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## Keywords

after-school, robotics, engineering education, STEM, longitudinal study

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**Abstract**

One result of the growing concerns over the numbers of young people moving into science, technology, engineering and mathematics (STEM)-related careers has been the expansion of formal and informal STEM education programming for pre-college youth, from elementary school through high school. While the number of programs has grown rapidly, there is little research on their long-term impacts on participant education and career trajectories. This paper presents interim findings from a multi-year longitudinal study of three national after-school robotics programs that engage students in designing, building, and competing complex robots with the goal of inspiring long-term interest in STEM. Focusing on the subset of study participants who had enrolled in at least one year of college (approximately 480 students in 2017), this paper examines program impacts on student attitudes towards STEM and STEM careers; participation in STEM-related college courses; intention to major in STEM-related fields; and involvement in STEM-related internships and other activities. Findings include positive, statistically significant impact on multiple measures of STEM engagement in college for program participants.

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## 1. Introduction

For more than a decade, educators and policy makers have expressed growing concerns over the levels of math and science achievement among American students and the gradual decline in the numbers of young people moving into science, technology, engineering, and math (STEM) careers (Campbell, Jolly, Hoey, & Perlman, 2002; National Science Board, 2012; TAP Campaign, 2005). These concerns have led to the development of new standards for science and technology education (International Technology Education Association, 2000; National Committee on Science Education Standards and Assessment, 1996; National Research Council, 2012), to policy initiatives aimed at promoting science and technology education (America COMPETES Reauthorization Act, 2010; U.S. Department of Education, 2006; White House Office of Science and Technology Policy, 2013), and to a growing body of research on math and science learning and the pathways leading to STEM-related careers (Cannady, Greenwald, & Harris, 2014; Jacobs & Simpkins, 2005). While the picture of looming shortages of scientists and engineers has been challenged and recent studies have indicated that American students are taking more science and advanced science courses in high school (Dalton, Ingels, Downing, & Bozick, 2007; Lowell & Salzman, 2007; National Science Board, 2012), the concerns persist that in an increasingly knowledge-driven global economy, the United States needs to continue its efforts to expand the pipeline into STEM-related careers (National Science Board, 2012; U.S. Congress Joint Economic Committee, 2012).

While the interest in expanding the numbers of young people moving into science and technology fields has grown, a relatively small proportion of the research on STEM education has focused on the role that after-school and out-of-school programs can play to reinforce STEM learning and help engage young people in educational pathways leading to STEM careers; this despite the fact that the numbers of young people involved in after-school STEM-related programs are growing. One national search identified over 70 existing robotics competitions in the United States, with several national organizations (*FIRST*®, BEST, Botball, etc.) operating in middle and high schools on a regional or national basis, and organizations like the Technology Student Association, which involves young people in science- and technology-related competitions, claiming memberships of 250,000 young people (Chung, 2006; Technology Student Association, 2018). Though there are scattered studies of individual after-school programs and summer science enrichment efforts (Barker & Ansorge, 2007; Barnett, Vaughn, Strauss, & Cotter, 2011; Chacon & Soto-Johnson, 2003; Fancsali, 2002; Gibson & Chase, 2002; Markowitz, 2004; Weinberg, Pettibone, Thomas, Stephen, & Stein, 2007; Welch, 2010), most of the existing studies focus on short-term outcomes, are based on self-reported impacts, and few incorporate a control or comparison group design (Whitehurst, 2004). Given the growing emphasis on after-school programming in education and in promoting more hands-on learning experiences in science- and technology-related fields, it is becoming increasingly important to better understand the role that after-school science and technology programs can play in moving young people toward STEM-related careers.

This paper presents interim findings from a multi-year longitudinal study of three programs operated by *FIRST*, a national after-school robotics organization that engages students in designing, building, and competing complex robots with the goal of inspiring long-term interest in STEM. The study, which began in 2012, is tracking more than 1200 program participants and comparison students over a five-year period through middle and high school and into college. Data sources include baseline and annual follow-up surveys of program participants and comparison students, as well as baseline parent surveys, surveys of adult team leaders/educators, and focus groups and telephone interviews with study participants. The goal of the study is to determine the extent to which this type of program is effective in moving young people *into* and helping them *persist within* the pipeline toward STEM-related education and careers. Specific outcomes of interest include increases in interest in STEM and STEM-related careers, high school STEM course-taking, pursuit of and persistence in STEM-related college majors and careers, and development of 21st century personal and workplace-related skills (e.g., communication, collaboration, critical thinking). At the same time, by examining key characteristics of participants' program experience and their relationship to program outcomes, the study hopes to provide practical guidance to educators and policy makers on how best to design and implement similar after-school STEM interventions.

