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The impact of college- and university-run high school summer programs on students' end of high school STEM career aspirations

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Abstract

Insufficient student interest in science, technology, engineering, and mathematics (STEM) careers has been identified as a pressing issue by educators and education policy makers. This retrospective cohort study examined one promising approach to reach and inspire students early on: college- and university- run high school STEM summer programs. Data were collected from 27 colleges and universities participating in the National Science Foundation's STEM Talent Expansion Program. We examined the impact of high school STEM summer program participation on end of high school career aspirations among a sample of 845 program participants and 15,002 controls. The study employed logistic regression modeling with propensity weighting to address differences in group characteristics to model the impact of programs. Results showed that students who participated in a program had 1.4 times the odds of wanting to pursue a STEM career, controlling for background characteristics. A closer look at program design revealed that students experiencing the real-world relevance of STEM had 1.8 times the odds of aspiring to STEM careers at the end of high school compared with controls. Findings suggest that scaling up STEM summer programs and carefully designing programs to show the real-life relevance of STEM may be an effective strategy to curtail pipeline attrition and to inspire more students to pursue STEM careers.

KEYWORDS
higher education, summer programs, STEM career aspirations

1 | INTRODUCTION

National projections suggest that the United States will soon face shortages in the supply of qualified STEM labor (Joint Economic Committee, 2012; Kuenzi, 2008; National Science Board, 2010; Sargent, 2014). Neither student STEM career interest nor preparation are on par with what the nation will need to supply an innovative and internationally competitive STEM workforce (ACT, 2006 , 2015; Bottia, Stearns, Mickelson, Moller, & Parker, 2015; Committee on

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Science, Space, and Technology, 2011; DeSilver, 2015; Kuenzi, 2008). These alarming trends have led to calls for greater investment in the country's portfolio of STEM education programs (Constan & Spicer, 2015; National Academy of Science, 2007; Tsui 2007; White House, 2014). High school outreach programs are one type of educational intervention intended to provide additional preparation and inspiration to boost students' interest in pursuing STEM careers (American Association of State Colleges and Universities [AASCU], 2005; Constan & Spicer, 2015; Miller et al., 2007). This article examines the impact of a particular brand of high school outreach programs—university- and college-run high school STEM summer programs—on end of high school STEM career aspirations.

2 | BACKGROUND

Interest in STEM blossoms early on among students (Maltese, Melki, & Wibke, 2014). While some suggest that students who pursue STEM careers often decide to do so before high school (e.g., Tai, Liu, Maltese, & Fan, 2006), others point out that career plans are not "etched in stone" during high school (Sadler, Sonnert, Hazari, & Tai, 2012). Indeed, schools have the ability to shape their pupils' decisions, and adolescence is an opportune time to intervene in a student's trajectory (Bottia, Stearns, Mickelson, Moller, & Parker, 2015; Constan & Spicer, 2015; Walsh, 2011; Wang, 2013). Some even contend that it is during the high school years when students are seriously considering career choices, becoming more aware of STEM careers, and making important decisions about their interest in STEM fields (Constan & Spicer, 2015; Hall, Dickerson, Batts, Kauffman, & Bosse, 2011; Miller et al., 2007; Sadler, Sonnert, Hazari, & Tai, 2012).

While K–12 institutions play an integral role in addressing the nation's STEM education challenges, scholars and policymakers have explicitly recognized that it is necessary for universities and colleges to partner with their K–12 counterparts to strengthen and diversify STEM pathways and to improve STEM education overall (Constan & Spicer, 2015; Eeds et al., 2014; Engberg & Wolniak, 2013; Kennedy & Odell, 2014; President's Council of Advisors on Science and Technology [PCAST], 2012; White House, 2013). For example, encouraging partnerships among stakeholders (e.g., colleges, high schools) to broaden participation in STEM is a major policy point highlighted in The PCAST (2012) report. One of the seven major recommendations made by PCAST to improve STEM education is to create opportunities to inspire student STEM interest through STEM-based activities, including STEM summer programs (PCAST, 2010, 2012). Scholars and researchers have similarly identified precollege programs as institutional vehicles to boost STEM interest (Burgin, McConnell, & Flowers, 2015; Constan & Spicer, 2015).

2.1 | Brief history of STEM summer programs

University-run STEM programs for high schoolers have existed since at least the 1950s (Cooley & Bassett, 1961; Day, 1959; Ferguson, 1963; Niemann, Miller, & Davis, 2004). The National Science Foundation (NSF) funded a number of summer science programs in this era, aimed to provide students with science and mathematics training beyond what was available in high school classes—and ultimately to promote interest in STEM (Cooley & Bassett, 1961; Smalheer, 1964). Many of these programs were established in a national response to the launch of Sputnik and Soviet advancement in space exploration (Katzenmeyer & Lawrenz, 2006; Roberts & Wassersug, 2009). Decades later, science education support came to be seen as a tool to generate economic development, and investments were made accordingly (Katzenmeyer & Lawrenz, 2006).

There are a few early accounts of STEM education interventions during high school. Ferguson (1963) described the Peabody Public School Summer High School Program in Tennessee, designed to provide science and mathematics enrichment for students. It was implemented through a collaboration between college and school facilities, high school teachers, and college professionals. The program started in the summer of 1959 and included class sessions to introduce students to new perspectives in mathematics and to provide laboratory experience in chemistry and physics. A study of the program concluded that participation resulted in gains in student achievement in physics, mathematics, and chemistry, as measured by several standardized tests. However, no gains were observed in students' ability to apply the scientific knowledge they learned (Ferguson, 1963).

