Growing the roots of STEM majors: Female math and science high school faculty and the participation of students in STEM

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ARTICLE INFO

ABSTRACT

The underrepresentation of women in science, technology, engineering, and mathematics (STEM) fields is problematic given the economic and social inequities it fosters and the rising global importance of STEM occupations. This paper examines the role of the demographic composition of high school faculty—specifically the proportion of female high school math and science teachers—on college students' decisions to declare and/or major in STEM fields. We analyze longitudinal data from students who spent their academic careers in North Carolina public secondary schools and attended North Carolina public universities. Our results suggest that although the proportion of female math and science teachers at a school has no impact on male students, it has a powerful effect on female students' likelihood of declaring and graduating with a STEM degree, and effects are largest for female students with the highest math skills. The estimates are robust to the inclusion of controls for students' initial ability.

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1. Introduction

The need to expand the science, technology, engineering and mathematics (STEM) workforce has become increasingly pressing in the last 20 years. Although the number of students earning STEM degrees has grown substantially in the last decade, the supply for the STEM workforce continues to trail the nation's demand. For example, the Bureau of Labor Statistics reported that the U.S. economy is expected to add at least 1.2 million computer science jobs from 2010 to 2020, but at the current pace, U.S. universities will only produce half the number of computer science graduates needed to fill those positions (Atkinson, 2013). Currently the mismatch between the STEM workforce supply and the economy's demand is filled by immigrant workers, but this is a short-term

solution that soon will be neither politically sustainable nor economically efficient (Ehrenberg, 2010). As a consequence, policy makers have openly acknowledged that the United States needs a long-term strategy to ameliorate the shortage of STEM graduates.

One untapped potential for increasing the numbers of STEM graduates is the population of female college students. Women are the majority of college students but represent a distinct minority of STEM degree holders. Although some STEM fields have started to graduate greater numbers of women (e.g., biology), strikingly few young women graduate with degrees in the physical sciences and engineering. This pattern draws attention to a major factor in the STEM workforce supply–demand dilemma: only a small number of women pursue STEM careers. National Science Foundation (2009) statistics report colleges and universities awarded only 40% of their STEM bachelor degrees to women (and most of these in the biological sciences). The attrition of women from STEM fields continues as they move into the

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labor market, where only 27% of STEM related jobs are held by women despite the fact that more than half of U.S. workers are female. Clearly, one strategy to fill the shortage in the supply of STEM workers is to encourage women to pursue STEM careers. Because these careers require specialized higher education, the factors related to the relatively weaker participation of women in college STEM majors are important topics of study.

The unequal participation by gender in STEM can potentially be explained by a variety of factors including: differential societal expectations for boys and girls, where boys receive more encouragement to pursue STEM fields (Ceci & Williams, 2007); a paucity of women role models and/or mentors (including school teachers and college professors) in STEM fields (Sonnert & Fox, 2012); and/or discriminatory environments and chilly climates (Hall & Sandler, 1982). Additionally, young women are likely to indicate that female teachers play important roles in shaping their early interests in STEM (Jackson, n.d.). We examine the role of the demographic composition of high school faculty—specifically the proportion of female high school math and science teachers—on college students' decisions to declare and/or graduate in STEM fields. Our results suggest that although the proportion of female math and science teachers at a school has no impact on male students, it has a powerful effect on female students' likelihood of declaring and graduating with a STEM degree, and effects are largest for female students with the highest math skills.

2. Previous research

Prior research has revealed a number of factors that affect women's decisions to participate in college STEM programs. This body of research suggests the importance of female college faculty for the STEM outcomes of women during the college years (Canes & Rosen, 1995; Hoffmann & Oreopoulos, 2009; Kokkelenberg & Sinha, 2010; Newmark & Gardecki, 1998; Price, 2010; Rask, 2010; Rothstein, 1995; Robst, Keil, & Russo, 1998). Most of these studies analyze the relationship between the persistence of students in STEM fields and the gender match between college faculty and students (Bettinger & Long, 2005; Griffith, 2010; Price, 2010; Robst, Keil, & Russo, 1998). However, several studies also look at the link between women's choices of STEM major and the proportion of female faculty at the college, sometimes referred to as the demography of the department (Canes & Rosen, 1995; Carrell, Page, & West, 2010; Qian, Zafar, & Xie, 2009; Rothstein, 1995).

2.1. Persistence and course taking behavior

Studies have indicated some mixed effects related to the presence of female university faculty on female college STEM outcomes. A portion of these studies analyze the relationship between the persistence of students in STEM and the gender ratio between faculty and students. For example, Robst, Keil, and Russo (1998) show that the percentage of female math and science teachers in college has a strong positive link to women's retention in science, mathematics and engineering. At the same time, one study concluded that

female students are no more likely to persist in a STEM field when they enroll in courses taught by female faculty (Price, 2010) and another found that female students' persistence in STEM fields was unaffected by the gender makeup of the STEM faculty (Griffith, 2010). Regarding course taking behavior, research has found that the likelihood of female students taking courses and majoring in mathematics, statistics, geology, sociology, and journalism was significantly higher when they were taught by female faculty (Bettinger & Long, 2005). Recently, Griffith (2014) reported that although major choice and course-taking behavior are mostly unaffected by the gender match between faculty and student, students earn higher grades in courses taught by same-gender instructors in fields like STEM fields that have traditionally been dominated by the opposite gender.

2.2. Graduating with a STEM degree

Studies have demonstrated that as the percentage of female faculty in STEM departments increases, the percentage of four-year degrees awarded to females in these departments will also increase (Qian, Zafar, & Xie, 2009). Prior research has also found a positive association between the percentage of female faculty and the probability that a female student will earn an advanced degree (Rothstein, 1995). Furthermore, Carrell, Page, and West (2010), using a sample of college students randomly assigned to professors, found that female professors have a powerful effect on high-performing female students' likelihood of graduating with a STEM degree. However, when Canes and Rosen (1995) analyzed the effect of the proportion of women in a department's faculty on the number of female majors within that department, they found no evidence that an increase in the share of women on a department's faculty led to an increase in its share of female majors. The mixed results regarding the influence of the gender distribution of college faculty on students' STEM outcomes suggest that looking at high school experiences might be able to shed more light on STEM college major choice.

2.3. Pre-college years

There is less research focused on the importance of female teachers during the pre-college years on young women's STEM outcomes. This is surprising given the fact that emerging evidence suggests that the pre-college setting is highly influential on students' choice of major in college (Maltese & Tai, 2011). The majority of studies that focus on pre-college years examine the gender match between teacher and student and its effect on students' non-STEM outcomes, such as achievement and engagement (Dee, 2005, 2007; Nixon & Robinson, 1999; Winters, Haight, Swaim, & Pickering, 2013). What is missing from the corpus of research is an analysis of how the proportion of female STEM high school teachers, as a whole, affects students' STEM participation in college.

By looking at the proportion of female math and science teachers at the high school students attended, we seek to gain insight into how the gender composition of the high school faculty influences student outcomes. Importantly, this paper shifts the attention of the inquiry about the role of women faculty from individual teachers to the proportion of women

in the high school's STEM faculty *as a whole* and examines the importance of these teachers for students' early academic trajectories. In so doing, we emphasize the importance of the cumulative nature of early school experiences and contexts for decisions to pursue STEM majors in college.

