

## Out-of-school time STEM program: Students' attitudes toward and career interests in mathematics and science

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### ABSTRACT

Internationally, out-of-school time (OST) science, technology, engineering, and mathematics (STEM) programs abound. However, rigorous evidence of their impacts on student outcomes is scarce. This study evaluated the relationships between OST STEM program participation and student motivational factors in math and science by analyzing survey and administrative data of 1,017 middle school students who participated in the seven-week, STEM-focused Prefreshman Engineering Program (PREP) in San Antonio, Texas, from 2015 to 2017. Multiple regression results indicated that the PREP participation was positively associated with students' attitudes toward math and interests in math-related careers, whereas the effects on students' attitudes toward science and career interests in science were negligible. No evidence was found to suggest that the associations between PREP participation and student motivational factors in math and science differed by gender, race/ethnicity, or socioeconomic status.

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## 1. INTRODUCTION

Enhancing science, technology, engineering, and mathematics (STEM) education and workforce has been a priority for many countries to compete in the global economy [1, 2]. The interest in improving STEM learning and participation has led to the creation and growth of various in- and out-of-school programs aimed at increasing the number of young students pursuing a college degree and ultimately a career in STEM fields. In the United States, for example, establishing more inclusive STEM high schools represents one rapidly expanding in-school STEM reform program [3, 4]. In the out-of-school contexts, many public and private organizations offer STEM outreach programs during school summer holidays (June to August) that are designed to stimulate or maintain an interest in STEM careers among students at the elementary, secondary, and postsecondary level. These STEM summer programs typically include STEM-focused learning activities such as math/science enrichment curriculum, STEM career seminars, and field trips to STEM professional settings [5-7].

Although out-of-school time (OST) STEM programs abound in the US and internationally, rigorous research on their effects on student outcomes is limited. The existing evidence is mixed at best. While several studies generally found positive effects on student cognitive and motivational outcomes [7-13], others failed to detect an effect of OST STEM program participation on desirable student STEM outcomes, such as STEM interest and college major [14-16]. The mixed findings of prior studies stemmed in part from research designs that relied on small sample sizes and imprecise outcome measures. There is clearly the need for more empirical

studies on the impact of OST STEM programs with larger student samples and more valid and reliable measures.

## 2. LITERATURE REVIEW

OST STEM programs in the USA and across the globe typically seek to increase students' attitudes toward and career interests in STEM through various approaches. Most OST STEM programs develop a STEM-based curriculum to improve students' critical thinking skills and knowledge as well as their motivational factors in STEM. These curricula tend to include a series of teaching and learning activities such as advanced coursework, hands-on activities, and group projects [17-19]. For example, Niemann, Miller, and Davis [12] reported that the Summer Science Institute, offered by the University of Alabama at Birmingham, Alabama, was a three-year progression of summer programs designed to introduce high school students to increasingly more rigorous scientific concepts and research skills through laboratory-based advanced science coursework over the course of three summers (six-week, three-day per week course each summer). The study found that students who returned each year were rated as being more motivated in learning science compared with first-year attendees by mentors, and students overall developed a deep understanding of what it is like to be a scientist. Similarly, several other studies based in various states in the US and focusing on STEM learning [9, 17, 20] concluded that their OST STEM programs' curriculum positively impacted students' attitudes toward and career interest in STEM.

In addition to rigorous coursework or enrichment learning activities, many OST STEM programs create opportunities for students to be exposed to real-world STEM professionals and settings, which are often unavailable during regular school hours [6]. These real-world STEM exposure activities include STEM career seminars featuring professionals from various STEM fields and STEM-related field trips such as visiting science museums, nature centers, and information technology companies. A growing body of research has reported that these opportunities of exposure to real-world STEM professionals and settings can boost students' attitudes toward and career interests in STEM [9, 21, 22]. For instance, Mohr-Schroeder and colleagues [22] demonstrated that middle school students who participated in a STEM summer program in Kentucky either developed an interest in STEM fields or their interest in STEM was heightened through touring and conducting hands-on learning activities in engineering laboratories and facilities, led by engineering experts. Elam, Donham, and Soloman [6] documented that middle and high school students who attended a two-week engineering summer program in Texas reported an increase in career interests in science and engineering, which could partially be explained by their positive experiences from interacting with professional scientists and engineers as well as visiting a food manufacturing plant and a construction site. Taken together, these studies offer evidence that exposing students to STEM professionals and environments can boost their attitudes toward and career interests in STEM.