Wood (1962) described a NSF-funded summer science program for high ability high school juniors at Thayer Academy in Braintree, Massachusetts. The program was run in partnership with Tufts University. The purpose of this particular program was to expose promising high school students to the work of scientists and engineers, to build skills and knowledge related to laboratory work and technical report preparation, to give students the opportunity to interact with scientists, and ultimately to provide students opportunities to consider their own career plans. In a similar vein, Smalheer (1964) offered a personal account of their summer science program experience, providing insights into program characteristics in this time period. They noted a range of program activities from hands-on research experiences to uniquely tailored coursework and lectures. These activities were intended to encourage high schoolers to pursue their science interests in the future. Smalheer noted that programs generally lasted between 2–8 weeks and existed nationwide. They also stated that the program experience provided benefits that would not have otherwise been available through high school alone, shaping their personal study habits, giving them personal contact with professors, and familiarizing them with scientific methods.

Astin (1971) studied another NSF STEM outreach program called the Student Science Training Program (SSTP). This program aimed to foster interest in science fields by exposing talented high school students to research and teaching at the postsecondary level. The SSTP was typically offered in the summer following junior year and featured a combination of science subject instruction and hands-on research experiences. This study found some promising results, suggesting that program participation boosted interest in pursuing a career in science for White students and to a lesser degree among Black males.

Despite these initial forays into STEM summer programs, scholars, policymakers, and the NSF have lamented the failures of programs over the years to bring more students, particularly a more diverse student population, into STEM fields—some even going so far as to say that past efforts were a waste of resources, despite good intentions (Johnson, 2012; Sims, 1992). Moreover, there has been a dearth of solid evaluation instruments and appropriate statistical studies to determine the impact of these STEM education interventions (Constan & Spicer, 2015; Katzenmeyer & Lawrenz, 2006). This is the case even though there have been calls for greater accountability through setting realistic program goals and conducting meaningful evaluation and research around program impacts (Katzenmeyer & Lawrenz, 2006; Sims, 1992). As Astin (1971) recognized early on, studying the impact of these programs is critical to understanding whether they accomplished their aims and whether they should be continued, expanded, or terminated.

2.2 | Review of high school STEM summer program research

Our review of the literature uncovered a growing number of studies examining the effects of participating in high school STEM summer programs in the past decade. Program descriptions gleaned from the literature suggest that no two high school STEM summer programs are identical. However, some common aims of these summer programs are to boost academic skills, raise confidence, provide hands-on learning experiences and exposure to STEM work, foster favorable STEM attitudes, and to promote STEM interest. These aims are accomplished through a range of activities including lectures, meeting STEM professionals, and working on STEM projects. Several studies indicate program participation may positively impact students, whereas others suggest that programs have their limitations. Study findings can be summarized in the following four areas: (a) knowledge, skills, and preparation; (b) STEM attitudes; (c) college enrollment; and (d) STEM career interest.

2.2.1 | Knowledge, skills, and preparation

Studies that examine the impact of high school STEM summer programs on students' knowledge, skills, and preparation were the most common among those reviewed. STEM summer program participation were found to promote gains in students' scientific knowledge and vocabulary (Niemann et al., 2004), perceived knowledge and comfort with science (Martinez, Lindline, Petronis, & Pilotti, 2012), and perceived gains in science skills, research skills, and confidence (Salto, Riggs, De Leon, Casiano, & De Leon, 2014). Students have reported improved mathematics study skills and heightened awareness of education planning and personal learning styles as a result of program participation (Enriquez, 2010). Other studies have shown improved mathematics or physics knowledge and skills following participation (Dimitriu &

O'Connor, 2006; Enriquez, 2010; Timme et al., 2013). Programs may also produce gains in individual student test scores as well as reduce test score variability among participants (Goonatilake & Bachnak, 2012). Students who participated in a summer STEM program also tended to feel better prepared for STEM coursework or college-level courses (Exstrom & Mosher, 2000; Markowitz, 2004; Rohrbaugh & Corces, 2011).

Research has shown that high school STEM summer program participants overwhelmingly enjoy hands-on activities during their program and find them to be educational (Kuyath & Sharer, 2006). Summer programs provide opportunities for students to use laboratory equipment that may not be available in their high schools (Markowitz, 2004). Opportunities to learn through hands-on activities, field trips, and lectures extend students' knowledge beyond what they were learning in high school (Mehrizi-Sani, 2012). In turn, hands-on activities may have a positive impact on students' confidence in their abilities to do scientific work (Knox, Moynihan, & Markowitz, 2003; Markowitz, 2004). Program participation—especially program activities like field trips and meeting with STEM professionals—can provide students important knowledge about the practical and real-life work of STEM professionals (Gonnatilake & Bachnack, 2012; Niemann et al., 2004).

2.2.2 | STEM attitudes

Evidence indicates that students who participate in a high school STEM summer program are likely to experience positive gains in their views of science as well as their interests in science and science coursework during high school (Markowitz, 2004). Participation was also found to help students find science more exciting and approachable (Martinez et al., 2012) and encourage them to pursue science during college (Tamburini, Kelly, Weerapana, & Byers, 2014). Programs have been shown to increase interest in learning about engineering and related work, and ultimately to elevate student attitudes toward engineering (Chen, Tomsovic, Aydeniz, 2014). Other studies have shown that summer programs improved students' attitudes toward the geosciences and impressed upon them the lucrative nature of related careers (Houser, Garcia, & Torres, 2015; Miller et al., 2007). Participants in at least one such program were likely to agree that the geosciences were interesting, useful, and respectable, following participation (Miller et al., 2007). However, not all prior evidence indicated positive program impacts on student STEM attitudes. Bachman, Bischoff, Gallagher, Labroo, & Schaumloffel (2008) study of the NSF-funded PR^{2}EPS program found summer camp program participation had limited effect on students' motivation, and they detected only marginal changes in students' science interest and attitudes toward science. The authors argued these results could potentially be due to students' already high levels of STEM interest and positive attitudes prior to program participation.