This paper focuses on the subset of approximately 450 *FIRST* alumni and comparison students who had enrolled in at least one year of college as of the fourth round of data collection (summer 2017). The paper examines program impacts on student attitudes towards STEM and STEM careers; participation in STEM-related college courses; intention to major in STEM-related fields; and involvement in STEM-related internships and other activities during the first year of college. Future papers will report on additional college-level outcomes, including persistence in major. Reports on prior rounds of data collection are available online from the *FIRST* website: http://www.firstinspires.org/resource-library/first-impact.

## 2. Background

While the core question for the study—does participation in an after-school robotics program help young people increase their interest in science and technology and lead to STEM-related education and career choices—is relatively straightforward, the proposed study is centered in a broad body of research in educational motivation and youth development. Over the past two decades there has been a growing body of literature on motivation and science and math learning that draws on Jacqueline Eccles' "Expectancy-Value" theory of achievement motivation. That developmental theory argues that "individuals' choice, persistence, and performance can be explained by their beliefs about how well they will do on the activity and the extent to which they value the activity" (Wigfield & Eccles, 2000). Studies using that model have found that students' beliefs about their math and science competency, their expectations of success, and their valuing of math and science can predict grades and course enrollments in middle and high school, with a higher expectancy of success and valuing of math and science courses associated with higher grades and enrollment in a more challenging math and science curriculum (Crombie et al., 2005; Simpkins, Davis-Kean, & Eccles, 2006; Wigfield, 1994; Wigfield & Eccles, 2000).

Eccles and her associates have also found that students' assessment of the "task value" of an activity, including its utility and inherent interest, are critical predictors of future activity, including enrollment in higher-level math and science classes (Eccles, 2007; Updegraff, Eccles, Barber, & O'brien, 1996). Studies have found that involvement in both organized and informal math and science activities outside of school can positively influence students' attitudes and subsequent academic achievement and course enrollments (Jacobs, Finken, Griffin, & Wright, 1998; Simpkins et al., 2006). Studies of summer and other types of science and math enrichment programs, primarily for older students, have also reported impacts on participants' self-concept, interests, and ultimately choice of potential career (Gibson & Chase, 2002; Markowitz, 2004). The Social Cognitive Career Theory developed by Lent, Brown, and Hackett (1994) suggests that these kinds of learning experiences can influence the sense of self-efficacy, outcome expectations, interests, and goals that inform the career choices that young people make. Maltese and Tai (2001) argue that hands-on learning, where students are able to "actively investigate the world around them" helps highlight the relevance of science and mathematics, leading to increased interest and persistence in STEM education. In that regard, this study tracks changes in participants' ability beliefs, interests, and task values related to math, science, and engineering as one set of potential impacts from participation in an after-school robotics program.

Other theories of achievement motivation and success in the math and science "pipeline" suggest additional links between participation in after-school robotics programs and school success, which may be considered a prerequisite for STEM-related careers. James Connell and his associates have argued that educational settings that provide students with opportunities for competence, autonomy, and relatedness (i.e., involved adults and families) help build a sense of competence and control and promote increased engagement in school. Those attitudes, in turn, have been found to be positively associated with persistence in school and improved school achievement (Connell, Spencer, & Aber, 1994; Institute for Research and Reform in Education, 1998; Skinner, Wellborn, & Connell, 1990). While less directly linked to achievement in STEM education, these measures provide a means of assessing the impact of involvement in after-school robotics programs on a broader set of educational attitudes that are also related to long-term achievement and success in school.

The youth development literature also points to positive impacts from these types of hands-on learning experiences on a variety of life and workplace-related skills, including teamwork, communications, project management, and problem-solving skills (Larson & Jarrett, 2004; Larson & Walker, 2006). These types of skills are increasingly considered essential workplace skills and the teaching of these skills is now considered an integral part of engineering education (Accreditation Board for Engineering and Technology, 2015; National Committee on Science Education Standards and Assessment, 1996; North Central Regional Educational Laboratory and the Metiri Group, 2003; Partnership for 21st Century Skills, 2008).

