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Long-Term Impact of Teacher Professional Development on Black Female Students' Engagement in STEM

Cecilia Henríquez Fernández, Christopher Barr, Allen Antoine, Christina Alston, and Carolyn Nichol

Department of Engineering, Office of Research of Development and Infrastructure, and Office of STEM Engagement, Rice University, Houston, TX

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ABSTRACT: In this paper, we argue that teacher professional development programs focused on inquiry-based learning increase students' likelihood of selecting STEM majors. Long-term student data was collected accessing the University of Houston's Educational Research Center database for each student whose teacher participated in the Applied Mathematics Program! (AMP!) professional development between the years 2014 and 2019. Using propensity scoring to create a matched comparison group, we conducted a logistic regression to model the likelihood of students choosing a STEM major in college if they had a teacher who participated in AMP! versus students who did not have a teacher who participated in the AMP!. Our analyses indicate that when teachers participate in AMP!, their students are more likely to select a STEM major in college. Additionally, female students had much larger effect sizes, particularly Black female students, whose likelihood of selecting a STEM major doubled when their teachers participated in AMP!.

INTRODUCTION

Black women remain underrepresented in Science, Technology, Engineering, and Mathematics (STEM). According to the National Center for Education Statistics (NCES) (2021), 11% of all science and engineering degrees earned by women in 2019 were earned by Black women nationwide, while 52% of all science and engineering degrees earned by women in the same year went to White women. Within the state of Texas, the data looks quite similar. NCES reports that 10% of all science and engineering degrees awarded to women in 2019 in Texas were to Black women and 41% to White women (Table 1). The low number of Black women awarded science and engineering degrees leads one to ask, how can the educational community better support Black women to matriculate and pursue STEM degrees?

In this paper, we argue that in-service teacher professional development (PD) grounded in inquiry-based pedagogical practices plays a vital role in supporting student matriculation into STEM majors, especially for Black women. We first review efforts made to diversify STEM, focused on Black females and classroom environments. We then review how the educational community has examined the impact of STEM teacher PD programs on students. Next, we describe our conceptual framework and how it influenced the development of an in-service teacher PD called the Applied Mathematics Program (AMP!). This provides the context for understanding the science and mathematics classroom environments that students of teacher participants in the AMP! experience after the teachers attend the PD program. We followed students of teachers who have participated in AMP! since 2014 using the University of Houston's Educational Research Center (EdRC) database. The database hosts data from the Texas Education Agency (TEA), the Texas Higher Education Coordinating Board (THECB), and the Texas Workforce Commission (TWC). Our analysis demonstrates that students of the teachers who participated in our PD were more likely to pursue a STEM major than students of teachers who did not participate in such a program. Finally, we discuss why this finding is important and our rationale for why we see an amplified effect on Black females.

Table 1. *Proportion of Female Students Obtaining Science and Engineering Degrees by Race.*

Sample	Female						
	Black	White	Hispanic	Asian	Native American	Pacific Islander	Other
National							
%	11	52	18	10	1	0	8
n	53,291	258,123	90,428	48,116	2,668	1,174	39,098
Texas							
%	10	41	34	10	0	0	5
n	3,008	12,300	10,461	3,022	87	36	1,427

Data obtained from the National Center for Education Statistics 2021.

Increasing the Number of Black Women in STEM. Efforts have been made on many fronts to address the low number of Black women in STEM fields. Some efforts have focused on creating interventions for Black women at various critical focal points of their careers through informal education. For example, some programs have focused on exposure to STEM fields for Black female students (King and Pringle, 2019), while some have focused on out-of-school interventions grounded in cultural practices that help Black girls thrive in STEM (Ashcraft et al., 2017; Scott, 2021). Other programs have focused on mentoring relationships between Black scientists and engineers with Black female students (Allen-Handy et al., 2020). Finally, some programs that aim to increase the representation of Black females in STEM have focused on creating social supports that help Black women navigate their STEM careers (Allen-Handy et al., 2020; King and Pringle, 2019; Lane and Id-Deen, 2020; Levine et al., 2015). These efforts successfully support women and girl participants in expressing an interest in STEM and provide safe spaces where Black girls and women can flourish in STEM.

Efforts have also been made to understand and intervene in the Black female student experience in the formal STEM classroom. For example, some research has focused on how teachers in K-12 classrooms interact with Black female students compared to other students and how these interactions reproduce gendered and racial stereotypes about Black girls' academic abilities (Morris, 2007). These examples of research around the diverse nature of observations and interventions highlight the complexity of the social situation that has led to a low number of Black women pursuing or obtaining STEM degrees and the various interventions that could help Black women make gains in science and engineering. However, they also highlight the need to understand how these initiatives impact Black girls' trajectories in STEM long-term. In this paper, we examine the relationship between sustained inquiry learning PD for teachers and Black female students' STEM college major choice.