2.2.3 | College enrollment

High school STEM summer programs may be linked to college enrollment (Kabacoff, Srivastava, & Robinson, 2013). Moreover, evidence suggests that program participants are likely to enroll in STEM and related majors during college (Hurtado, Conkey, Blasingame, 2009; Kabacoff, Srivastava, & Robinson, 2013). For instance, 90% of students who participated in the Pre-College for Engineering Systems program at Howard University ultimately majored in electrical engineering or another related STEM field (Momoh, 2014). For the first 3 years of the QUEST program at Mississippi State University (MSU), 81% of students went on to enroll at MSU and 73% enrolled at the college of engineering (Green & Taylor, 2005). Nevertheless, desired program impacts are not always observed across all studies, and sometimes findings are mixed (Enriquez, 2010; Miller et al., 2007).

2.2.4 | STEM career interests

Lastly, some emerging research on the effect of high school STEM summer programs on students' STEM career interests found program participation was linked to increased science career motivation (Salto et al., 2014) and to increased interest in pursuing a science career (Knox et al., 2003). For example, one study found that program participation encouraged students to consider incorporating STEM into their future college and career plans (Harriger, 2008). An evaluation of 154 participants in the Engineering Insights Summer program at Texas A&M University found that 99% of participants reported improved engineering career knowledge and a better understanding of the subdisciplines of engineering (Hurtado et al., 2009). Eighty-six percent indicated they were more likely to study engineering following the program—which bodes well for pursuing a STEM career path. Enriquez (2010) found that students who participated in an engineering-related summer program generally reported a better understanding of engineering careers. Elam, Doham, and Solomon (2012) studied an engineering summer program called X-TEEMs. Sixty-two middle and high school students participated in the program, which included hands-on experience, exposure to engineering disciplines and STEM professionals, and career awareness activities. Descriptive results showed gains in science career interest.

Data collected through an evaluation of the Geosciences Exploration Summer Program ($N = 59$) showed an increase in participants' awareness of the kinds of careers available in the geosciences (Houser et al., 2015). Rohrbaugh and Corces (2011) studied the Emory University RISE program, which, at the time of the study, had enrolled 39 students. The majority of participants indicated they would be more likely to pursue a career in science (Rohrbaugh & Corces, 2011). Qualitative results from the Martinez et al. (2012) study showed that about 69% of participants felt that program participation positively influenced their attitudes toward pursuing a STEM career. Students in the Center for Ultra-wide-area Resilient Electrical Energy Transmission Networks' (CURENT) and College of Engineering summer program at the University of Tennessee, Knoxville also reported being slightly more likely to major in a STEM field in college and pursue a STEM career after participating (Chen, Tomsovic, & Aydeniz, 2014). Kuyath and Sharer (2006) studied a high school summer camp ($N = 45$) that took place at UNC-Charlotte. Results of a survey administered at the end of the program showed that about 42% of female participants planned to pursue a career in engineering or science, 40% of Black students said they planned to pursue a career in engineering, 25% of Black students planned to pursue a science career, and approximately 33% of Hispanic participants said they planned to pursue a career in engineering. No Hispanics said they planned to go into science careers.

Bhattacharyya, Nathaniel, and Mead, (2011) examined the impact of a science summer program, LAGEAR UP, on high school students' attitudes toward science and related career choices. The authors surveyed three program cohorts yielding a total of 313 participating students. Descriptive results from a pre- and post-program survey suggested a number of positive impacts, such as an increased percentage of students who planned to go on to major in science during college. However, virtually no change was observed in science career aspirations following participation. A recent study by Constan and Spicer (2015) examined the Physics of Atomic Nuclei Program that aimed to provide students information about nuclear science careers. The authors examined survey data for 30 program participants and a matched comparison sample drawn from the Education Longitudinal Study of 2002 (ELS, 2002) data set. Program participants were nine times as likely to pursue a STEM major relative to the control group. The desire to have a STEM career was also eight times as high for program participants.

2.3 | Purpose

The federal government, STEM industry, and higher education institutions have made substantial investments in programs geared toward expanding STEM education during the high school years. The 2015 federal budget alone allocated $2.9 billion to its STEM education program portfolio (White House, 2014). One increasingly popular type of STEM education intervention is the college- or university-run high school STEM summer program. According to our data, such programs enroll approximately 5.3% of college-bound high school students nationally.

To date, many high school STEM summer program studies examined the role of a single program, studied programs at a single institution, included a small number of participants, relied strictly on descriptive statistics, did not control for confounding effects, or did not employ a demographically similar comparison group—if any comparison group at all. Across studies, results related to program impacts are not universally positive, and in some cases findings are mixed. To gain solid evidence about program effectiveness, it would be necessary to pool data across institutions and employ more robust statistical study designs. Moreover, despite the ultimate goal of inspiring more students to go into STEM careers, only a fraction of existing studies address the influence of high school summer program participation on STEM *career aspirations*. More conclusive evidence is needed to advance our understanding of high school STEM summer programs and to ascertain whether these interventions should be adopted or scaled up nationwide to address projected STEM labor shortages. This study answers the following research questions:

(a) Do students who participate in college and university-run STEM summer programs during high school have greater odds of aspiring to a career in STEM at the end of high school, relative to nonparticipants? Does showing the real-life relevance of STEM during the program affect the odds?