We focus on the contextual effects of the gender composition of the math and science faculty in students' high schools because prior research on faculty gender composition in higher education indicates a more diverse climate, in terms of gender, provides an atmosphere that is more welcoming to female students. It can provide greater opportunity to develop teacher and/or peer networks (Robst, Keil, & Russo, 1998), which, in turn, also increase the availability of potential role models and/or mentors for girls – resources that are very influential for academic and career success of female students (Butler & Christensen, 2003; Day & Allen, 2004; Nixon & Robinson, 1999). Role models may be especially salient for young women because their behavior appears to be more responsive to the needs and requests of significant others, and to the situational constraints that influence their own and others' behaviors (Cross & Madson, 1997; Mickelson, 2003; Moller, Stearns, Southworth & Potochnick, 2013). Moreover, female role models push girls to take risks (Smith, 2000) and resist stereotypes prescribing gender-role stereotypical jobs for men and women.

Prior studies have also suggested that many STEM fields are still characterized by a "chilly climate"[1] that is unwelcoming to girls in high school and young women in college. The chilly climate pushes them away from STEM fields in spite of girls' interest and aptitude (Herzig, 2004; Zhao, Carmi, & Kuh, 2005). Faculty gender is a major influence on the factors that comprise measures of culture and climate (Bulach & Berry, 2001), and a higher proportion of female math and science teachers could translate to a friendlier environment in STEM courses (Statham, Richardson, & Cook, 1991).

Although on average, women are not underrepresented among high school STEM faculty, it is still possible that a 'chilly climate' persists in some schools, even in schools that have a gender balance or even a majority of female math and science instructors. How can there be a 'chilly climate' in a school where the majority of math and science teachers are female? We envision two potential ways this chilly climate could occur. First, even if female math and science faculty are the norm in a given high school, there are likely to be proportionally fewer females in these areas compared to the humanities and social science departments. The lower proportion of female math and science faculty relative to other departments could contribute to a perception among high school students that women are less welcome in math and science compared to the humanities and social sciences and that science and math are male intellectual domains. Second, prior evidence suggests classroom signs of a non-inclusive climate can prevent girls from exploring certain areas of interest (Mitchell & Hoff, 2006). Having a higher proportion of female math and science teachers provides students with the opportunity to gain a more "feminine" approach of what

STEM fields are and could, therefore, work against the entrenched stereotypes that STEM fields are "manly" fields.

Furthermore, when a greater proportion of the faculty are male, female students may come to see success and persistence in math and science fields as fundamentally masculine domains, while concomitantly learning to doubt their own competencies in these areas (Correll, 2001; Eisenhart, Finkel, & Marion, 1996; Guimond & Roussel, 2001; Lee, 1998). In general, a higher proportion of female math and science teachers may improve girls' perceptions of school STEM cultures, helping them to see STEM as more welcoming to women (Fox, Sonnert, & Nikiforova, 2009; Statham, Richardson, & Cook, 1991), less male-biased, and having higher expectations for girls (National Alliance for Partnerships in Equity, 2013), all contributing to higher odds that young women will enroll in STEM majors once they reach college.

In our study we examine the role of the demographic composition of high school faculty—specifically the proportion of female high school math and science teachers—on college students' decisions to declare and/or major in STEM fields. Our results suggest that although the proportion of female math and science teachers at a school has no impact on male students, it has a powerful effect on female students' likelihood of declaring and graduating with a STEM degree, and effects are largest for female students with the highest math skills. Given that the gender composition of the high school math and science teachers is unrelated to most other characteristics that influence college major, our estimates likely reflect causal effects.

This research adds to the literature several ways. First, we center attention on teachers during the secondary school years when it is more likely that students lay the academic groundwork for their future college plans – or, in some cases, make up their minds about their likely college majors. Second, we focus on the importance of the gender composition of teachers at the high school, instead of the gender match between student and teacher, thereby investigating possible contextual effects of the gender composition of secondary schools' teacher workforce on choice of college STEM majors. Third, we focus on the gender composition of math and science classes in the high school because these are the subjects most directly related to STEM interest, given that there can be substantial variation in faculty gender composition between subjects in high school (for example, English compared to physics). Fourth, our unique dataset of students who matriculated as freshman at one of the 16 University of North Carolina (UNC) system campuses in 2004[2] allows us to link an individual's secondary school experiences and characteristics in grades 7–12, as well as college characteristics and experiences, with a host of individual-level and demographic variables. In doing so, we are able to link past lived experiences in homes, communities and at secondary schools with future college STEM outcomes. This research design that follows students through time adds a dynamic component to the investigation of the underrepresentation of young women in college STEM majors.

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[1] This "chilly climate" is expressed as the difficulties experienced by girls in high school and young women in college in terms of the social relations of authority in classrooms and peer networks among other students.

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[2] Using a selected sample of people who attended public universities in North Carolina is a potential source of bias.

Table 1
Gender distribution of students in the UNC system.

Gender	Number of students	% in the system	Number of students who graduated from a major	% who graduated in the system	Number of students who declared a STEM major	% of students who declared a STEM major	Number of students who graduated from a STEM major	% of students who graduated with a STEM major
Young men	9,320	44%	5,600	41%	2,050	57%	1,540	56%
Young women	12,020	56%	8,140	59%	1,550	43%	1,190	44%
Total	21,340	100%	13,740	100%	3,600	100%	2,730	100%

3. Data, variables and methods

3.1. Data

We analyze the North Carolina Roots of STEM Success dataset (Stearns, Mickelson, Moller, & Bottia, 2013) to test our hypotheses. It contains longitudinal information on the academic performance and scholastic experiences of all 2004 North Carolina public school graduates who also matriculated at one of the 16 campuses of the University of North Carolina system. Data for these individuals includes student, family, school, and achievement indicators from seventh grade through their college graduation. Additionally, the roots dataset contains information about the characteristics of the schools and colleges that students attended throughout their educational careers. North Carolina Department of Public Instruction data from grades 7 to 12 for 2004 high school graduates were provided to the North Carolina Education Research Data Center at Duke University (NCERDC) where they were merged with data on the same students' college experiences provided by the University of North Carolina General Administration. In addition, we utilized College Board information regarding the SAT scores (a composite score of student's performance on the critical reading and mathematics sections), and students' responses to survey questions concerning their high school experiences including courses taken, academic interests, extracurricular activities, family background, and college preparation and academic goals.

We focus on a racially, ethnically, and socioeconomically diverse sample of roughly 19,000[3] college-bound students who attended approximately 350 high schools in North Carolina (there are no all-girls public schools in our sample), and later attended any of the 16 University of North Carolina colleges in 2004. Taking into account that only about 16,000 actually went on to declare any major, that we excluded approximately 1400 students that attended high schools with a math and science focus, and that we had some missing values on control variables, our sample size was further decreased.[4] We used a sample of approximately 12,550 students coming

from about 270 high schools with characteristics similar to our original sample. Given our ultimate sample, we acknowledge that this potentially idiosyncratic group of students may be biased in unobserved ways; therefore we can only generalize these results to those students who attended secondary public school in North Carolina and later pursued their undergraduate studies in the UNC system and have declared a major.