LITERATURE REVIEW

This literature review focuses on STEM teacher PD and the impact of teacher PD on their students because research has shown that there is a positive relationship between high-quality PD and teacher quality (Cochran-Smith, 2004; Guskey, 2000; Guskey, 2002; Hassel, 1999; Joyce and Showers, 1988; Soine and Lumpe, 2014). We begin by defining high-quality teacher PD. We then examine what we know about the relationship between PD and student impact, focusing on how previous studies have examined student impact. We conclude by explaining why it is important to develop measures that help us better understand the relationship between teacher preparation and student trajectories.

Defining High-Quality Teacher Professional Development. High-quality PD includes five specific features: (1) content focus, (2) active learning, (3) coherence, (4) duration, and (5) collective participation (Desimone, Laura M., 2009). Of these facets, it has been found that PD needs to be long-term and sustained to impact teaching practices. Supovitz and Turner (2000) found that it is not until teachers have received over 80 hours of PD that they fully incorporate inquiry and investigative practices in the classroom. Because short-term PD produced limited impact, PD providers in the US have been moving away from one-time half-day workshops and are increasingly providing teachers with more sustained PD (Wei et al., 2010). Substantial research supports Desimone's five featured conceptual frameworks, including long-term support (Desimone et al., 2013; Desimone, 2009; Garet et al., 2010; Garet et al., 2010; Penuel et al., 2011). However, teachers' jobs are multifaceted, and there is a great degree of variation in how teachers respond to PD. In addition, there is substantial debate about how it translates into student outcomes, and few rigorous studies explore this translation (Garet et al., 2010; Loucks-Horsley et al., 2009; Yoon et al., 2007).

Professional Development Impacts on Students. Studies on how in-service teacher PD impacts student outcomes have had mixed results. When analyzing student impact of teacher PD, confounding factors include the quality of the PD, administrative support, school culture, implementation barriers, teacher attitudes, and other aspects of school change (Desimone, 2009; Fischer et al., 2018; Fischer et al., 2020; Ingvarson et al., 2005; Polly et al., 2015). Studies on student outcomes have ranged from smaller qualitative studies where the researchers have observed teacher implementation and student work to large meta-studies of large databases and multiple research studies. When researching student outcomes, one of the most challenging questions is what measure to use to gauge student outcomes. Often, researchers narrow this down to standardized tests. One example of this is an extensive study by Fischer et al. (2009), which investigated the relationship between teacher PD and teacher instructional practices, and then on teacher instructional practices and student performance on Advanced Placement © (AP) and Preliminary Scholastic Aptitude Test (PSAT) exams. This large study included 33,336 students and 7,434 teachers. While they found that high-quality PD, as described by Desimone (2009), did translate into positive changes in teacher practices (e.g., participation in PD was positively associated with teachers' increased use of laboratory activities), they did not find a strong link between these practices and improved AP© test results. In a smaller study of a mathematics PD, which utilized a randomized control trial, 4th-grade teachers (104 treatment and 117 control) who participated in the 93-hour PD improved their mathematical content knowledge and pedagogical practice (relative to the control teacher). Still, there was no statistical difference in student achievement between the treatment and comparison groups as measured by an adaptive assessment provided by the Northwest Evaluation Association (NWEA) (Garet et al., 2010). However, in a similarly designed study of 125 teachers and 1676 of their students in grades 4–8 in urban schools, researchers found that students of teachers in the treatment group did show a 4% gain in science content knowledge relative to the comparison student group using multiple choice questions from state standardized tests (Aaron Price and Chiu, 2018).

Professor Linda McNeil, who dedicated her life to addressing educational inequity, curriculum, and public-school reform, was quoted by Education Week stating, "Measurable outcomes may be the least significant results of learning" (Kohn, 2001). The lack of solid data showing the student impact of in-service teacher PD could be because researchers typically use limited measures such as short-term outcomes and standardized tests to examine this relationship rather than looking into the long-term impact of teacher PD on student progression in their academic studies. This paper examines long-term outcomes and, to McNeil's point, a more significant question: Are students, especially young Black women, more likely to pursue STEM careers when they have had teachers that participated in high-quality STEM PD?