(b) Do student background characteristics and experiences moderate the relationship between STEM high school summer program participation and end of high school STEM career aspirations?

3 | CONCEPTUAL FRAMEWORK

Vocational Anticipatory Socialization (VAS) Model of STEM served as the guiding theoretical framework for this study (Myers, Jahn, Gaillard, & Stoltzfus, 2011). VAS explains career socialization and the development of career interests in STEM fields (Jahn & Myers, 2014, 2015; Myers et al., 2011). Notably, the theory has been advanced, refined, and substantiated through empirical STEM-related studies of high school students (e.g., Myers et al., 2011) that addressed factors that can promote or hinder students entering into STEM career fields. Thus, this empirically supported theoretical model is particularly well suited for the present study. VAS is a socialization theory that explains the way one learns about particular disciplinary fields and how one develops an interest in a particular educational and career path (Myers et al., 2011). VAS posits a number of important factors that shape student interest in STEM including gender, socioeconomic status, messages students receive (e.g., career opportunities or descriptions), experiences students have, and personal factors (e.g., exposure to STEM careers), to name a few (Myers et al., 2011). The theory centers the role of information and messages that students receive about career options and their influence on students' interests; it also draws attention to the sources of that information, or socializing agents (i.e., parents, teachers, STEM professionals), and their impact on student academic and career interests (Jahn & Myers, 2014; Myers et al., 2011). Exposure to socializing agents and experiences helps students to understand the nature of STEM careers and shapes their desire to pursue them (Jahn & Myers, 2014).

VAS suggests that STEM classes, socializing messages, and direct experiences with STEM shape what students know about STEM careers and their interests in those fields (Jahn & Myers, 2015). While students learn STEM concepts in school, they often must rely on other sources to learn about how STEM is relevant in real-life and to future career opportunities (Jahn & Myers, 2015). The messages and first-hand STEM experiences students are provided may in turn help persuade them to consider STEM careers (Jahn & Myers, 2015). Seeing how STEM concepts can be applied in real life may increase their interest in these subjects (Jahn & Myers, 2015)—a prerequisite for students to express interest in pursuing STEM careers. The lack of access to experiences that demonstrate the nature of STEM careers and limited opportunities to interact with STEM professionals may affect students' interest in STEM careers. Thus more intentional strategies are necessary to promote students' knowledge around STEM careers (Jahn & Myers, 2014, 2015). We contend that the messages, exposure, and experiences afforded to students through college- and university-run high school STEM summer programs could affect student STEM career aspirations.

4 | METHODS

Data for this investigation came the NSF-funded "Outreach Programs and Science Career Intentions" (OPSCI) study. Data were collected through a large, nationwide survey administered in the fall term of 2013 to first-year students at a sample of U.S. colleges and universities participating in the NSF's STEM Talent Expansion Program (STEP). The purpose of STEP was to support initiatives intended to increase the number of students earning associate and baccalaureate degrees in STEM.

Surveys were typically administered in required first year English courses. First year English courses were selected to obtain a representative sample of STEM and non-STEM participants at each institution. In usual circumstances, personalized emails were sent to the English Department Chairs, naming the STEP principal investigator at their respective institutions. Sometimes it was necessary to recruit participants from comparable required first-year courses when an English Department was unable to participate. One-hundred and fifty institutions were asked to participate. Of the 150 institutions, 46 responded and 104 did not respond to repeated inquiries. Twenty-seven (57%) of the 46 institutions that responded participated in the study with at least one professor. The recruitment process yielded 23 four-year and 4 two-year institutions. Initially, 535 instructors agreed to participate in the survey. Of those who agreed, 414 (77%) followed through and participated. Ultimately, 15,847 students completed and returned surveys. Hardcopies of the survey were administered during class which generated close to 100% participation rates among students. Missing survey data were dealt with using multiple imputation (Rubin, 1987; Schafer, 1999).

The OPSCI survey includes 37 items measuring a number of student background, behavioral, and attitudinal characteristics. Survey items were spread across five sections including: (a) career plan development, (b) middle school science and mathematics experiences, (c) high school background, (d) STEM-related interests, and (e) student and family characteristics. Survey items that were developed and used in a prior study titled, “Persistence Research in Science and Engineering” (PRiSE), were also used in the OPSCI survey. New questions were developed and added specifically intended for the OPSCI survey. The survey was piloted with 67 students at a southern university. The survey was administered twice to 57 students at the same university over the course of approximately 2 weeks to establish test–retest reliability. The Pearson correlation coefficient between test and retest responses was the measure of reliability for continuous variables and Cohen's kappa was used for categorical variables. Overall means for correlation coefficients were .73 and .59 for Cohen's kappas. There was less than a 0.04% chance of reversal between the 50th and 75th percentiles for groups of 100 (Thorndike, 1997). Validity of the survey instrument was supported through discussions with an expert group of science educators and science education researchers.