Nonetheless, the sample of students we employ in this study is representative of North Carolina's in-state four-year college-going population. The majority of college-attending students in North Carolina remain in-state[5] in part because the UNC system is very diverse in levels of prestige (including very competitive public universities such as UNC Chapel Hill and North Carolina State University) as well as types of institution and area of specialty. Based on SAT survey data provided to the Roots of STEM Success Project by the College Board, the sample of young men and women included in our study had, on average, higher math and reading SAT scores than the North Carolina students who did not attend college in the UNC system but planned to attend a four-year college when they took the SAT (see Appendix A).

The unequal gender distribution of STEM majors is readily apparent in the UNC system. For the 2004 entering freshman cohort under study, 17% of students declared a STEM major, and 20% of students who graduated did so with a STEM major. As is commonly the case, young men are overrepresented in STEM majors: although only 44% of students in the entire system are male, 56% of students who graduated with a STEM major were young men (see Table 1). UNC system-wide, there is an overall 14 point gender gap in the declaration of a STEM major, and a 12 point gender gap in the completion of a STEM major. Young women constitute around 43% of students who declared and 44% of students who graduated with a STEM major despite the fact that they make up 56% of the state university system's students. The gender gap is most striking in the fields of engineering and computer science where women comprise only 21% of majors (see Table 2).

3.2. Variables

3.2.1. Outcome variables

The dependent variables we employ to test our hypothesis are whether a student (1) declared and (2) graduated with a STEM major (out of those who graduated with a major in

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[3] All student numbers in text and in tables are rounded to the nearest 10 to preserve anonymity.

[4] We utilize information of the major students declared between the years 2005 and 2011. The vast majority of the students declared their majors when they were in their sophomore or junior year. In several cases students declared more than one major. Importantly, approximately 24% of our sample never declared a major (either dropped out of college before declaring a major, transferred to a community college, transferred to a campus out of the North Carolina system or died) and are not included in our analysis. Therefore our sample is one of college-bound students who declared a major and attended middle and high school in North Carolina.

[5] About 38% of North Carolina's high schools graduates reported an intention to attend a public higher education institution and only about 3% of graduates said they planned to attend an out-of-state institution (DPI, 2003).

Table 2
Gender of students by declaration of major in the UNC system.

	UNC system		National	
	% Young women	% Young men	% Young women	% Young men
UNC overall	56	44	57	43
Biology	65	35	58	42
Math	50	50	43	57
Physical science	48	52	41	59
Agricultural science	48	52	49	51
Engineering and computer science	21	79	17	83

Source: Authors calculations and NCES (2004).

college). We use multinomial dependent variables, where 0 indicates no declaration/graduation of a STEM major, 1 represents declaration/graduation with a major in biological sciences, and 2 indicates declaration/graduation with a major in any other STEM discipline other than biological sciences (such as physical sciences, engineering and mathematics). We chose a multinomial approach because it is most appropriate given the different demographic composition of students in biology as opposed to other STEM disciplines (Newton, Torres, & Rivero, 2011). We separate biology from other physical sciences, mathematics, and engineering majors because the biology major does not suffer from an underrepresentation of women found in other STEM disciplines, whereas two-thirds of the students who declare a major in physical sciences, engineering, and mathematics are men.

To define a STEM major, we use the categorization utilized by the National Science Foundation Advance Program (2001) where majors such as engineering, physical sciences, earth, atmospheric or ocean sciences, mathematical and computer sciences, and biological and agricultural sciences are considered to fall within the STEM category. A variety of both individual and school level variables were included in this study. Their names, means and standard deviations are shown in Table 3. The first column in Table 3 also shows that our sample is very similar to the sample of all students in the North Carolina system as a whole.

3.2.2. Student-level variables

Our models include student demographic and family characteristics such as race/ethnicity, gender, and SES (defined as whether student received a need-based Pell grant in college, and is (or not) a first-generation college student in his or her family). Drawing on factors identified in previous research (e.g. Bartolj & Polanec, 2012; Bottia, Stearns, Mickelson, Moller, & Parker, 2015; Federman, 2007) as possible explanations for differential participation rates of male and female students in STEM, we include (a) measures for math SAT scores (divided by 100), (b) whether the student took algebra 2, and biology in an advanced academic track, and (c) and whether the student took physics during high school. We also utilize math SAT scores to categorize students into students with high math ability, average math ability, and low math ability. Indeed, Carrell, Page, and West (2010) find that the gender of the professor has a powerful impact on female students' performance in math and science classes that is largest for female students with very strong math skills.

3.2.3. School-level variables

Our key independent variable is the proportion of science and math teachers who are women among the math and science faculty of the high school from which each student graduated. We focus specifically on the math and science teachers because these are the ones who could be available to serve as possible role models, mentors, or who could most directly challenge the "chilly climates" towards STEM that might otherwise exist at the high school. In addition, because students are required to take algebra 1, algebra 2, and biology, we can be certain that there was at least some interaction between these teachers and students.

We use the proportion of female math and science teachers as a measure of the opportunity for female students to identify with female role models or mentors in the field, as well as for the likelihood that there was a neutralization of the possible "chilly climate" towards STEM at that school. We use data on each high school classroom's personnel to calculate the gender composition of the math and science[6] teachers at each high school between 2000 and 2004. We then calculate the average proportion of female math and science teachers over the years the student is in high school.[7]

On average, across the roughly 270 high schools included in the study, 63% of the math and science teachers were women (68% of the math teachers were women and 56% of the science teachers were women) compared to 80% women teachers in all subjects in the state of North Carolina. Although over half of North Carolina's secondary math and science teachers are women, female representation is proportionally lower in these disciplines than it is in other subject fields such as English or social studies. When we divide the sample of high schools into terciles based on the distribution of proportion female math and science teachers the average for the schools with low representation of female math and science teachers is 47%, the middle tercile has an average of 63% math and science female teachers, and the highest tercile has an average of 75% female math and science teachers (see Table 4).

In all models, we also control for variables correlated with probability of declaring and/or graduating with a STEM degree and our primary independent variables. These controls include racial composition of the school (proportion of white students at school); proportion of female students in the school (recognized as an important characteristics

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[6] Based on the State Course Code Subject Area, which indicates the state-defined subject area to which this teachers' activity can most closely be associated, we determined each teachers' subject area of instruction. We also used the Outline of the Course Coding Structure for North Carolina Public Schools 2005–2006, which defines the discipline of the subject. We categorized all of those teachers in the disciplines of mathematics and science as math and science teachers. Then we determined the proportion of women teachers among all of the math and science teachers in each of the high schools. This variable measures the exposure that students had to a math and science faculty with various proportions of females during secondary school.

[7] We also employed a model specification in which the key independent variable was the proportion of female math and science faculty calculated during the year when each student took most of his or her math and science classes. Because the gender composition of the math and science faculty at a school remains relatively stable over time, results were substantively similar to the dependent variable and key independent variable specification presented here.

Table 3
Summary statistics for the roots dataset by gender, declared major field and graduated major field.