CONCEPTUAL FRAMEWORK

Meaning-making and *thinking* have consistently been reported as essential constructs that should be thoughtfully incorporated into teaching practices to promote student learning (Anderson, 2017; Peker and Dolan, 2012). Within scholarship on Constructivist Learning Theory, these two constructs are interconnected, with teachers facilitating social situations in which students can create their own knowledge (*think*) by making sense of the social world around them (*meaning-making*) (Bozhovich, 2009; Hsu et al., 2019; Liu and Chen, 2010):

- *Thinking* is centered on the learner's knowledge creation (Dewey, 1966; Piaget, 1951; Wertsch, 1985). Specifically, teachers that abide by constructivist learning theory believe it important to consider the mental processes that children engage in during thinking that facilitate learning rather than memorizing and reciting subject matter. To promote thinking, teachers must create opportunities for students to ask questions, make observations, and generate ideas. In a constructivist framework, thinking is not learning a core "truth" but instead actively engaging with information by oneself and with others to make sense of an array of experiences, sensations, and information that have no specific order except within the explanations that aid the establishment of one's knowledge.
- *Meaning-making* emphasizes the significance of students doing something with a purpose or goal. Specifically, when students engage in meaning-making, they actively engage in cultural practices. Learning these cultural practices is necessitated by the need to participate in one's world (Dewey, 1966; Liu and Chen, 2010; Wertsch, 1985). Meaning-making is an active mental process that pushes students beyond hands-on experiences to deepen their understanding. Learners generate new knowledge while building on their existing knowledge through social and linguistic reflections with peers.

Our defined constructs incorporate ideas from constructivist approaches in teacher PD literature (Chang and Park, 2019; Fischer et al., 2018; Soine and Lumpe, 2014). We believe that math and science teachers can replicate these practices in their classrooms, improving students' ability to think about and make sense of natural phenomena. As a result, a STEM culture is promoted.

Context. We developed the Applied Mathematics Program (AMP!) to create and sustain a diverse STEM workforce with the robust technical and scientific skills needed to solve real-world problems. Specifically, AMP! approaches this goal by directly having mathematics and science educators support one another and highlight overlaps in their curricula. Highlighting the overlap between math and science provides context for mathematics lessons. It integrates different STEM subject content standards into mathematics classroom instruction and vice versa (Antoine et al., 2021). Teacher participants in AMP! were provided with trainings to facilitate this type of instruction in their science or math classrooms. Throughout a year-long PD program focused on using inquiry-based instructional methods, instructional coaching, standards-based lessons, and connections between mathematics and science lessons, AMP! aimed to:

- Increase mathematics and science teacher content knowledge and pedagogical knowledge, and support teachers' further enrichment through intensive PD for pairs of mathematics and science teachers from the same school campus;

- Increase student engagement and achievement in STEM grounded in mathematics inquiry by making connections between inquiry science and applied mathematics through engaging, creative, and rigorous learning experiences for students; and
- Establish professional learning communities in a supportive and rewarding environment that sustains teacher participants in high-needs schools by supporting team learning, team building, mentoring and coaching, and teacher training for successful content standard implementation.

A significant focus of AMP! was to provide PD for teacher teams. Mathematics and science teacher pairs from the same campus were selected for this experience. Teacher participants received over 110 hours of sustained PD via a one-week summer institute and a series of PD weekend and weeknight sessions throughout the school year following the summer institute. Teacher pairs from the same campus were intentionally selected to ensure that teachers could support each other on their own campus outside of the program, assist each other in building content knowledge to answer student inquiries across subject areas and develop the foundational partnership essential for sustaining professional learning communities. Additionally, the teacher pair partnerships allowed teacher pairs to integrate cross-curricular teaching approaches more effectively.

Throughout the program, AMP! instructors presented diverse lessons that combined grade-level appropriate mathematics and science lessons that were interesting and thought-provoking for students. Mathematical concepts were delivered using science concepts in an inquiry-based way that prompted students to ask questions and build their own understandings. By using hands-on, technology-based activities and group discussions, participating educators could put themselves in their students' shoes and brainstorm methods for delivering this type of instruction to their students.

In addition to the program components, each educator who participated in the program could conduct peer-to-peer observations at the campus of another participant in the cohort or have a program facilitator come to their classroom for mentoring visits. During the program year, various mentoring support mechanisms were also provided, such as emphasizing quality questioning, teaching with culture in mind, and understanding cross-curricular teaching in practice.

METHODS

Study Design. This study utilized archival data obtained from the Texas Education Research Center (EdRC) database. The EdRC database is a product of a collaboration between the Texas Education Agency (TEA), the Texas Higher Education Coordinating Board (THECB), and the Texas Workforce Commission (TWC). The EdRC database contains data on Texas K-16 students, including state standardized test results, high school graduation information, undergraduate graduation information, college major, attendance, courses taken, profession, and many others. This database allows for comparing college majors for students who were instructed by AMP! teachers with students who were not instructed by AMP! teachers. We used a statistical equating procedure, propensity score matching, to create a matched comparison group (Rosenbaum and Rubin, 1983). We matched students with colleges/universities on various demographic characteristics, including gender, race, and economic status. Because the database of students not instructed by AMP! teachers is substantially larger than the database of students instructed by AMP! teachers, we were able to leverage the non-AMP! instructed student sample to generate a larger comparison group and thus increase our statistical power to detect effects. In the models described below, we used a 1-to-10 AMP! student to comparison student ratio.