Studies relying on survey instruments must carefully attend to the reliability and accuracy of participant recall. The reliability and accuracy of self-reported survey responses are chiefly dependent on their relevance, the context, and how clear the survey is (Bradburn, 2000; Niemi & Smith, 2003; Pace, Barahona, & Kaplan, 1985). Prior scholarship suggests that self-report surveys are widely used and tend to be reasonably reliable (Oetting & Beauvais, 1990), and produce accurate student responses (Sanchez & Buddin, 2015). For example, college student self-reported grades, standardized test scores, and courses taken are usually highly accurate when compared with transcripts (Anaya, 1999; Baird, 1976). Responses on self-report surveys are also especially accurate when the topics addressed in the survey are relevant to the respondents (Kuncel, Crede, & Thomas, 2005), as one would expect to be the case for students who have recently graduated high school, started college, and who are reflecting on what career path is for them. The recall of information tends to be reliable when set in an organized manner, especially if the survey instrument includes appropriate contextual clues (Bradburn, 2000), which we attended to in our survey. Prior work conducted with our surveys of similar design demonstrated reliable responses and reproducibility over time (Sadler, Sonnert, Hazari, & Tai, 2012).

4.1 | Variables

Variables from the OPSCI survey included in the analysis are presented in Table 1 with the respective coding for each variable.

4.1.1 | Dependent variable

The dependent variable for this investigation was end of high school STEM career aspirations. Students were asked to report their career interests at the end of high school. A range of options were available that included both STEM (e.g., engineer, chemist) and non-STEM (e.g., teacher, artist) careers. The variable was dummy-coded (0: no STEM career aspirations; 1: STEM career aspirations).

4.1.2 | Primary independent variables

The primary independent variables were participation in a high school STEM summer program and whether the program demonstrated the real-life relevance of STEM. The OPSCI survey asked students to report whether or not they attended a college- or university-run STEM summer program during high school (0: did not participate; 1: participated).

TABLE 1 Independent and dependent variable coding

Variable	Description
Independent variables	
Gender	0 = Female; 1 = Male
Race/ethnicity	Categorical variable: 1 = White; 2 = Asian; 3 = Black; 4 = Hispanic; 5 = Other
Parent education	0 = Neither parent earned a 4-year degree or higher; 1 = At least one parent earned a 4-year degree or higher
STEM tutoring	0 = No STEM tutoring; 1 = Received STEM tutoring
SAT math score	Continuous variable measuring SAT math scores. ACT scores were converted to SAT scores. Range: 200–800
Number of math courses	Count variable measuring number of math courses taken. Maximum number possible = 11
Beginning high school career aspirations	0 = No STEM aspirations; 1 = STEM aspirations
H.S. Summer Program participation and real-life relevance	0 = Did not participate; 1 = Participated in a program that did not show real-life relevance of STEM; 2 = Participated in a program that showed real-life relevance of STEM
Dependent variable	
End of High School STEM career aspirations	0 = No STEM aspirations; 1 = STEM aspirations

Program participants were also asked to report whether their program showed them the real-life relevance of STEM (0: did not show real-life relevance; 1: showed real-life relevance). Real-life relevance was included in our analysis to shed light on the potentially different impacts of summer programs depending on curricular designs. A single new variable was computed from these two variables. In the new variable, "0" indicated no program participation, "1" indicated participation in a program that did not show students the real-life relevance of STEM, and a "2" indicated participation in a program that reportedly showed students the real-life relevance of STEM. No program participation, or "0," served as the baseline of this categorical variable.

4.1.3 | Control variables

A series of control variables was used to account for factors that could potentially confound the analysis, especially since students with an initial interest in pursuing a STEM career are more likely to attend a STEM summer program. Variable coding is shown in Table 1. Controls included student demographic traits such as gender, race/ethnicity, and parents' education as a proxy of socioeconomic status. Race/ethnicity was a categorical variable and "white" served as the baseline for comparison. If a student selected "Hispanic," they were considered Hispanic, regardless of race. Students who selected other or multiple racial categories were coded as "other." Students' SAT mathematics score was also included to account for their scholastic aptitude in STEM. If the SAT score was not available, a student's ACT score was converted to an SAT score through a concordance scale (College Board, 1999). The total number of mathematics classes a student took during high school and STEM tutoring were also controlled for to account for STEM preparation. The STEM tutoring variable asked students to indicate whether or not their "family arranged for tutoring in math and science." This measure was intended to gauge whether students had additional STEM preparation beyond what was available in their school math and science courses. Importantly, we controlled for beginning of high school STEM career aspirations to take into account earlier STEM career interests, a factor rarely controlled for in prior studies on this subject.

4.2 | Propensity weighting

Preliminary descriptive analyses showed imbalances across a number of characteristics between students who participated in a high school STEM summer program and those who did not. The significant differences between our sample of

TABLE 2 Comparison of weighted and unweighted predictors with significance testing

Variable	Unweighted (%)			Weighted (%)		
	H.S. program ($n = 845$)	No program ($n = 15,002$)	Significance	H.S. program ($n = 848$)	No program ($n = 14,999$)	Significance
Gender (male = 1)	49.1	43.7	*	44.4	44.0	–
Race/ethnicity						
Asian	14.1	9.5	**	9.7	9.7	–
Black	16.2	9.8	***	9.8	10.1	–
Hispanic	21.3	20.3	-	20.7	20.3	–
White	40.6	53.8	***	52.8	53.1	–
Other	7.8	6.7	-	7.1	6.7	–
Parent education	56.9	56.4	-	55.5	56.4	–
STEM tutoring	12.7	8.5	**	8.5	8.7	–
Standardized math score (*M*)	551	526	***	525	527	–
Number of math courses (*M*)	4.4	4.1	***	4.1	4.1	–
BHS STEM career aspirations	38.3	27.3	***	27.7	27.9	–

Notes. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$, – = nonsignificant. Race/ethnicity may not add to 100% due to rounding. Program participation totals slightly differ due to propensity weighting.

participants and controls could potentially confound the analysis, raising the possibility that observed effects are due to factors other than the program participation. This uncertainty can be dealt with by weighting the participant and comparison groups such that they are similar along demographic lines and across other characteristics (Austin, 2011; Linden & Adams, 2012; Rosenbaum & Rubin, 1983; Thoemmes & Ong, 2016).