Variable	All students in NC system N	All students in NC system Mean	Students in our sample Mean	Women Mean	Men Mean	Declared non STEM majors Mean	Declared STEM majors Mean	Graduated non STEM majors Mean	Graduated STEM majors Mean
Declared									
Non-STEM	14886	.785	.784	.838∗∗∗	.712	1.000	.000	.974∗∗∗	.013
Biological sciences	14886	.074	.074	.084∗∗∗	.059	.000∗∗∗	.342	.012∗∗∗	.334
Physical sciences, engineering and mathematics	14886	.142	.142	.078∗∗∗	.229	.000∗∗∗	.658	.014∗∗∗	.653
Graduated									
Non-STEM	12687	.808	.810	.860∗∗∗	.736	.997∗∗∗	.103	1.000	.000
Biological Sciences	12687	.060	.065	.070∗∗∗	.058	.001∗∗∗	.310	.000∗∗∗	.345
Physical sciences, engineering and mathematics	12687	.125	.125	.069∗∗∗	.206	.002∗∗∗	.587	.000∗∗∗	.655
Student level variables									
Male	19802	.435∗∗	.422	.000	1.000	.383∗∗∗	.565	.372∗∗∗	.566
African American	19802	.264∗∗∗	.214	.238∗∗∗	.181	.226∗∗∗	.171	.198∗∗∗	.130
Latino/a	19802	.017	.017	.017	.015	.018	.015	.017	.013
Asian	19802	.033	.036	.033∗∗∗	.011	.027∗∗∗	.068	.028∗∗∗	.073
American Indian	19802	.012	.011	.011∗∗∗	.040	.009∗∗∗	.016	.010	.013
White	19802	.671∗∗∗	.721	.698∗∗∗	.752	.719	.728	.747∗∗	.769
Receives financial aid (PELL grant)	19802	.191∗∗∗	.165	.175∗∗∗	.151	.165	.165	.151	.143
First generation college student	18199	.135∗∗∗	.111	.119∗∗∗	.099	.116∗∗∗	.090	.109∗∗∗	.083
Math SAT (divided by 100)	19101	5.410	5.538	5.378∗∗∗	5.757	5.414∗∗∗	5.989	5.476	6.100
Took advanced algebra 2 in HS	18751	.435∗∗∗	.494	.481∗∗∗	.513	.455∗∗∗	.639	.475∗∗∗	.665
Took advanced biology in HS	18500	.515∗∗∗	.571	.568	.576	.551∗∗∗	.646	.570∗∗∗	.669
Took physics in HS	19802	.256∗∗∗	.286	.224∗∗∗	.370	.235∗∗∗	.470	.244∗∗∗	.490
School level variables									
School locale is rural (versus urban)	18012	.370	.371	.374	.366	.365∗∗	.392	.367∗	.388
School locale is suburban (versus urban)	18012	.289	.286	.293∗∗	.277	.288	.280	.286	.286
Proportion of female students at school	17967	.496	.496	.496∗∗∗	.495	.496∗∗	.495	.495	.495
Proportion of students on free/reduced lunch	19802	.143∗∗∗	.119	.134∗∗∗	.099	.125∗∗∗	.098	.106∗∗∗	.076
Proportion of white students	17967	.636∗∗∗	.649	.644∗∗∗	.657	.649	.649	.658	.658
Proportion of students in advanced academic tracks	18147	.032∗	.033	.032∗∗∗	.034	.033	.033	.033	.033
Proportion of female math and science teachers	18374	.633∗∗	.631	.631	.630	.629∗∗∗	.635	.629∗∗∗	.638
Proportion of licensed teachers	18272	.820∗∗∗	.824	.823	.825	.823∗∗	.826	.825∗∗∗	.830
Proportion of teachers with advanced degrees	18271	.267∗∗∗	.272	.270∗∗∗	.275	.272	.273	.274	.275
Proportion of experienced teachers	18272	.542	.544	.545∗∗	.542	.544	.544	.544	.545
Teacher turnover rate	18270	.189∗∗∗	.186	.186	.186	.187	.185	.185	.183
Observations		16000	12550	7250	5300	9850	2700	8620	2030

Asterisks represent significant differences in means ∗∗∗ 1%, ∗∗ 5% and ∗10%.

for school choice of female students by Schneeweis & Zweimuller, 2012); proportion of students in advanced college preparatory courses (see Ost, 2010 for a study that highlights the importance of quality of peers' grades and retention in STEM at the college level); proportion of students receiving free/reduced lunch; and school locale (urban, suburban, or rural). In addition, we include a set of variables that aim to capture important aspects of the high school that could be associated with students' interest in STEM, including measures of teachers' experience, teachers' education (advanced degrees and licensure), and teacher turnover (percent of teachers employed in a school when the students are in a grade who are no longer employed in the same school when students are in following grade). All of these school-level variables were included as averages of the years the majority of the students were in high school (2000–2004). Controlling for these confounding variables helps increase the reliability of our finding regarding the effect of proportion of female math and science teachers.

3.3. Empirical methods

The previous sections have illustrated the importance of student and contextual characteristics on the participation of students in STEM majors. At the same time they have also laid out the differences in STEM participation among students based on their gender and previous academic achievement. In order to examine the effect of school characteristics on students' chances of graduating and/or declaring a STEM major during the years 2005–2011[8], a number of empirical specifications are estimated. Due to the nested structure of the data (Raudenbusch & Bryk, 2002) and the fact that the response variable has a multinomial distribution we utilize multilevel multinomial logistic models with linear predictors

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[8] Our tables also show additional results with models that control for categories of college campuses in the North Carolina University System to control for college group fixed effects. We do so to isolate the treatment effect that does not operate via college choice.

Table 4

Descriptive characteristics of high schools, categorized by concentration of women math/science teachers.

School level variables	Lower tercile		Middle tercile		Higher tercile	
	Mean	Std.	Mean	Std.	Mean	Std.
Proportion of female math and science teachers (2001)	.487	.124***	.640	.093***	.748	.106
Proportion of female math and science teachers (2000–2004)	.473	.106***	.629	.024***	.750	.070
Proportion of students declare biology+	.036	.037**	.055	.089	.051	.091
Proportion of students declare physical sciences/eng/math+	.083	.105	.091	.068	.092	.105
Proportion of students graduate biology+	.025	.031**	.043	.088	.042	.090
Proportion of students graduate physical sciences/eng/math+	.056	.058	.069	.058	.064	.060
Proportion of female students at school	.493	.026	.491	.047	.493	.024
Proportion of experienced teachers	.569	.093**	.538	.102**	.566	.097
Teacher turnover	.205	.082	.212	.078	.196	.073
Proportion of schools with a math and science focused program	.027	.163	.023	.152	.063	.244
Total students in 10th grade	240.340	114.916***	297.250	140.203*	262.932	140.065
Pupil teacher ratio	14.402	2.946	15.135	3.778	14.825	3.463
Proportion of teachers with advanced degree	.262	.093	.252	.078	.237	.075
Proportion of students at grade level algebra 1	.762	.147	.739	.169	.774	.164
Proportion of students at grade level algebra 2	.774	.146	.766	.153	.769	.148
Proportion of students at grade level biology	.706	.142	.682	.145	.689	.133
Proportion of students at grade level chemistry	.700	.180	.697	.163	.697	.171
Proportion of students at grade level physics	.837	.156	.823	.136	.819	.179
Proportion of students at grade level physical sciences	.565	.190	.606	.191	.610	.207
Proportion of students enrolled in advanced/college tracks	.023	.025	.022	.020**	.017	.016
Average math SAT school (divided by 100)	4.944	.412	4.919	.368	4.886	.356
Average total SAT school	9.739	.838	9.699	.714	9.634	.667
Percent of students at grade level	69.230	12.924	69.144	10.933	69.272	11.751

These variables were calculated only with the sample of students that we have in our sample (that attended colleges in the NC college system) which are the only ones we have information for. This is not a 100% accurate measure at the school level but serves as reference point.