Research Questions. This study examines the long-term outcomes of yearlong sustained inquiry-based PD on Houston's Black female students' STEM educational trajectories. Specifically, we ask (1) Are female students of teachers in AMP! more likely to pursue STEM majors compared to female students of teachers who did not participate in AMP!? and (2) Are Black female students of teachers who participated in AMP! more likely to pursue STEM majors than Black female students of teachers who did not participate in AMP!?

Sample Participants and Procedures

AMP! Student Sample. Students of AMP! teachers were identified in the year the teachers participated in AMP! and all subsequent years, and these students served as the basis for the undergraduate major sample. These students were then merged into a database containing all university, community college, and private college/university students and their declared major. Majors were listed by name, e.g., mechanical engineering, and an 8-digit numerical identifier known as a Classification of Instructional Programs (CIP) code. This college-level database contained multiple records per student, as students often change majors. For this sample, only the most recently declared major was retained. Finally, this database of students of AMP! teachers was mapped to a database from the Department of Homeland Security (2022), which contained a list of all college major CIP codes deemed to be STEM-related. As such, we could produce a list of all students of AMP! teachers present in the college level database, and to assign a flag variable indicating if the student endorsed a STEM major. The final dataset contained N = 13,786 AMP! students.

Non-AMP! Student Sample. All students who were present in the college major database but were not instructed by AMP! teachers were retained. These students were also mapped to the CIP code database and flagged for STEM major/non-STEM major. These students served as the basis for generating the comparison sample described below.

Comparison Sample. To generate the comparison sample, we used a propensity score matching strategy. With propensity score matching, the outcome is whether students were in the treated group (instructed by AMP! teachers) or the comparison group. This binary outcome variable is predicted by a set of variables potentially related to the presence or absence from the treated group. For the matched comparison sample, we included campus, gender, race/ethnic status, English proficiency status, and economic status. Model results provide a probability of being in the treated group based on these variables. We then matched students from the AMP! groups with non-AMP! students based on these probabilities. As mentioned above, we used a one to ten AMP! to non-AMP! student match, such that the control group was 10 times the size of the AMP! student group, which served to increase statistical power to detect effects. This matching resulted in a comparison sample of N = 137,860 control students.

Data Collection Procedures

EdRC Description. Students were identified as being instructed by or not instructed by an AMP! teacher. Student were instructed by an AMP! teacher if they were instructed in the same year the teacher participated in the AMP! program, or if they were instructed by the teacher in any subsequent years by the teacher following their participation in AMP!. All other students were flagged as non-AMP! instructed students. We were able to follow these AMP! instructed students to colleges and universities using a database-generated ID variable that was considered a social security number replacement. This variable, along with race and gender demographic data, served as predictor variables of interest. Regarding the outcome variable, STEM major status, we relied on the CIP major code, as mentioned above.

Data Analyses. All data analytic modeling to test study hypotheses utilized logistic regression. We modeled STEM major as a binary outcome predicted by a student's AMP! status and gender, as well as by the AMP! status-gender interaction. We subset the data for race-specific models such that we separately modeled the impact of AMP! status, gender, and the interaction between AMP! status and gender for the four primary race categories (Black, White, Hispanic, and Asian American). We note that some models were at higher aggregate levels, e.g., examining AMP! status ignores race and gender, but the model generally takes the form below.

$$Logit(\pi_{STEM_{major_i}}) = \beta_0 + \beta_1 Gender_i + \beta_2 AMP!_i + \beta_3 Gender_i AMP!_i$$

Where $Logit(\pi_{STEM_{major_i}})$ is the log odds of person i majoring in a STEM field, β_0 is the intercept, gender is the gender status for person i, AMP! is the AMP! status for person i, β_1 is the parameter estimate for the effect of gender, β_2 is the parameter estimate for AMP! status, and β_3 is the parameter estimate for the interaction of gender and AMP! status.

RESULTS

Finding 1: Students of AMP! Teachers Were More Likely to Select a STEM Major. We conducted a logistic regression to predict STEM major selection by students who had and did not have AMP! teachers during their academic trajectory. We conducted these analyses for the impact of AMP!, for the sample as a whole as well as by gender. All models were significant at $p < .05$ with students of AMP! teachers majoring in STEM at a higher rate than students of non-AMP! teachers. Table 2 below shows that overall, students were 5.3% more likely to major in STEM when they went to college than students who did not have an AMP! teacher. We then broke the models down by gender, comparing female students of AMP! teachers with matched samples of female students with non-AMP! teachers and male students of AMP! teachers with matched male students of non-AMP! teachers.

