse group could be less productive because of coordination and communication problems. But the point here is different: A diverse group can be more productive than a homogeneous group. Which organization structure allows the full use of such potential is a different research question and it is not addressed here.

2. The underlying theoretical model has multiple equilibria where the current "bad" equilibrium has female underrepresentation in STEM fields. If this equilibrium was stable, a marginal improvement as the one discussed in this article may not be enough. However, in case of instability, even a small change may initiate a virtuous circle that would eventually lead to a more gender-balanced equilibrium. Similar cases, such as the gradual increase in female participation to tertiary education and the labor force, suggest that these initial equilibria are indeed unstable (probably due to their inherited inefficiency and unfairness).

3. The Appendix contains a detailed description of all the variables used in this study. All sample size numbers have been rounded to the nearest 10 for security reasons. When not reported, tables are available upon request.

4. The "Extensions" section and the Appendix discuss several extensions analyzing alternative definitions of this variable.

5. The main conclusions from Table 2 do not change also if the effects of teacher characteristics on student beliefs are estimated separately for each subject, that is, without between-subject student fixed effect. Tables available upon request.

6. Also in this case, there are reasons to be worried as such measure of self-confidence is self-reported, thus if a female student believed that women were better than men in math, she was probably also more confident in her own abilities. In other words, self-efficacy may capture an indirect effect of the regressor of interest. Indeed, in the last column of Table 4 the coefficient of student *i's* belief is lower than in the previous specifications. Despite this, it remains significant and with a large magnitude.

7. The coefficient of teacher gender remains statistically insignificant also when excluding student beliefs from the set of controls.

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