While math- and science-related attitudes and those related to educational competence and engagement provide an interim set of outcomes or predictors of interest, this study also focuses on more direct measures of STEM-related *behaviors*. Involvement in higher-level math and science courses in high school, for example, has been seen as an important predictor of who will engage in math- and science-related occupations and careers (Updegraff et al., 1996). As enrollment in higher-level high school math and science courses has increased in recent years generally, overall enrollment levels are still relatively low and there are significant enrollment gaps between different populations (Dalton et al., 2007). As such, for those students who entered this study in middle school, enrollment in math and science courses (particularly upper-level math and science courses) in high school is one of the critical outcomes examined in the study.

The other major educational outcomes of interest are college-going and enrollment in STEM-related courses and majors in college. An earlier study of the *FIRST* Robotics Competition by Melchior, Cohen, Cutter, and Leavitt (2005) found that program alumni were significantly more likely to major in science and technology and engineering fields, and to expect to go on to STEM careers, than a comparison group of students with similar backgrounds in high school math and science. At the same time, an analysis by the National Center for Educational Statistics found that 48% of bachelor's degree students and 69% of associate's degree students who entered STEM majors left those majors before completing college (Chen, 2013). As such, a major goal of this study is to track college-going among the participants and their selection of STEM-related college majors, and persistence in those majors.

There is substantial literature on the issues of gender and race in math, science, and engineering, highlighting the concerns that women and minorities are less likely to major in engineering and technology fields or pursue occupations in those areas (Catsambis, 1994; Crombie et al., 2005; Eccles, 1994; National Science Board, 2006; U.S. Congress Joint Economic Committee, 2012; U.S. Department of Education, 2012). As noted earlier, some studies also suggest that part of the solution lies in providing young women in particular with more hands-on math and science experiences (Lee & Burkam, 1996; Updegraff et al., 1996), and experiences that highlight the social utility of engineering (Eccles, 2007). One of the questions this study examines is whether robotics competitions are effective in keeping young women in the STEM "pipeline" and can serve as a model for increasing STEM involvement for young women and other underserved populations.

Lastly, the research on achievement motivation and educational success is clear that family background and attitudes play a key role in guiding students' attitudes and choices. In the Expectancy-Value Model, these "influencers" represent critical contextual factors (Bleeker & Jacobs, 2004; Dabney, Chakraverty, & Tai, 2013; Jacobs & Bleeker, 2004; Simpkins, Davis-Kean, & Eccles, 2005). As such, this study design includes collecting baseline information from parents on family context, including parental education, in order to be able to examine and control for those variables in the analysis.

## 3. *FIRST* Programs

As noted above, this study focuses on participants in after-school robotics programs operated by *FIRST*, a national nonprofit organization that provides after-school robotics programs for young people aged 6–18 years in the United States and internationally. The mission of *FIRST* is to inspire young people to be science and technology leaders by engaging them in mentor-based programs that build science, engineering, and technology skills, that inspire innovation, and that foster well-rounded capacities including self-confidence, communication, and leadership. The three programs that are included in the study are the *FIRST*® LEGO® League, which serves primarily middle school-aged youth (ages 9–14), *FIRST*® Tech Challenge, which serves youth in grades 7–12, and the *FIRST*® Robotics Competition, serving high school-aged youth (grades 9–12).

While differing in their specific designs and target age groups, all three programs are built on a common concept: in each, teams of school-aged youth work together under the guidance of one or more adults (an adult team leader plus technical mentors and other volunteers) and take leadership in designing and building robots that compete with other youth-led teams in completing a set of prescribed tasks. The primary goal of all three programs is to promote increased interest in science and technology through hands-on engagement in designing, building, and competing the robots, with the ultimate goal of moving participants towards STEM-related education and careers. However, all three programs also place a heavy emphasis on the involvement of adult leaders and mentors from the community, the development of teamwork skills and team spirit, and the demonstration of values of "*Gracious Professionalism*®" and "*Coopertition*®" (the ability to both work with and compete against the same individuals and teams) in working both within the team and with competitor teams at the competition. As such, the programs are designed to promote both interest in STEM and a broader set of 21st century life and workplace skills and values, including critical thinking, problem-solving, teamwork, communications, and project planning and management.

In 2016–17, *FIRST* reported that over 460,000 young people participated in its programs on more than 52,000 teams and competing in more than 2,600 events worldwide. As such, it represents one of the largest after-school STEM initiatives in the United States and globally.