Asterisks represent significance at *** 1%, ** 5% and *10%.

(Grilli & Rampichini, 2007) which allow us to examine the effect of school characteristics that impact college students' decision to declare a non-STEM major, biology as a major or PSEM as a major, taking into consideration the fact that certain groups of students attended the same high schools, and thus considering that the individual error terms may be correlated between individuals at the same high school.

Specifically, we utilize the **proc glimmix** command in SAS with a multinomial distribution function and glogit link function to estimate the probability of enrollment and graduation in non-STEM, biology or physical sciences/engineering/mathematics (PSEM) majors correcting for the school random effects. We estimate the model using different samples depending on sex and ability levels (based on math SAT scores) and we use school-level variables centered at the grand mean.[9] We ran separate analyses for each outcome (those who declare and those who graduate from a STEM major). Such an approach permits us to look both at short-term (major election) and long-term (major completion) effects for college students. This analytic strategy is necessary because in the cohort of North Carolina university system students that we analyzed, 24% of the students who initially declared a STEM major never graduated.

3.4. Possible sources of bias

We include additional control variables to reduce bias caused by school-level characteristics that are correlated

with both our main explanatory variables and the outcomes. Table 4 shows that the measure of female math and science teachers is essentially uncorrelated with other teacher or student characteristics at the school level. More specifically, schools in the lowest tercile of the distribution of the proportion of female math and science teachers are made up of, on average, 49% of female students, a gender composition that is identical to those schools in the middle and higher tercile. In addition, schools across the three different terciles of the female math and science teacher distribution share an almost equal level of academic achievement among students and nearly equivalent teacher characteristics (such as teacher turnover, teachers' experience, teacher with advanced degrees, etc.). The nonexistent correlation of the treatment (proportion female math and science teachers) with other school-level variables provides support for interpreting our estimates as evidence of the causal effect of female faculty and not simply a correlation caused by some other school-level factor or student characteristic.

4. Results

4.1. Short-term effects (declaring a STEM major)

Previous research shows that the majority of students who pursue STEM degrees make this decision during high school (Maltese & Tai, 2011). Therefore, students' high school experiences are important for understanding college STEM outcomes. We investigate, in particular, the relevance of the gender distribution of their math and science teachers in the choice to major in STEM. Because the majority of students are non-STEM majors, we use non-STEM as the baseline category; the two logit equations will then describe the log-odds

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[9] We center school level variables around the grand mean by subtracting the mean of each of these school-level variables at the school level with the purpose of making the intercept more meaningful (the intercept reflects the value of *Y* at the mean of the school variables).

that students declare a major in the biological sciences or the physical sciences, engineering, or mathematics field, as opposed to a non-STEM area.

Table 5 reports average marginal effects from results of the probability of declaring a STEM field major using the Roots of STEM Success sample. We first estimate a model with the entire sample of approximately 12,550 students and then estimate models separately by gender (for the 7250 women in the sample, and then for the 5300 men). The first four columns of Table 5 show the estimated effects for all students, the next three columns focus on subsets of female students with different levels of math skills, and the last column shows the estimated effects for a sample of all male students. All models include a variable measuring the proportion of female math and science teachers. We start by presenting results of models with no controls, then with individual-level controls, and finally models that include individual- and school-level controls for the full sample of students. By doing so, we are able to examine the extent to which the proportion female math and science teachers at a school correlates with other unobserved factors. We then present the models including individual- and school-level variables for the sample of female and male students. Furthermore, we look at different subsamples of female students by perceived math ability. We do not present results for male students by perceived math ability because our key independent variable is not significant in explaining male students' declaration of STEM as majors.

We first look at the results for the entire sample. Models 1 through 4 show the positive and significant relationship between proportion female math and science teachers and students' chances of declaring physical sciences, engineering and/or mathematics as a major. Because estimates change little when individual- and school-level controls are introduced, our assumption of no unobserved cofounders is more plausible. Declaration of STEM as a major differs significantly between women and men. Men are much more likely to declare a PSEM (physical sciences, engineering, and mathematics) major than women, although women are more likely to declare biological sciences as a major. Students with better prior academic achievement as measured by math SAT scores, those who enrolled in advanced algebra II classes when in high school, and those who took physics in high school are more likely to declare a STEM major.

Importantly, our findings indicate that attending a school with a higher proportion of female math and science teachers is related to a significant increase in the chances of declaring physical sciences, engineering, or mathematics as a major. Other high school characteristics are also important. For example, if a student's high school was located in a rural or suburban area rather than in an urban area, students had higher odds of declaring a STEM major. Attending a school with a higher percentage of students in advanced academic tracks increased students' chances of declaring a biological science as a major while it reduced their chances of declaring a PSEM as a major.

The estimated effect of proportion female math and science teachers at a high school varies across the sub-samples of students. As we anticipated, attending a school with a higher proportion of female math and science teachers appears to inspire girls to declare a STEM major (at a 10% signif-

icance in both biology and PSEM), while having no significant relation to male students' STEM major declaration. No significant effects were found regarding the importance of female math and science teachers and the odds of declaration of STEM among high skilled girls (girls with math SAT scores in the top tercile of the distribution) compared to lower skilled girls. The results appear to be driven by high skilled girls although the estimate is not statistically significant in either subsample, despite the fact that overall estimates are significant. Other school-level variables regarding teacher characteristics were not consistently significant across subsamples of students.

4.2. Long-term effects (graduating with a STEM major)

We now turn to our analysis of the possible influence of proportion female math and science high school teachers on college students' likelihood of graduating with STEM majors. We acknowledge the fact that the decision to graduate with a STEM major involves additional factors that go beyond the experiences student had during their high school years. These additional variables include college experiences and characteristics that could influence students' decision to stay in their STEM majors as suggested by prior research (Griffith, 2010; Maltese & Tai 2011; Price, 2010). Table 6 presents findings from our models predicting the chances that students graduate with a STEM major compared to not graduating with a STEM major but still graduating from any other major.[10] Findings show that the influence of proportion of female math and science teachers is even stronger for students' odds of graduating with a STEM major than for students' chances of declaring a STEM major. In this case, a higher proportion of female math and science teachers at a high school is not only related to students' chances of graduating with a PSEM degree, but also shows a significant association with students' odds of graduating with a biological sciences degree. For example, when we calculate predicted probabilities based on the estimates of our models when variables are at their mean value, we find that when students move from attending a school that has a proportion of female math and science teachers of .54 (1 s.d. below the mean distribution of female math and science teachers of .63) to one that has a proportion of female math and science teachers of .72 (1 s.d. above the mean distribution of female math and science teachers of .63) their chances of *graduating* with a biology and a PSEM major increase 19%, while their chances of *declaring* a PSEM major increase 14% (see Appendix B).[11]

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[10] Results from models that include the analysis without excluding people who dropped out of the university (combining their category with the non-STEM majors) are presented in Appendix C. Findings are very similar to those obtained when students that dropped out are not included in our sample.