We found the effect of having an AMP! teacher on major selection was even more pronounced for female students. Female students of AMP! teachers were 5.5% more likely to major in STEM when attending college than female students of non-AMP! teachers (Table 2). Table 2 also shows that male students were 5% more likely to select a STEM major when matriculating into college when instructed by an AMP! teacher than male students of non-AMP! teachers. Thus, the models show that when a student had a teacher who participated in the AMP! program, regardless of gender, they were more likely to major in STEM in college than students who did not have AMP! trained teachers. We also note that the likelihood was larger for female students than for male students.

Finding 2: Black and Asian Students of AMP! Teachers More Likely to Major in STEM. We then conducted a logistic regression to predict STEM Major for students using AMP! teacher status as the predictor variable for the differ-

Table 2. *STEM Major Selection of Students of AMP! Teachers vs. Matched Controls.*

Sample	Gender	Sample N	Proportion STEM Major	Number STEM Major
Non-AMP! instructed	All	13,786	0.154	2,125
AMP! instructed		13,786	0.207	2,855
Non-AMP! instructed	F	7,848	0.116	907
	M	5,938	0.205	1,218
AMP! instructed	F	7,852	0.171	1,343
	M	5,934	0.255	1,512

ent race and ethnicity samples. All models were significant at $p < 0.05$, indicating that all students of AMP! teachers were more likely to select a STEM major than matched comparison groups of students of non-AMP! teachers across all races and ethnicities. Specifically, Table 3 shows that Asian students were 6% more likely to select a STEM major in college when they were instructed by an AMP! teacher compared to Asian students who were not instructed by AMP! teachers. Additionally, Table 3 shows that Black students were 6.6% more likely to select a STEM major in college when instructed by an AMP! teacher compared to Black students who were not instructed by AMP! teachers. White students were 5.2% more likely to select a STEM major in college when instructed by an AMP! teacher compared with White students who had not been instructed by an AMP! teacher. Finally, Table 3 shows that Hispanic students were 4% more likely to select a STEM major when instructed by an AMP! teacher than Hispanic students who were not instructed by an AMP! teacher. Overall, we see the effect of having an AMP! teacher was strongest amongst Black and Asian students when they selected a major in college.

Finding 3: Black and Asian Female Students of AMP! Teachers More Likely to Major in STEM. Our final model examined the interaction between race and gender. We conducted a logistic regression using AMP! status to predict STEM major selection across genders within racial/ethnic groups. Except for the White student sample, all gender by race interaction models were significant at $p < 0.05$ with students of AMP! teachers majoring in STEM at a higher rate than matched students of non-AMP! teachers. Table 4 shows that Asian female students were 7.1% more likely to select a STEM major in college when having been instructed by an AMP! teacher compared to Asian female students that were not taught by AMP! teachers. In contrast, Asian male students of AMP! teachers were 3.6% more likely to select a STEM major in college than Asian male students of non-AMP! teachers.

Hispanic female students of AMP! teachers were 5.1% more likely to select a STEM major in college than Hispanic female students of non-AMP! Teachers (Table 4). In contrast, Hispanic male students of AMP! teachers were 2.8% more likely to major in STEM in college than Hispanic male students of non-AMP! teachers. Finally, Table 4 also shows that Black female students of AMP! teachers were 7.2% more likely to major in STEM in college than Black female students of non-AMP! teachers. Black male students were 5.2% more likely to major in STEM in college when having had an AMP! teacher than Black male students of non-AMP! teachers. These findings indicate that AMP! is related to the increased likelihood of female Asian and Black students selecting STEM majors. Additionally, while the increase in likelihood of selecting a STEM major was smaller for Hispanic female students (compared to Asian and Black female students), Hispanic female students were still twice as likely to major in STEM when having an AMP! teacher compared to their male counterparts.