Despite informative findings, previous studies are limited in terms of methodological issues. They were largely descriptive in nature, and their studied samples tended to be small (typically composed of no more than a few dozens of participants). Most studies used only single-item survey measures to assess the impact of STEM summer programs on student outcomes, which have low level of measurement reliability and validity. Moreover, student samples in prior studies were not sociodemographically diverse, and therefore, had limited generalizability and offered no estimates for different sociodemographic subgroups, which could be informative evidence for understanding the changes in STEM motivations among underrepresented groups [23, 24]. Improving on prior work, this study aimed to assess the associations between OST STEM program participation and students attitudes toward and career interests in STEM by analyzing multiple years of data from a STEM summer program based in San Antonio, Texas, USA, with a sizable and diverse student sample and a rich set of measures on students' attitudes toward and career interests in math and science.

## 3. METHOD

To investigate the relationships between OST STEM program participation and student motivational factors, this study employed multiple regression models with covariate adjustments to analyze multiple years of participant data from the Prefreshman Engineering Program (PREP) in San Antonio, Texas, USA. PREP is a seven-week STEM summer program offered to middle and high school students in grades six to eleven, over the course of four summers with different levels of STEM curriculum and learning activities. PREP was founded at the University of Texas at San Antonio (UTSA) in 1979 to prepare young students, especially women, underrepresented racial/ethnic minorities (URM, who were mostly Blacks, Hispanics, and Native Americans, as opposed to Whites and Asians), and low-socioeconomic status (SES) students, for success in advanced studies leading to careers in STEM. In the summer of 2018, there were 40 PREP sites across the state of Texas, New Mexico, Arizona, California, Utah, and North Dakota, enrolling over 4,000 students. This study

focused only on the PREP sites in San Antonio, which surveyed STEM motivations of participants in every summer since 2015.

PREP pursues its' mission by providing students a rigorous STEM-based curriculum taught by college professors or certified teachers for seven weeks (four days per week; 140 instructional hours in total) during the summer, where students attend program activities Mondays through Thursdays and the average day is six to seven hours long plus homework. The rigorous curriculum consists of various hands-on activities, group projects, and STEM coursework that facilitates the growth of essential academic and cognitive skills needed for STEM success. In particular, PREP exposes middle and high school students to advanced courses, including logic and applications to mathematics, introduction to engineering, introduction to physics, statistics and probability, and introduction to computer science, to help prepare students for advancement in STEM. PREP also provides opportunities for students to engage with STEM professionals through STEM-related field trips and daily STEM career seminars. Over the course of the seven week program, students engage with different STEM professionals through roughly two dozen of career seminars and at least one STEM-related field trip to enhance their attitudes toward and career interests in STEM.

### 3.1. Sample

By utilizing three years of student data from PREP sites in San Antonio (2015 to 2017), rising 8<sup>th</sup> graders (7<sup>th</sup> graders in prior school year) who participated in PREP for the second time were identified as the "treatment group," whereas the "comparison group" consisted of rising 8<sup>th</sup> graders who were first-time PREP participants. In other words, students in the treatment group *attended one additional seven-week PREP program*, compared with the comparison group. The analytic sample of this study includes a total of 1,017 rising 8<sup>th</sup> graders, consisting of 641 treated and 376 comparison cases. Table 1 shows descriptive statistics on the demographic characteristics of study samples by treatment status. Chi-square ( $\chi^2$ ) test results indicate that there was no significant difference by gender between treated and comparison groups (56% versus 52%). However, the comparison group had disproportionately more underrepresented racial/ethnic minorities (81%) and low-SES students (37%), compared with the treatment group (76% and 31%, respectively).

Table 1. Demographic characteristics of study sample (N=1,017)

	Treated		Comparison		p-value ( $\chi^2$ test)
	n = 641		n = 376		
	Mean	S.D.	Mean	S.D.	
Demographics					
Female	.56	.50	.52	.50	.207
URM	.76	.43	.81	.39	.071
Low-SES	.31	.46	.37	.48	.049

Note. N/n = sample size; S.D. = standard deviation;

URM = underrepresented racial minorities; SES = socioeconomic status.

### 3.2. Measures

In this study, four measures on student STEM motivations are used as outcomes. The first two outcome measures are *math attitudes* and *science attitudes*, assessed by using the scales of student attitudes toward STEM, developed by Unfried and colleagues [25]. Both scales of the math and science attitudes consist of seven items with a five-point Likert scale ("strongly disagree" up to "strongly agree"). Two example items for measuring math attitudes are: "I am the type of student to do well in math" and "I can get good grades in math." Two example items for assessing science attitudes are: "I am sure of myself when I do science" and "I know I can do well in science" (see Table 2 for the complete set of items for both math and science attitudes). The third and fourth outcome measures are *interest in math-related careers* and *interest in science-related careers*, which were assessed by asking students to respond to the following two statements: "I would consider choosing a career that uses math" and "I would consider a career in science" (five-point Likert scale: "strongly disagree" up to "strongly agree"). These two items were coded into binary variables, indicating whether a student is interested in math- or science-related careers.