Propensity scores were computed in a logistic regression where the intervention, high school summer program participation, was the outcome variable. All student background and demographic factors were included as predictors in the model. Summer program outcomes (e.g., program relevance) were excluded from the propensity score calculation because they measure postprogram effects. The result is a predicted probability or *propensity score* for each student that represents the probability of belonging to the treatment group (summer program participation), given the set of covariates (Austin, 2011). Next, the propensity weight is converted into a stabilized inverse probability of treatment weight (IPTW) for summer program participants and for those who did not participate in a summer program (Linden & Adams, 2012; Thoemmes & Ong, 2016). When the IPTW is applied to the sample, it has the effect of balancing covariates between high school STEM summer program participants and nonparticipants. Table 2 demonstrates the effectiveness of propensity weighting in balancing covariates between the two groups, simulating a random assignment study (Linden & Adams, 2012; Thoemmes & Ong, 2016). Thus, when a regression model is estimated with the propensity weighted data set, collinearities of the group variable with the other predictors are minimized. This, in turn, allows for a more precise estimate of the net group effect than would be possible in an unweighted regression model.

4.3 | Analysis

First, descriptive statistics were calculated, and summer program outcomes were summarized. Second, a logistic regression was computed to model main effects and produce odds ratios (OR) for the unweighted and weighted samples. Third, product terms were computed and entered into the weighted logistic regression model to identify any interaction effects between summer program participation and student background factors.

TABLE 3 Percentage of program participant agreement with statement

H.S. summer program outcomes	Yes (%)	No (%)
Increased STEM knowledge, skills, information	65.2	34.8
Showed real-life relevance of STEM	49.2	50.8
Would recommend participation to a friend	93.0	7.0

5 | RESULTS

Descriptive statistics for student background characteristics are presented in Table 2. There were 845 students who reported participating in a university- or college-run high school STEM summer program. The gender breakdown for summer program participants was 49.1% men and 50.9% women; for the control group, the breakdown was 43.7% men and 56.3% women. White students represented 40.6% of high school summer program participants, whereas they represented 53.8% of the control group. Thus, students of color were more heavily represented among high school summer program participants, relative to their counterparts in the control group. There was no statistically significant difference in parents with four-year college degrees between participants (56.9%) and nonparticipants (56.4%). Students who participated in a high school STEM summer program were significantly more likely to have STEM tutoring, compared with nonparticipants (12.7% vs. 8.5%). There were statistically significant differences in SAT mathematics scores and number of mathematics courses between summer program participants and the control group. On average, students who participated in a high school STEM program reported higher SAT mathematics scores than did the control group ($M = 551$, $SD = 166$ vs. $M = 526$, $SD = 138$) and took more mathematics courses ($M = 4.4$, $SD = 1.9$ vs. $M = 4.1$, $SD = 1.4$). That said, standard deviations suggest there was also greater variability in math scores and number of courses taken among program participants compared to the control group.

Descriptive statistics also provided insight into STEM career aspirations at the beginning and end of high school. As expected, students who participated in a high school STEM summer program were more likely to have beginning of high school STEM career aspirations, compared with their nonparticipating peers (38.3% vs. 27.3%). At the end of high school, summer program participants were similarly more likely to indicate STEM career aspirations compared with their nonparticipating peers (39.9% vs. 27.2%). This final data point is interesting and would seem to suggest a slight positive program impact. However, descriptive statistics alone provide limited insight into program effects on end of high school STEM career aspirations, particularly because they do not control for student characteristics and, most importantly, do not account for the high pre-program STEM career aspirations among participants (i.e., beginning of high school STEM career aspirations). Robust statistical modeling conducted in phase two of our analysis provides better evidence about program effects on career aspirations.

Descriptive statistics were also calculated for a number of program outcomes summarizing whether students thought their program increased their skills, knowledge, and information about STEM, showed them the real-life relevance of STEM fields, and whether they would recommend high school summer program participation to a friend. Results are presented in Table 3. The majority of high school STEM summer program participants reported that their program increased their STEM knowledge and skills (65.2%). The overwhelming majority of participants said they would recommend participating in their program to a friend (93.0%), suggesting a highly positive experience. Approximately half of participants thought their program showed them the real-world relevance of STEM and half did not. The impact of this particular program characteristic on end of high school career aspirations is addressed in our statistical models.

5.1 | Logistic regression and odds ratios

Logistic regression models and the resulting odds ratios were estimated for both the unweighted and propensity weighted data sets. Results for the propensity weighted model are shown in Table 4. The results for main effects in the unweighted model were very similar.

TABLE 4 Logistic model: Odds ratios (OR) and significance of main effects

	Weighted main effects	
Variable	OR	Significance
Gender	2.23	***
Asian	0.98	–
Black	1.02	–
Hispanic	1.10	–
Other	0.98	–
Parent education	0.94	–
STEM tutoring	1.02	–
Number of math courses	1.15	***
SAT math score	1.26	***
Beginning HS career aspirations	8.77	***
H.S. Summer Program-not relevant	1.14	–
H.S. Summer Program-relevant	1.81	***

Notes. $N = 15{,}847$. pseudo-$R^2 = 0.24$, $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$, – = nonsignificant. Dependent variable is end of high school STEM career aspirations.