## 4. Methodology

In 2011, *FIRST* contracted with the Center for Youth and Communities at Brandeis University's Heller School for Social Policy and Management to conduct a multi-year longitudinal study of *FIRST*'s middle and high school programs. The goal of the study, building on more than a decade of prior short-term evaluation studies, was to document the longer-term impacts of *FIRST*'s after-school robotics programs on participating youth and to do so through a design that meets the standards for rigorous, scientifically based evaluation research.

Three major questions guide the study:

1. **What are the short- and longer-term impacts of the *FIRST* LEGO League, *FIRST* Tech Challenge, and *FIRST* Robotics Competition programs on program participants?** Specifically, what are the program impacts on a core set of participant outcomes that include: interest in STEM and STEM-related careers, college-going and completion, pursuit of STEM-related college majors and careers, and development of 21st century personal and workplace-related skills?
2. **What is the relationship between program experience and impact?** To what extent are differences in program experience—such as time in the program, participation in multiple programs, role on the team, access to mentors, quality of the program experience—associated with differences in program outcomes? What can we learn about "what works" to guide program improvement?
3. **To what extent are there differences in experiences and impacts among key subpopulations of *FIRST* participants?** In particular, are there differences in impacts among young women, white and non-white youth, and youth from low-income communities? If there are differences, what can we learn about why those differences occur and how to address them in the future?

To address these questions, the multi-year study is tracking 1,273 students (822 *FIRST* participants and 451 comparison students) over five plus years (the study began in 2012). Participants in the study were recruited through a national sample of over 200 *FIRST* teams in 10 states participating in the after-school programs. The team sample was selected through a stratified random sampling process aimed at matching the national distribution of teams in each of the *FIRST* programs in terms of (a) type of community (urban, rural, suburban); (b) community income (percent above/below poverty level); and proximity to other teams in the same program (to make it possible to track participants across multiple teams). New *FIRST* team members with no prior program experience were then recruited to the study by team leaders. Comparison group students were recruited from math and science classes in the same schools and organizations where the *FIRST* teams were located. Participant recruitment took place in two waves, with recruitment of the initial group of students in Fall 2012 and recruitment of additional participants in Fall 2013 to increase the size of the overall sample for the study.

### A. Data Collection

The primary source for the study is a series of baseline, post-program, and annual follow-up surveys of program participants and comparison students, supplemented by baseline parent surveys and surveys of team leaders during the first year of the study. Surveys have been supplemented by telephone interviews and focus groups with participants in several years of the study. Baseline surveys were administered to program participants and comparison students as paper-based surveys in Fall 2012 and 2013. Follow-up surveys have been administered as an online survey in each subsequent spring. With completion of the spring 2017 survey, the study has 48-month follow-up data for both waves of study participants. Response rates for both *FIRST* program participants and comparison group members have been strong with 80% of the study participants completing the 48-month follow-up survey for the study (74% of program participants and 90% of comparison group members). Table 1 shows the survey response rates for the study through 48 months.

### B. Survey Instruments

The major focus of the study is on program impacts on STEM-related interests, attitudes, and behaviors. Key outcomes, developed in collaboration with staff at *FIRST* and with the program and technical advisory groups during the planning phase of the study, include a combination of interest and attitudinal measures (for example, increased interest in STEM and STEM-related careers, sense of educational efficacy, and postsecondary aspirations); measures of self-reported life and workplace skills; and shorter- and longer-term behavioral measures such as increased STEM-related course-taking, high school graduation and college-going, postsecondary STEM course-taking and college majors, and continued involvement in *FIRST*. Table 2 provides an overview of the key outcome measures.

In addition to the key outcome measures, the baseline surveys collected demographic information including age, gender, race/ethnicity, ESL status, and grade in school as well as information on program participation and academic background (grade point average, honors courses at baseline). Parent surveys provided information on family income and parental support for their children's involvement in STEM. As discussed below, these baseline characteristics were used in the analysis to control for differences between *FIRST* participants and comparison group member characteristics at baseline and to control for the influence of characteristics like race or gender on outcomes. The survey items were drawn from a mix of existing national surveys (for example, the U.S. Department of Education's National High School Longitudinal Study of 2009), questions that had been used in previous evaluation studies, and items developed specifically for this study

Table 1
Response rates through 48-month surveys.