We note that the proportion changes in STEM majors described above are on an unstandardized metric and thus not comparable across groups. Thus, to compare the impact of

Table 3. *Comparison of STEM College Major Selection of Students of Program Participants vs. Comparison Students by Race/Ethnicity.*

Sample	Race/ Ethnicity	Sample N	Proportion STEM major	Number STEM Major
Non-AMP! instructed	Asian	1,418	0.258	366
AMP! instructed		1,419	0.319	453
Non-AMP! instructed	Black	3,816	0.120	459
AMP! instructed		3,818	0.186	711
Non-AMP! instructed	White	4,016	0.144	579
AMP! instructed		4,017	0.196	789
Non-AMP! instructed	Hispanic	4,455	0.160	713
AMP! instructed		4,451	0.200	888

Table 4. *Comparison of STEM College Major Selection of Students of Program Participants vs. Comparison Students by Race and Gender.*

Sample	Race/ Ethnicity	Gender	Sample N	Proportion STEM Major	Number STEM Major
Non-AMP! instructed	White	M	17923	0.201	3,603
		F	22284	0.093	2,072
AMP! instructed		M	1789	0.263	471
		F	2228	0.143	319
Non-AMP! instructed	Asian	M	6640	0.327	2,171
		F	7542	0.209	1,576
AMP! instructed		M	663	0.363	240
		F	756	0.280	212
Non-AMP! instructed	Hispanic	M	18727	0.213	3989
		F	25790	0.118	3043
AMP! instructed		M	1873	0.241	451
		F	2578	0.169	436
Non-AMP! Instructed	Black	M	15748	0.164	2,583
		F	22390	0.093	2,082
AMP! Instructed		M	1576	0.216	340
		F	2242	0.165	370

Note: 10:1 control sample

the program across groups, we calculated the odds ratios, which are a standardized effect size for data with a categorical outcome, for Hispanic, Black, and Asian women in the model above. We report the odds ratios here as it is a more useful metric for comparing the impact of having an AMP! trained teacher on selecting a STEM major for these three groups of women. The odds ratio for Hispanic women was calculated as 1.52. This indicates that the odds of a Hispanic woman who had an AMP! trained teacher selecting a STEM major is 1.52 times higher than Hispanic women who did not have an AMP! trained teacher. The odds ratio for Asian women was 1.48. This indicates that the odds of an Asian woman who had an AMP! trained teacher selecting a STEM major is 1.48 times higher than an Asian woman who did not have an AMP! trained teacher. Finally, the odds ratio for Black women was 1.93. This odds ratio indicates that the odds of a Black woman who had an AMP! trained teacher selecting a STEM major was 1.93 times than for a Black woman who did not have an AMP! trained teacher selecting a STEM major. The odds ratio results clearly indicate that for Black women, having an AMP! trained teacher is related to increased odds of Black women selecting a STEM major in college to a greater extent relative to Hispanic and Asian women. In sum, across the three models, we found that all students of teachers who participated in AMP! were more likely to select a STEM major when they attended college than students who did not have a teacher who participated in AMP!. In addition, when we examined the likelihood of students pursuing STEM degrees across gender demographics, we found that female students had higher proportion rates of selecting a STEM major compared to their male counterparts when their teachers participated in AMP!. Examining racial groups indicated that Black and Asian students had larger proportion rates when selecting a STEM major than their White and Hispanic counterparts when their teachers participated in AMP!. Finally, when examining the interaction between race and gender, we found that Black female students had the highest increase in proportion rates when their teachers participated in AMP! compared to female students across other racial demographics.

Power Analysis. We note that we were able to leverage the EdRC database to increase the size of our comparison students to a 10:1 non-AMP! to AMP! Ratio. As mentioned above, our 10:1 model found significant AMP! status by gender interactions for Asian, Hispanic, and Black students. We examined 1:1 models and found that the AMP! status by gender interaction for Black students was still significant at $p < 0.05$ but only approaching significance for Asian and Hispanic students ($p > 0.05$ but $p < 0.1$). To investigate why the 1:1 result did not yield the same significant results, we examined the effect sizes and power calculations for all groups with 1:1 and 1:10 ratios. In all 1:10 ratios, the power exceeded Beta=.99 for all groups. However, for the 1:1 ratio, power was only at Beta=0.99 for the Black student sample. The remaining samples had power ranging from Beta=0.71-0.77. This differential power is a function of the effect size on which the power is based, and as seen above the odds ratio effect size was greatest for Black women. Additionally, when comparing proportions, both the proportions' location and the magnitude of the proportion difference impact the power to detect differences. For example, it is more challenging to detect a difference of 10% when the proportions are 45% versus 55%, relative to when the proportions are 5% and 15%. To compare proportions, they must undergo a transformation of $\varphi=2\sin^{-1}(\sqrt{P})$, where P is the proportion of a given group. The phi values can be directly compared and yield an effect size of h. For the four groups, the h effect sizes were 0.09 for the white sample, 0.13 for the Asian sample, 0.12 for the Hispanic sample, and 0.16 for the black sample. Thus, the larger effect size for Black students is likely why the interaction was still detectible in the 1:1 sample at $p < 0.05$, while the remaining samples' values slightly exceeded 0.05.