[11] We also conducted additional analyses (not shown) including type of college-level fixed effect given that there is evidence that institutional characteristics affect STEM related decisions in college (Griffith, 2010). We did not utilize true institution fixed effects due to sample size issues per campus. There are some colleges at which there are very few female STEM majors. Therefore we created four different categories of types of colleges to control for specific institutional characteristics of these types of colleges that might have a relationship to our outcome. Categories include: (1) other large predominantly white institutions (Appalachian State University, University of North Carolina–Charlotte, East Carolina University, University of North Carolina–Wilmington, and University of North Carolina–Greensboro); (2)

Table 5
Average marginal effect from multi-level multinomial estimations of probability of declaring a STEM major for roots sample, by gender and observed math skills.

		All students in sample				Sample of just girls			Sample of just boys
		Model 1. No controls	Model 2. Individual level controls	Model 3. Individual school level controls	Model 4. Individual school college level controls	Model 5. All girls	Model 6. High skilled girls	Model 7. Lower skilled girls	Model 8. All boys
Key independent variable									
Proportion of female math and science teachers	Biology	.062** (.022)	.053** (.029)	.038 (.029)	.039 (.029)	.074* (.040)	.148 (.100)	.032 (.044)	-.014 (.040)
Proportion of female math and science teachers	PSEM	.077** (.039)	.065** (.046)	.092** (.043)	.093** (.045)	.075* (.030)	.178 (.110)	.026 (.031)	.098 (.071)
Student level variables									
Male	Biology		-.025*** (.005)	-.026*** (.005)	-.024*** (.005)				
Male	PSEM		.066*** (.007)***	.116*** (.007)	.118*** (.007)				
Math SAT (divided by 100)	Biology		.038** (.003)	.041*** (.004)	.031*** (.007)	.027*** (.009)			.036*** (.012)
Math SAT (divided by 100)	PSEM		5.210 (.005)	.096*** (.005)	.075*** (.005)	.044*** (.009)			.041*** (.007)
Took advanced algebra 2 in HS	Biology		.018*** (.005)	.018*** (.005)	.015*** (.005)	.020** (.008)	.017 (.011)	.030*** (.008)	.016** (.008)
Took advanced algebra 2 in HS	PSEM		.021*** (.008)	.038*** (.008)	.029*** (.008)	.019** (.008)	.008 (.020)	.036*** (.007)	.056*** (.012)
Took advanced biology in HS	Biology		.003 (.005)	.003 (.005)	.001 (.005)	.006 (.008)	-.017 (.020)	.013* (.008)	.000 (.008)
Took advanced biology in HS	PSEM		-.007 (.008)	-.014 (.008)	-.017** (.008)	-.015* (.008)	-.054*** (.020)	.002 (.007)	-.013 (.011)
Took physics in HS	Biology		.022*** (.005)	.023*** (.005)	.021*** (.005)	.039*** (.008)	.065*** (.010)	.035*** (.009)	.005 (.008)
Took physics in HS	PSEM		.055*** (.007)	.098*** (.007)	.093*** (.007)	.059*** (.007)	.084*** (.010)	.061*** (.007)	.144*** (.010)
School level variables									
Proportion of female students at school	Biology			-.322* (.178)	-.342* (.178)	-.172 (.240)	-.644** (.691)	.238 (.240)	-.530 (.271)
Proportion of female students at school	PSEM			.059 (.267)	.006 (.274)	.173 (.220)	.147 (.652)	.092 (.212)	-.260 (.490)
Proportion of students on free/ reduced lunch	Biology			-.003 (.008)	-.003 (.009)	-.013 (.012)	-.209*** (.070)	-.003 (.010)	.008 (.011)
Proportion of students on free/ reduced lunch	PSEM			.002 (.013)	-.003 (.013)	.008 (.010)	-.044 (.040)	.018** (.009)	-.010 (.022)
Proportion of White students	Biology			-.074*** (.016)	-.071*** (.016)	-.089*** (.020)	-.081 (.060)	-.078*** (.021)	-.051* (.021)
Proportion of White students	PSEM			-.048** (.024)	-.033 (.025)	-.025 (.020)	-.019 (.060)	-.018 (.021)	-.087** (.041)
Proportion of students in advanced academic tracks	Biology			.248** (.119)	.242** (.119)	.383** (.160)	.072 (.470)	.467** (.191)	.085 (.220)
Proportion of students in advanced academic tracks	PSEM			-.655*** (.203)	-.692*** (.212)	-.351** (.170)	-1.166** (.561)	-.001 (.162)	-.936*** (.341)
Proportion of licensed teachers	Biology			-.006 (.059)	.003 (.059)	.084 (.080)	.001 (.220)	.164* (.090)	-.108 (.100)
Proportion of licensed teachers	PSEM			.109 (.089)	.154* (.092)	.108 (.080)	.164 (.250)	.172** (.071)	.095 (.155)
College level variables									
Other large predominantly White institution	Biology				-.041*** (.006)				
Other large predominantly White institution	PSEM				-.114*** (.008)				
Small predominantly White institution	Biology				-.024** (.010)				
Small predominantly White institution	PSEM				-.071*** (.014)				
Historic Black college	Biology				-.032*** (.012)				
Historic Black college	PSEM				.009 (.017)				
Observations		12,550	12,550	12,550	12,550	7,250	2,180	5,070	5,300

Standard errors in parenthesis. Asterisks represent significance at *** 1%, ** 5% and *10%.
PSEM stands for physical sciences engineering and mathematics.
Individual level controls also include: race, receives PELL grant, first generation college student. *School level controls* also include: school locale (urban, rural, suburban), percent teachers with advanced degree, percent experienced teachers, teacher turnover.

Table 6
Average marginal effect from multi-level multinomial estimations of probability of graduating a STEM major for roots sample, by gender and observed math skills.