### 3.3. Analytic strategy

Confirmatory factor analysis (CFA) was applied to test the validity and to compute the standardized composite scores of math and science attitudes [26]. To evaluate the goodness-of-fit of CFA model, Hu and Bentler [27] recommended that a Root Mean Square Error of Approximation (RMSEA) at or below 0.06 indicates a good fit, whereas Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) greater than 0.95 are preferred. Reliability tests were conducted to calculate Cronbach's alpha coefficients for the two constructs of

math and science attitudes [28]. To quantify the relationships of STEM summer program participation and students' attitudes toward and career interests in math and science, multiple regression models with covariate adjustments were used. For the dependent variables of interests in math/science-related careers that were dichotomous, regression models were estimated with a linear probability model [29]. To test the heterogeneous effects of PREP, a series of regression models were re-estimated by adding the interaction term between treatment status and sociodemographic characteristics, defined by gender, race/ethnicity, and SES. Robust standard errors were computed and used for statistical significance tests. All data was analyzed using STATA 14.2.

## 4. RESULTS AND DISCUSSION

### 4.1. Results of confirmatory factor analyses for math and science attitudes

Confirmatory factor analysis results showed an adequate fit of the model ( $\chi^2(66) = 175.3, p < .001$ ; RMSEA = 0.040; CFI = 0.985; TFI = 0.980) for constructing two latent factors—math and science attitudes—from 14 survey items, with the exception of a significant  $\chi^2$  value due to the large sample size. As shown in Table 2, most of the factor loadings were large ( $>.60$ ) and all of them were statistically significant. The calculated Cronbach's alpha coefficients for math and science attitudes were both 0.88, exceeding the 0.60 threshold. Taken together, these results suggest the two constructs of math and science attitudes possessed adequate reliability and validity, as indicated in the Unfried and colleagues [21].

Table 2. Results of confirmatory factor analysis and reliability test

	Factor Loading	Alpha
Math Attitudes		.88
<sup>a</sup> Math has been my worst subject	.80	
<sup>a</sup> Math is hard for me	.76	
I am the type of student to do well in math	.79	
<sup>a</sup> I can handle most subjects well, but I cannot do a good job with math	.77	
I am sure I could do advanced work in math	.66	
I can get good grades in math	.67	
I am good at math	.84	
Science Attitudes		.88
I am sure of myself when I do science	.66	
I expect to use science when I get out of school	.81	
Knowing science will help me earn a living	.80	
I will need science for my future work	.84	
I know I can do well in science	.66	
Science will be important to me in my life's work	.83	
I am sure I could do advanced work in science	.70	

Note. <sup>a</sup>Reversed coded in factor analysis. Sample size is 1,017 students.

### 4.2. STEM summer program participation and attitudes toward math and science

Having constructed the two outcome measures of student motivational factors—math and science attitudes, we examined their relationships with the STEM summer program participation. Table 3 displays results from estimating a series of multiple regression models that predict math and science attitudes with PREP participation, controlling for sociodemographic characteristics. It appeared that participating in a STEM summer program is positively associated with students' attitudes toward math ( $\beta = 0.112, p < 0.01$ ) but has no effect on science attitudes. The estimates on a couple of socio-demographic characteristics were in the expected direction. For example, women and URMs had a significantly lower level of attitudes toward math. Furthermore, the interaction effects models (Models 2 to 4) suggested that the relationships among STEM summer program participation and math and science attitudes were not varied across sociodemographic groups, defined by gender, race/ethnicity, and SES.

Table 3. Results of multiple linear regression models (N=1.017)

	Model 1		Model 2		Model 3		Model 4	
	$\beta$	RSE	$\beta$	RSE	$\beta$	RSE	$\beta$	RSE
Panel 1: Math Attitudes								
STEMSP	.112**	(.038)	.074	(.052)	.198*	(.086)	.131*	(.051)
Female	-.157***	(.036)	-.201***	(.058)	-.156***	(.036)	-.159***	(.036)
URM	-.124**	(.045)	-.124**	(.045)	-.052	(.079)	-.124**	(.045)
Low-SES	.027	(.042)	.025	(.042)	.028	(.042)	.027	(.066)
STEMSP x Female			.071	(.074)				
STEMSP x URM					-.109	(.095)		
STEMSP x Low-SES							.002	(.085)
Intercept	.079	(.055)	.102	(.059)	.021	(.079)	.069	(.062)
R <sup>2</sup>		.038		.038		.039		.039
Panel 2: Science Attitudes								
STEMSP	.012	(.022)	.015	(.031)	-.007	(.046)	.024	(.029)
Female	-.026	(.022)	-.023	(.033)	-.027	(.022)	-.026	(.022)
URM	-.040	(.027)	-.040	(.027)	-.056	(.039)	-.039	(.027)
Low-SES	-.014	(.025)	-.013	(.025)	-.014	(.025)	.003	(.037)
STEMSP x Female			-.005	(.043)				
STEMSP x URM					.024	(.052)		
STEMSP x Low-SES							-.027	(.050)
Intercept	.045	(.030)	.044	(.033)	.058	(.038)	.037	(.034)
R <sup>2</sup>		.006		.006		.006		.007