DISCUSSION

The findings of this study have many implications. First and foremost, teachers matter. This study shows that accounting for various social demographic factors that can impact students' educational trajectories, students who had teachers that participated in AMP! were more likely to major in STEM. This finding is not entirely surprising, as a long track record of research shows teachers' power and influence on their students' lives. Most dedicate their lives to support their students' achievement (Ansari et al., 2020; Day et al., 2007; Ladson-Billings, 2014).

A sociocultural perspective of learning allows us to understand why teachers can have such an impactful position in their students' lives. Teachers spend up to 1,000 hours per school year (depending on grade level) teaching and engaging with their students (OECD, 2021). In the classroom, the teacher holds power to lead the direction of the social environment that can either engage or disengage students in STEM subject matter. For example, an abundance of research in mathematics education has shown how social normative behavior around legitimate participation in mathematics classrooms and social mathematical normative (socio-mathematical norms) behavior contributes significantly to student's understanding of what counts as mathematics, what legitimate forms of mathematical participation look like, who is capable of succeeding in mathematics classrooms, and the roles of students and teachers in mathematics classrooms (Cobb et al., 1992; Cobb, 1994; Heller, 2015; Kohen and Borko, 2022; Sfard, 2007; Walshaw and Anthony, 2008). At the K-12 education level, these experiences play an early and vital role in creating an affinity and positive disposition towards STEM fields.

For both AMP! and non-AMP! instructors, confounding factors such as administrative support, school culture, teacher attitudes, and the quality of PD outside of AMP! are unknown. However, participating in AMP! prepares teachers to understand the interdisciplinary nature of their content, that is, that mathematics and science in the real-world work in concert together, and this relationship needs to be reflected in teachers' classroom practice. Thus, teachers are equipped with the pedagogical skills to reshape the norms of participation in the classroom. For mathematics teachers, this indicates using science as the context in which students can practice "doing" mathematics, thus expanding the forms of mathematical participation to include rigorous inquiry practices. For science teachers, this indicates applying mathematical concepts to the practice of "doing" science and making visible the connections between mathematics and science in engaging and rigorous ways. Students can develop positive dispositions in STEM when they can purposefully engage in science and mathematics in thought-provoking ways. As such, we must support in-service mathematics and science teachers to design learning environments that move beyond speed and memory so that teachers can create learning environments more reflective of communities' use mathematics in their everyday contexts (Ambrose, 2018). AMP! does just that. As a result, we see evidence of an increase in the likelihood of students selecting a STEM major when their teacher has participated in AMP! compared to students whose teachers do not participate in the AMP!

The Impact on Female and Black Female Students. Our analysis found a significantly greater difference in the likelihood of selecting a STEM major when their teachers participated in AMP! amongst Black women and women in general. This finding was of interest to us for several reasons. First, as noted at the start of the paper, Black women continue to be excluded from many STEM fields. Research has shown that it is not because of a lack of interest or abilities but rather many social conditions that continue to marginalize Black females from participating in these fields (Alexander and Hermann, 2016; Carlone, 2004; Fordman, 1993; Joseph et al., 2017; Malcom, 1976; McGee, 2016; Ong et al., 2011). We were excited to discover that when teachers participated in our program, their Black female students were likelier to major in STEM. However, we are not entirely clear what precisely about the program is leading to such an increase in likelihood among Black female students. We turned to the body of literature on the influences of STEM major selection to understand why inquiry-based PD for teachers might impact the likelihood of Black female students and female students choosing a STEM major more than other racial and gender groups.

A factor critical to broadening STEM participation is having mentors and instructors that align with students' social and cultural groups (Espinosa, 2011; Johnson, 2011; Rainey et al., 2018). Having mentors and instructors from one's social and cultural background can lead to a stronger disposition and affinity towards STEM fields because there is a shared understanding of expected behaviors and practices within and across social, cultural, and historical groups (Bergey and Kaplan, 2010). Cultural norms and practices within STEM disciplinary fields are "dynamically unfolding, culturally variable, historically rooted, and socially and materially constituted" (Bell et al., 2017). When there is a shared understanding between the mentors/instructors and youth, STEM behaviors and practices can be validated. Youth can feel free to participate in STEM in ways that are recognized as legitimate, stimulating a sense of belonging in STEM fields (Strayhorn, 2015).

We examined the demographics of the teacher participants in AMP! compared to the demographic composition of mathematics and science teachers across the state of Texas (Table 5). We found that within AMP!, 80% (n = 393) of the teacher participants were female compared to, on average, 64% of math and science teachers self-reporting as female in the state of Texas (Smith, 2021). Table 5 shows that in AMP!, 38.5% of the teachers self-identified as Black, compared to only 10.2% of math and science teachers in Texas. Could the fact that Black and female teachers have higher rates of participation in the AMP! compared to Texas math and science teacher demographics help explain the increase in the likelihood of choosing a STEM major we see amongst Black girls when their teachers participate in this program?