5.1.1 | Background characteristics

The model revealed a number of statistically significant main effects for student background traits and characteristics. As one might expect, students who reported STEM career aspirations at the beginning of high school had much greater odds of reporting STEM aspirations at the end of high school relative to their peers who did not aspire to STEM careers at the start of high school (OR = 8.8). Males had 2.2 times greater odds of reporting end of high school STEM career aspirations relative to their female counterparts. The number of mathematics courses a student completed in high school was also a significant predictor of end of high school STEM career aspirations. A one course increase was associated with 1.2 times greater odds of reporting end of high school STEM career aspirations. Students' SAT mathematics scores were also statistically significant. A 100 point increase in SAT mathematics score was associated with a 26% increase in the odds of reporting end of high school STEM career aspirations. Taken together, the mathematics course and SAT mathematics score findings suggest the importance of high school mathematics preparation for boosting STEM career aspirations. STEM tutoring, parents' education, and race/ethnicity made little difference in students' end of high school aspirations.

5.1.2 | High school STEM summer program

Initial modeling revealed that high school STEM summer program participation boosted end of high school STEM career aspirations. Students who participated in a high school STEM summer program had 1.4 times the odds of indicating end of high school STEM career aspirations relative to those who did not participate in a summer program, and the result was statistically significant ($p < .01$). Examining the relationship between summer program participation and end of high school aspirations in greater detail revealed important distinctions across programs based on design and curriculum. Specifically, students who participated in a high school summer program that showed them the real-life relevance of STEM had odds that were 1.8 times those of students who did not participate in a program ($p < .001$). On the other hand, students who indicated that they participated in a summer program that did not show them the real-life relevance of STEM was statistically no different from students who did not participate in a program at all in terms of their end of high school STEM aspirations (OR = 1.1; $p = .43$). Moreover, students who reported participating in a summer program that showed them the real-life relevance of STEM had 1.6 times the odds of reporting STEM career aspirations at the end of high school compared with students who participated in a program that did not show them the real-world relevance of STEM ($p < .05$).

5.2 | Interactions

We computed an additional propensity weighted model to determine whether the relationship between high school STEM summer program participation and end of high school STEM career aspirations differed across student characteristics and experiences. We found no statistically significant interaction terms at the $p = .05$ level. This suggests the impact of high school STEM summer programs on end of high school STEM career aspirations was not conditional on the student background characteristics, prior STEM interest, or experiences included in our model.

6 | LIMITATIONS

A few limitations to this study should be noted. First, we explored the impact of one particular program design feature (real-life relevance of STEM), but there are other potentially influential program elements (e.g., program duration) that are not addressed in this particular study. Second, this study does not address the timing of high school summer programs. The impact of participating in a summer program after ninth grade may be different from participating in a program in the summer after 11th grade, for instance. A third limitation of our study is that we do not have data on participants' career interests precisely before attending a high school STEM summer program. We do, however, control for students' career aspirations at the beginning of high school, which significantly improves over most prior studies of high school STEM summer programs and their impact on career aspirations. While controlling for beginning of high school STEM aspirations does not completely eliminate selection effects, it does control for a very powerful predictor of end of high school STEM interest. Moreover, the use of propensity weighting yields summer programs participants and nonparticipants that are as similar as possible on all covariates, including beginning of high school STEM aspirations. We recruited a national sample of students; however, there is not readily available data to determine whether the demographics of our sample are generally reflective of high school STEM program participants. As a final note, we use parent education as a proxy for socioeconomic status. We do not have direct information on students' family income, which could have a potential effect on whether or not students are in a position to participate in these programs, particularly if a program charges a fee. Despite these limitations, this study is one of the first of its kind to use a national sample that pools program participants across institutions, incorporates a similar comparison group, and addresses differences by program design to determine effects on end of high school STEM aspirations.

7 | DISCUSSION

The United States education system is not producing enough graduates who aspire to STEM careers to maintain a competitive edge internationally, sparking concern among industry professionals, policymakers, and educators alike (Gottfried, Bozick, & Srinivasan, 2014). High school is the last stage of compulsory education in the United States and thus represents one of the final times when educators and policymakers can intervene and provide additional STEM preparation and encouragement for a broad and diverse group of students. There are calls for increased university and high school collaboration to address a leaky STEM pipeline, and precollege programs like university- or college-run high school STEM summer programs have been identified as a promising option (Scott, 2012).

Our study found that, in a model that carefully controlled for relevant background characteristics, students who participated in a high school STEM summer program had 1.4 times the odds of reporting end of high school STEM career aspirations, relative to their nonparticipating peers. A closer look at program characteristics revealed that students truly benefitted most from participating in high school summer programs that also showed them the real-world relevance of STEM fields (OR = 1.8). We uncovered no statistically significant interaction effects, suggesting programs have broad appeal to students from a variety of backgrounds, and that the benefits of program participation are similar for retention and attraction, i.e., for students with and without a prior STEM career interest. Results from this study support at least two primary conclusions.

First, college- or university-run high school STEM summer programs are effective interventions to promote end of high school STEM career aspirations. Prior work on high school STEM summer programs has examined gains in knowledge, skills, and preparation, STEM attitudes and interests, college retention and enrollment, and to a much lesser extent STEM career interest. Furthermore, past studies have yielded somewhat mixed results about program efficacy and rarely control for preprogram STEM career aspirations. Moving beyond the limited sample sizes and problems with design and analysis that were common among many of the earlier studies, this study significantly expands what we know about the impact of these programs. It contributes robust statistical evidence affirming the positive impact of programs on end of high school STEM career aspirations. As our theoretical model suggests, these out-of-class experiences and the messages they receive during the program appear to shape students' interest in STEM. As policymakers and educators scan the landscape for viable STEM education initiatives to shore up STEM career interests, results from this study can inform programming decisions with added confidence provided by solid empirical evidence.