Note. N = sample size;  $\beta$  = coefficient; RSE = robust standard error; STEMSP = STEM summer program; URM = underrepresented racial/ethnic minorities; SES = socioeconomic status.  
 \*\*\*  $p < .001$ ; \*\*  $p < .01$ ; \*  $p < .05$  (two-tailed test).

#### 4.3. STEM summer program participation and interests in math- and science-related careers

Our second set of regression analyses estimated the associations among STEM summer program participation and students' interests in math- and science-related careers. Table 4 reports results from estimating linear probability models that predict career interests in math and science with PREP participation, controlling for sociodemographic characteristics. Similar to the findings above, STEM summer program attendance is positively related to students' interest in math-related careers ( $\beta = 0.070$ ,  $p < 0.05$ ) but has no effect on students' interest in science-related careers. There was also no evidence to suggest that the associations among STEM summer program participation and students' interests in math- and science-related careers differed by sociodemographic characteristics, including gender, race/ethnicity, and SES.

Table 4. Results of linear probability models (N=1.017)

	Model 1		Model 2		Model 3		Model 4	
	$\beta$	RSE	$\beta$	RSE	$\beta$	RSE	$\beta$	RSE
Panel 1: Math Career Interest								
STEMSP	.070*	(.032)	.027	(.045)	.040	(.069)	.051	(.042)
Female	-.173***	(.030)	-.223***	(.050)	-.173***	(.030)	-.174***	(.030)
URM	.008	(.037)	.007	(.037)	-.017	(.063)	.006	(.038)
Low-SES	-.002	(.036)	-.004	(.036)	-.003	(.036)	-.038	(.057)
STEMSP x Female			.080	(.063)				
STEMSP x URM					.037	(.077)		
STEMSP x Low-SES							.058	(.072)
Intercept	.639***	(.046)	.665***	(.050)	.659***	(.061)	.654***	(.051)
R <sup>2</sup>		.035		.036		.035		.035
Panel 2: Science Career Interest								
STEMSP	-.005	(.031)	-.043	(.044)	-.040	(.064)	.028	(.040)
Female	-.051 <sup>†</sup>	(.030)	-.094 <sup>†</sup>	(.059)	-.051 <sup>†</sup>	(.030)	-.050 <sup>†</sup>	(.030)
URM	-.035	(.036)	-.036	(.036)	-.064	(.059)	-.034	(.035)
Low-SES	-.040	(.034)	-.042	(.034)	-.041	(.034)	.004	(.054)
STEMSP x Female			.070	(.061)				
STEMSP x URM					.044	(.073)		
STEMSP x Low-SES							-.070	(.069)
Intercept	.764***	(.043)	.786***	(.047)	.787***	(.057)	.739***	(.048)
R <sup>2</sup>		.008		.009		.008		.010

Note. N = sample size;  $\beta$  = coefficient; RSE = robust standard error; STEMSP = STEM summer program; URM = underrepresented racial/ethnic minorities; SES = socioeconomic status.  
 \*\*\*  $p < .001$ ; \*\*  $p < .01$ ; \*  $p < .05$ ; <sup>†</sup>  $p < .10$  (two-tailed test).

## 5. CONCLUSION

To recap, the findings of this study indicate that participating in PREP-an OST STEM program-is positively associated with higher levels of students' attitudes toward math and interest in math-related careers, but has no significant relationships with students' science attitudes and career interests. These results were encouraging for OST STEM program providers and educators. However, it is important to note that estimates were not causal as there may be confounding factors that were not accounted for, which could bias our results. Nonetheless, by analyzing a large sample of middle school students from multiple cohorts and socio-demographically diverse backgrounds, this study offers new evidence suggesting that OST STEM programs could be a promising intervention to increase student motivational factors in STEM areas. Furthermore, our findings indicate that OST STEM programs have no differential effects for students across gender, racial/ethnic, or SES groups. Future initiatives aimed at improving STEM learning and participation among underrepresented groups, including women, URM, and low-SES students, could be designed to and test for gender-specific or culturally responsive interventions or programs in STEM.

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