Table 5. *Racial Demographics of Math and Science Teachers in AMP! vs. Texas, from 2014-2020*

Race/Ethnicity	AMP! (N = 491)	Texas* (N= 10,397)
Black	38.5% (n=189)	10.2% (n = 1,062)
Hispanic	13.2% (n=65)	24.7% (n = 2,571)
Asian	7.1% (n=35)	7.1% (n = 735)
White	34% (n=167)	55.2% (n = 5742)
American Indian/ Alaska Native	0.2% (n=1)	0.4% (n = 38)
Pacific Islander	0.2% (n=1)	0.1% (n = 9)
Two or More Races/ Ethnicities	3.9% (n=19)	2.3% (n = 238)
Other/Not Specified	4.9% (n=24)	0.02% (n = 2)

**Data from (Smith, 2021)*

Based on the literature, the effects of AMP! might be compounded by the teachers participating in the PD program's racial/ethnic and gender compositions. Further research will be needed to investigate the roles that race and gender of the participating AMP! teachers play in impacting student selection of STEM Majors.

CONCLUSION

In this paper, we presented the findings of a longitudinal study that illustrated that the students of teachers who participated in the AMP!, a year-long PD that prepares teachers to engage in inquiry-based practices in the classroom, were more likely to pursue STEM majors compared to students who did not have an AMP! prepared teacher during their K-12 education. In addition, we found that having an AMP! prepared teacher increased female students' likelihood of selecting STEM majors in college. Finally, we saw the most significant increase in the likelihood of selecting a STEM major amongst Black female students.

We used a sociocultural framework to help us frame our findings and hypothesize why we see significant increases in the likelihood of pursuing STEM careers when female and Black female students had a teacher who participated in the AMP!. Specifically, we argued that participating in AMP! prepared mathematics teachers to provide context to the mathematical concepts grounded in science. Similarly, science teachers were prepared to extend mathematical learning into their own classrooms. This interdisciplinary approach to teaching mathematics and science allowed teachers to contextualize mathematics, prepared science and mathematics teachers to collaborate and coordinate the delivery of their content using inquiry-based strategies, and allowed students to have a real-world experience of both mathematics and science such that students were able to visualize themselves in STEM careers. However, questions remain. For example, we saw that Black females experienced a greater likelihood of selecting a STEM major than students from other demographics. Based on the literature, we hypothesize that we see this increase due to the demographics of teacher participants in the AMP! being predominantly Black and female compared to teacher demographics across Texas. We will need to investigate and confirm this hypothesis. We also have additional questions, such as "Why does AMP! draw more Black women teachers?" There is a great need to make more visible the science talents and proficiency of Black women and girls (King and Pringle, 2019). Does the program somehow provide Black female teachers with a context in which their STEM educational talents are recognized, elevated, and validated by the staff that delivers AMP!? A deep dive grounded in observational and participant-observation methods will be needed to understand the culture of AMP!.

There is a demonstrated need to increase the participation of Black girls in STEM fields, specifically in engineering, computer science, and the physical sciences (King and Pringle, 2019, page 540). Black women often experience racial and gendered biases throughout their educational journey that push them out of careers in these fields, including Black science and mathematics teachers (Crawford, 2020; McGee and Bentley, 2017). Issues of educational equity are deeply connected to the institutions and systems we interact with in our everyday lives, specifically in the cultural practices that these communities engage in that support or restrict Black women from participating in STEM education (Bell et al., 2017). To overcome these inequities, we need to understand how to support Black females at every stage in their careers, including those that teach the future generation of STEM leaders. Understanding how high-quality PD can increase the likelihood of Black girls pursuing STEM majors can help us determine how to adapt the program to meet the needs of K-12 students by preparing in-classroom teachers to successfully engage students of diverse backgrounds via a rigorous science and math curriculum while simultaneously creating an inclusive classroom environment.

AUTHOR INFORMATION

Corresponding Author

Carolyn Nichol, Ph.D. Rice University. 6100 Main Street, Houston, TX 77005. cnichol@rice.edu

Author Contributions

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ABBREVIATIONS

AMP!: Applied Mathematics Program!; AP: Advanced Placement ©; EdRC: Educational Research Center; NCES: National Center for Education Statistics; NWEA: Northwest Evaluation Association; PD: Professional Development; PSAT: Preliminary Scholastic Aptitude Test; STEM: Science, Technology, Engineering, and Mathematics; TEA: Texas Education Agency; THECB: Texas Higher Education Coordinating Board; TWC: Texas Workforce Commission

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