		All students in sample				Sample of just girls			Sample of Just boys
		Model 9. No controls	Model 10. Individual level controls	Model 11. Individual school level controls	Model 12. Individual school college level controls	Model 13. All girls	Model 14. High skilled girls	Model 15. Lower skilled girls	Model 16. All boys
Key independent variable									
Proportion of female math and science teachers	Biology	.000*** (.029)	.000*** (.029)	.000** (.029)	.000** (.029)	.094** (.034)	.187*** (.081)	.044 (.040)	.015 (.040)
Proportion of female math and science teachers	PSEM	.000** (.040)	.000*** (.027)	.000*** (.044)	.000*** (.046)	.111*** (.037)	.234** (.101)	.039 (.031)	.093 (.040)
Student level variables									
Male	Biology		.000*** (.005)	.000*** (.005)	.000*** (.005)				
Male	PSEM		.000*** (.004)	.000*** (.008)	.000*** (.008)				
Math SAT (divided by 100)	Biology		.000*** (.004)	.000*** (.004)	.000*** (.004)	.046*** (.005)			.038*** (.007)
Math SAT (divided by 100)	PSEM		.000*** (.007)	.000*** (.005)	.000*** (.006)	.051*** (.009)			.131*** (.008)
Took advanced algebra 2 in HS	Biology		.000*** (.006)	.000*** (.006)	.000** (.011)	.013* (.008)	.028 (.010)	.019** (.007)	.019** (.009)
Took advanced algebra 2 in HS	PSEM		.000*** (.005)	.000*** (.009)	.000** (.005)	.017** (.008)	.007 (.011)	.033*** (.006)	.045*** (.005)
Took advanced biology in HS	Biology		.000 (.006)	.000 (.006)	.000 (.011)	.006 (.008)	-.027 (.011)	.016** (.007)	.002 (.009)
Took advanced biology in HS	PSEM		.000 (.005)	.000 (.009)	.000* (.005)	-.017** (.008)	-.046** (.010)	-.002 (.006)	-.005 (.005)
Took physics in HS	Biology		.000*** (.005)	.000*** (.005)	.000*** (.009)	.026*** (.008)	.049*** (.010)	.030*** (.008)	.010 (.008)
Took physics in HS	PSEM		.000*** (.004)	.000*** (.004)	.000*** (.004)	.057*** (.007)	.090*** (.011)	.054*** (.006)	.153*** (.004)
School level variables									
Proportion of female students at school	Biology			.000* (.339)	.000* (.339)	-.003 (.240)	-.104 (.550)	.266 (.221)	-.234** (.301)
Proportion of female students at school	PSEM			.000 (.157)	.000 (.163)	.087 (.261)	-.252 (.641)	.167 (.210)	.156 (.180)
Proportion of students on free/reduced lunch	Biology			.000 (.017)	.000 (.017)	-.008 (.011)	-.132 (.072)	-.001 (.013)	.004 (.011)
Proportion of students on free/reduced lunch	PSEM			.000 (.008)	.000 (.008)	.020 (.010)	.028 (.014)	.013 (.009)	-.041 (.010)
Proportion of White students	Biology			.000*** (.028)	.000*** (.028)	-.071*** (.018)	-.059 (.042)	-.060*** (.020)	-.065** (.021)
Proportion of White students	PSEM			.000** (.013)	.000* (.014)	-.014 (.021)	.029 (.063)	-.021 (.021)	-.132*** (.011)
Proportion of students in advanced academic tracks	Biology			.000 (.216)	.000 (.218)	.193 (.169)	-.105 (.341)		-.054 (.212)
Proportion of students in advanced academic tracks	PSEM			.000*** (.115)	.000*** (.121)	-.304 (.202)	-.894 (.492)		-.991*** (.120)
Proportion of licensed teachers	Biology			.000 (.060)	.000 (.109)	.095 (.083)	-.072 (.180)	.222*** (.083)	-.015 (.101)*
Proportion of licensed teachers	PSEM			.000 (.092)	.000* (.053)	.114 (.092)	.215 (.231)	.155** (.071)	.197 (.050)
College level variables									
Other large predominantly White institution					.000*** (.011)				
Other large predominantly White institution					.000*** (.004)				
Small predominantly White institution					.000 (.017)				
Small predominantly White institution					.000*** (.008)				
Historic Black college					.000** (.024)				
Historic Black college					.000 (.011)				
Observations		10,950	10,950	10,950	10,950	6,370	2,030	4,340	4,580

Standard errors in parenthesis. Asterisks represent significance at *** 1%, ** 5% and * 10%.
PSEM stands for physical sciences engineering and mathematics.
Individual level controls also include: race, receives PELL grant, first generation college student. *School level controls* also include: school locale (urban, rural, suburban), percent teachers with advanced degree, percent experienced teachers, teacher turnover.

Additionally, following Carrell, Page, and West (2010), we focus on the sample of students that enter college with the highest observed math skills; these are the students with the most appropriate academic preparation to continue their training toward a career in STEM. We conducted the analysis for the top tercile of students based on their math SAT scores (a math SAT score of 580 or higher). Results in Table 6 show that the estimated marginal effects of the proportion of female high school math and science faculty are larger and stronger for the sample of high-skilled women's chances of declaring physical sciences, engineering and mathematics and biology as a major. For the case of high skilled women, their chances of graduating with a biology and PSEM major increases 44% when they move from attending a school that has a proportion of female math and science teachers of .54 (1 s.d. below the mean distribution of female math and science teachers of .63) to one that has a proportion of female math and science teachers of .72 (1 s.d. above the mean distribution of female math and science teachers of .63). Again, results for men are statistically non-significant. Because our models control for initial SAT math scores and advanced math and science placement (taking advanced biology and taking physics) it is unlikely to reflect men's higher likelihood of scoring at the very top of the distribution prior to college. We also conducted analyses for the sample of young women in the bottom two terciles of math achievement (lower skilled girls), operationalized as those with SAT math scores below 580. For these students, the proportion of female math and science teachers has no significant association with women's chances of graduating with STEM. These results suggest that the benefits of having higher proportions of female math and science teachers in high school are restricted to the highest-skilled women.

4.3. Biological sciences versus physical sciences, engineering and mathematics (PSEM)

There are important differences in the participation of women in biological sciences as opposed to the PSEM fields. Women have a much higher representation in the biological sciences than in PSEM, where their participation is marginal. Our findings show that the relationship between proportion of female math and science teachers in high school and women's STEM declaration and graduation from STEM fields is larger and stronger for PSEM majors specifically. Furthermore, when we analyze results by female students' levels of observable math skills, we find that the proportion of female math and science teachers in high school is significantly and more strongly linked with higher-skilled female students' odds of declaring and graduating with a PSEM degree (compared to their chances of declaring and graduating with a biology degree).

Three important features of these findings require our attention. First, all female students' likelihoods of majoring in a STEM field are positively affected by attending a high school whose math and science faculty has a larger female membership. Given that the gender composition of the high school math and science teachers is unrelated to most other characteristics that influence college major, our estimates likely reflect causal effects. Second, the level of a female student's math skills moderates the significance of her high school female math and science faculty's influence: those with higher skills are likely to pursue PSEM or biology majors, while young women with less developed math skills are not significantly influenced this way. Third, male students' likelihoods of majoring in a STEM field are unaffected by attending a high school whose math and science faculty has a larger female membership.

5. Discussion

Our findings lend support for our hypothesis that women who attend high schools with a higher proportion of female math and science teachers are more likely to declare and to graduate with a STEM major in college. Unlike the STEM-related college faculty, who are primarily men, it is important to keep in mind that the majority of high school math and science teachers are, in fact, female. Nonetheless, even though the majority of North Carolina high school math and science teachers are women, the proportions of female teachers of math and science are lower than those in other subjects.[12] And, although the majority of teachers are women, not all high schools have similar proportions of female faculty teaching math and science classes, as our tercile analysis revealed. Together these findings suggest that a preponderance of female math and science faculty may be necessary for countering the pervasive gender stereotypes that math and science are masculine domains, especially for the female high school students who score the highest in math.

Although our data do not permit us to investigate the mechanisms that underlie this relationship, we speculate that two different, but related, processes are at work. First, by having a preponderance of female math and science teachers in high school, the "chilly climate" in STEM could decrease and consequently might provide a more positive normative atmosphere for young women to express their interest in STEM without fear of negative social sanctions. Second, a preponderance of female math and science teachers in high school could offer young women greater availability of role models or mentors who might encourage them towards a STEM major and later, a STEM-based career. Because of the gender distribution of math and science faculty at

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small predominantly white institutions (Western Carolina, University of North Carolina—Asheville, and University of North Carolina—Pembroke); 3) historically black colleges (North Carolina A&T, Elizabeth City State University, North Carolina Central University, Winston-Salem State University, and Fayetteville State University); and the excluded category 4) prestigious and flagship institutions that has 60% of the STEM students in our sample (UNC-Chapel Hill and North Carolina State University). Results of these models with college fixed effects maintain our key findings.