Our second major conclusion pertains to different summer program designs and the impact of these designs on end of high school STEM career aspirations. An important feature of this study is the distinction between programs that reportedly showed students the real-world relevance of STEM and those that reportedly did not. Our study found that students in programs showing real-life relevance of STEM have 1.6 times the odds of aspiring to STEM careers at the end of high school, relative to students in programs that do not show relevance. In fact, students who participate in a program that reportedly does not show how what they are learning is relevant in the real world are statistically no different from students who do not participate in a program. Thus, while programs may be an effective strategy to address projected labor shortages, our results lend support to adopting a more nuanced understanding of program effects. Taking into account the features of programs when examining how effective they are in boosting STEM career interests is crucial. This finding is consistent with the assumption advanced in the VAS theoretical model that helping students connect what they are learning to "real-life" situations may influence their interest in STEM and related careers.

In the context of STEM learning, real-world relevance is facilitated by undertaking activities and projects that have similar features, methods, and underlying principles to those engaged in by professionals in the field (Lombardi, 2007). For example, measuring the forces acting on riders at an amusement park to design a new roller coaster (Underman, 2001), or using colorimetric analysis to identify the perpetrator in a crime scenario (Ravgiala et al., 2013). In contrast, a lack of real-world relevance may be associated with more traditional textbook or lecture-based STEM instruction in which exercises and activities bear only superficial resemblance (if at all) to recognizable events, phenomena, or problems.

The intent of applied STEM instruction is to build the skills and knowledge students need to deal with issues they would encounter on a daily basis in a STEM career, and to show the relevance of the concepts they learned in traditional coursework (Christensen, Knezek, & Tyler-Wood, 2015). Prior evidence suggests that application-based instruction may yield positive achievement outcomes in STEM (Gottfried, Bozick, & Srinivasan, 2014). Moreover, hands-on engagement activities may be linked to fostering and maintaining positive views about STEM careers among high school students (Christensen et al., 2015). Conversely, Strayhorn, Long, Kitchen, Williams, & Stentz (2013) found that students who encounter difficulty in understanding how what they are learning in STEM is relevant in the real world and addresses societal needs may succumb to boredom with the material and loss of motivation. Prior studies have indicated that program participation provides students hands-on experience that may show them the real-life relevance and application of STEM (Burgin et al., 2015; Goonatilake & Bachnack, 2012). However, studies have typically stopped short of exploring the larger implications of showing students the real-world application of STEM during high school summer programs. Our results extend prior work in this area and suggest that showing real-world relevance in the context of college- and university-run high school summer programs is essential to inspiring students to go into STEM careers.

Calls to show real-world relevance to positively influence student outcomes is not without precedent. John Dewey's work emphasized the importance of learning by doing, of engaging students in active learning that shows the real-world relevance of concepts, and of providing opportunities for students to use what they are learning to solve real-life problems facing society (Christensen et al., 2015; Dewey, 1938). Moreover, the importance of real-world relevance in STEM has been identified as a national policy priority. President Obama called for investment in strategies to show high school students the real-world relevance of STEM through programming that includes college and industry partnerships (White House, 2014). Our findings supply empirical evidence to further justify these priorities.

8 | IMPLICATIONS

Our findings have significant implications for policies, practice, and research. First, as Sadler et al. (2012) noted, students' career aspirations are still malleable during high school. This study demonstrates that malleability and highlights STEM summer programs as a viable option for shaping the aspirations of high schoolers. Higher education institutions making decisions around resources for programming to attract more students into STEM should consider investing in high school STEM summer programs on their own or in partnership with K–12 schools.

Second, funding agencies and policymakers should prioritize the development and support of STEM summer programs that incorporate elements intended to demonstrate the real-world relevance of STEM to students. Funding agencies looking to invest in effective programs should take a close look at program proposals to determine whether they include efforts to demonstrate the real-life relevance of STEM and award funding accordingly. Program staff should provide the necessary scaffolding to fortify students' understanding of the real-world relevance of what they are learning to maximize program impact.

Third, future research should explore what program features or activities tend to make the real-life relevance of STEM most salient to students. Additional work in this area can help program designers tailor their summer programs to yield better odds of STEM career aspirations at the end of high school. Moreover, this study demonstrates the value in examining programs more closely in terms of their characteristics and outcomes. Future research might examine other aspects of high school STEM program design (e.g., program timing) to determine whether these distinctions make a difference in outcomes like STEM career aspirations. Finally, there are other characteristics that future program research could take into consideration. For instance, it is possible that some programs may charge a fee. Future studies should take into consideration program fees and whether it influences program participation because this could have policy implications.

9 | CONCLUSION

It was recognized decades ago that "[i]n our dynamic age of science and technology, no nation can hope to achieve or maintain a position of world leadership unless it successfully solves the problem of fully developing its scientific potential" (Smalheer, 1964, p. 424). Results from this study suggest that college- and university-run high school STEM summer programs are effective education interventions that can promote STEM career aspirations among high schoolers. Closer examination revealed that high school STEM summer programs that showed students the real-life relevance of STEM are in the best position to boost end of high school STEM career aspirations. While no one type of program will be a "silver bullet" to solve the nation's STEM crisis, these programs offer unique opportunities to infuse students' high school years with additional STEM preparation and exposure, which could, in the long run, help strengthen the future STEM workforce.

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