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[12] Although nationally the gender distribution of public school teachers is 76% women and 24% men, the gender composition is substantially different when one looks at the subjects of math and science in high school. Data from the National Center for Education Statistics (2008) School and Staffing Survey report that in 8th grade and 12th grade, 65% and 52% of the teachers in math were women, respectively; and 52% and 44% of the science teachers were women. Similarly, the gender distribution of teachers in the state of North Carolina in 2000 was unequal. Across all public school teachers in North Carolina, 80% of them are women and 20% are men, and the percentage of women math and science teachers altogether in 10th grade totaled 64% (Roots Data, authors' calculations).

high schools, we know that adolescent girls are actually more likely to find a math or science teacher of their gender compared to boys (unlike female students at college campuses). Therefore our findings offer less support for an explanation built upon role model theory; instead, we interpret our findings as support for an explanation that draws upon female math and science faculty's potential to undermine the "chilly climate."

Regarding the significantly stronger influence of female high school math and science teachers on higher-skilled female math students' odds of choosing a STEM major, we speculate that students with stronger mathematics skills are better positioned to succeed in STEM majors that tend to be more mathematics-based. Therefore they may be more susceptible to other factors' influence (beyond ability) in their decision to major in STEM. For instance, a high school student with strong math skills may simply require encouragement or some indication that she could succeed as a STEM major, while a lower-ability student would need both academic support and encouragement that she could successfully major in STEM.

An additional striking finding that our quantitative data do not allow us to investigate more completely concerns the gender difference in the relationship of the proportion of female high school's math and science to the likelihood a student will major in STEM. Our theory suggests that more female math and science teachers should inspire girls to enter STEM, but this should have no impact on boys. In fact, our analysis shows that although a number of expected factors predict a STEM major choice among our sample of male college students, the proportion of their high school's math and science faculty who were women had no significant effect on their STEM trajectories. Moreover, this non-significant effect for boys provides further support to our conclusion that omitted variable bias is not driving our results.

6. Conclusions

The increasing demand for a STEM workforce and the insufficient supply produced by American educational institutions has led many researchers and policy analysts to focus on the shortage of women in these important fields. Too few female students appear interested in pursuing degrees in science, technology, engineering or mathematics, and even if they have a strong interest, too few remain in STEM majors once they arrive in college. The results from this study echo earlier findings (Crisp, Nora, & Taggart, 2009) that point to the crucial role that secondary school factors have in addressing this problem. We advance this literature by showing that the gender composition of high school math and science faculties has an important relationship to whether or not young women will pursue STEM degrees once they arrive at college. Although previous studies have analyzed the importance of the gender composition of the college faculty on postsecondary STEM outcomes, there has been little empirical research on the importance of female teachers in the early pre-college years on postsecondary STEM outcomes.

Our study is the first to analyze the importance of the gender composition of high school math and science teachers on students' STEM participation during college using a

longitudinal dataset. We use a sample of students who attended NC public high schools and later enrolled in one of the 16 campuses of the NC university system and declared a major. The longitudinal nature of the Roots of STEM Success dataset allowed us to examine the roles of individual, pre-college and college level characteristics on the participation of students in STEM majors. Results show that young women's pre-college experiences can have an important impact on their decision to declare and graduate with a STEM major. Specifically, our results demonstrate that secondary school exposure to faculties with a preponderance of female math and science teachers is particularly important for young women's STEM outcomes. Higher proportions of female math and science teachers in high school increase young women's probability of declaring and graduating with a STEM degree, while secondary school faculty gender composition has no significant effect on young men's odds of declaring or graduating with a STEM major. Even more striking, our results show that the positive influence of attending a high school with a higher proportion of female math and science teachers is stronger and greater for the participation of higher-skilled young women (those with math SAT scores in the top tercile of the distribution) in the physical sciences, engineering and mathematics fields and in biology.

Previous research has found mixed evidence regarding the influence of the gender of college faculty on STEM outcomes in college. Nevertheless, when the focus of such analysis is limited to math and science college faculty (rather than the entire college faculty), researchers obtain findings similar to our own: the gender composition of the math and science faculty is significantly associated with female students' chances of participating in STEM. This relationship is even stronger for high-skilled young women. Our findings support those of Carrell, Page, and West (2010) regarding the importance of math and science college professors' gender on women's STEM participation. Furthermore, our high school-focused results also extend their findings because we link this known importance of female math and science professors to research showing that the majority of the students who concentrate in STEM make that choice during high school (Maltese & Tai, 2011; Schneeweis & Zweimuller, 2012). Our findings offer empirical evidence that highlights the influential role of a preponderance of female math and science *high school* teachers on short- and long-term STEM outcomes.

There is something about high schools with very high proportions of female math and science teachers that has a powerful effect on the STEM interest of highly skilled young women—with virtually no expense incurred by their comparable male peers. We speculate that it is important during the pre-college years to help disrupt the pervasive stereotypes regarding which individuals are suitable for a job in science, technology, engineering and mathematics. Our findings suggest that increasing the proportion of female instructors, particularly in math and science subjects, might be an efficient way of making the STEM environment at schools friendlier for girls.[13] In the case where hiring more women is

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[13] The most important limitation of this study is that our data do not permit us to investigate why a preponderance of female high school math and science teachers has a positive relationship to STEM majors among female undergraduates, especially the students with the highest mathematics skills;

not an option, high schools should aim to make the school's math and science classroom climate one that is more normative for females. One way to do this is by implementing a student-centered pedagogy designed to be more inclusive of young women (this could mirror the one to which girls are exposed when attending schools with very high proportions of female math and science teachers) that could contribute to fostering the STEM interest in girls, particularly high-skilled girls. There is a need to further explore what other possible benefits attending a high school with very high proportions of female math and science teachers offers to girls' interest in STEM. Based on our evidence from a selected sample of students in North Carolina public colleges, which provide high quality STEM college options in-state in North Carolina, female math/science teachers are successful in encouraging female students to pursue these majors.[14]

We conclude by emphasizing the importance of providing women with early opportunities to attend schools that challenge long-entrenched gender stereotypes about math and science. Doing so will likely sustain and support greater numbers of young women pursuing careers in science, technology, engineering and mathematics. In these ways, greater numbers of women in STEM majors will grow the academic roots that will enable them to pursue STEM careers. Our findings suggest they will contribute to a virtuous cycle of more female incumbents in STEM careers, more female role models, and stronger challenges to any lingering fictions that science, technology, engineering, and mathematics are not for young women.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.econedurev.2015.01.002.

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and why the effects are absent for male undergraduates. The larger project from which this study is drawn has a qualitative component that the authors are conducting. In-depth interviews of 317 seniors across the 16 UNC campuses have been completed and are being analyzed as of this writing. The qualitative data should shed light on the unanswered questions raised by our findings reported in this paper. Future research should pursue answers to these questions.

[14] However, in the absence of this type of opportunity, we may not see this relationship.

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