| | Baseline | 24-month follow-up | | 36-month follow-up | | 48-month follow-up | |
|---|---|---|---|---|---|---|---|
| | *N* | *N* | % of baseline | *N* | % of baseline | *N* | % of baseline |
| *FIRST* participants | 822 | 665 | 80.9% | 636 | 77.4% | 611 | 74.3% |
| Comparison students | 451 | 411 | 91.1% | 409 | 90.7% | 406 | 90.0% |
| **Total** | **1273** | **1076** | **84.5%** | **1045** | **82.1%** | **1017** | 79.9% |

Table 2
Key outcome measures.

| STEM-related interest and attitude scales | Personal development and workplace-related scales | Behavioral measures |
|---|---|---|
| • STEM interest (level of interest in science, technology, engineering, and mathematics)<br>• STEM activity (involvement in non-school STEM activities)<br>• STEM careers (interest in STEM-related careers, such as scientist, engineer, computer specialist, etc.)<br>• STEM identity (extent to which students see themselves as science, math, or technology people)<br>• STEM knowledge/understanding (awareness of applications of STEM in real world, interest in learning more about STEM) | • Academic self-concept (students' sense of their educational competence/commitment to learning)<br>• College support (adult support for college readiness/knowledge)<br>• Self-efficacy/prosocial values (self-confidence, sense of belonging, and contribution)<br>• 21st century skills (self-assessed life and workplace skills, includes teamwork, problem-solving, and communications subscales) | • STEM course-taking (high school)<br>• Interest in STEM majors in college/declared majors<br>• STEM-related college course-taking<br>• Involvement in college STEM-activities (clubs, competitions, internships, summer jobs)<br>• STEM-related college grants and scholarships |

(U.S. Department of Education, 2009). The surveys were piloted with students on local *FIRST* teams and revised based on their feedback.

### C. Analysis

This paper focuses on the subset of study participants who had enrolled in at least one year of college as of the fourth round of data collection (summer 2017). The sample includes 289 *FIRST* program alumni and 162 comparison group members, a total of 451 study participants. Of those, 59% of the sample were males, 41% were females. Approximately 70% of the sample members were White, which is consistent with the larger study; the largest group of non-White study participants were Asian (18%); 8% were African-American. Table 3 summarizes the demographic characteristics of the sample. Because of the relatively small number of young people of color in the sample and their division into several groups, we determined that we would not examine racial differences until the college sample was larger in future years. We will, however, examine differences based on gender.

Analysis of the data uses a mix of multivariate regression approaches, depending on the types of data involved. The primary analysis uses a repeated measures linear mixed models analysis for analysis of outcomes that are continuous variables. The mixed models analysis controls for baseline differences on the outcome measures and allows consideration of all of the data points in the longitudinal study, including cases with missing data points (O'Connell & McCoach, 2008; Singer, 1998). The study also incorporates logistic regression analysis when appropriate. All analyses include adjustments for differences between the participant and comparison groups at baseline, including covariates for gender, race/ethnicity, family income, participation in STEM honors courses at baseline, and baseline parental support for STEM. Analysis of behavioral measures (e.g., college major, college course-taking) also includes STEM interest at baseline as a covariate.

Table 3
Demographic characteristics of sample.

| Characteristic | *N* | Percent of total |
|---|---|---|
| *Total sample* | 451 | |
| *FIRST* participant | 289 | 64.1% |
| Comparison group member | 162 | 35.9% |
| *Gender* | | |
| Male | 265 | 59.3% |
| Female | 182 | 40.7% |
| Missing | 4 | |
| *Race/ethnicity* | | |
| Asian | 75 | 18.0% |
| Black or African-American | 33 | 7.9% |
| Multi-racial | 15 | 3.6% |
| Others (Native American, Hawaiian/Pacific Islander) | 2 | 0.4% |
| White | 292 | 70.0% |
| Missing | 34 | |

## 5. Findings

Data from prior years surveys (24 and 36 months) have indicated that, for the program participant group as a whole, participation in the three *FIRST* robotics programs produced positive statistically significant impacts on STEM-related attitudes and interests relative to students in the comparison group. The question for this paper is whether those positive impacts on attitudes carry forward for those *FIRST* participants who have entered college, and whether there is further evidence of longer-term impacts from program participation in the form of increased interest in STEM-related majors, STEM course-taking, and involvement in other STEM-related activities in college. The data presented below point to positive impacts in a number of areas.

### A. Student Attitudes Toward STEM and STEM Careers

As noted above, among the key measures for the longitudinal study are a set of STEM-related attitudes, including overall interest in STEM, involvement in non-school STEM activities, interest in STEM careers, a sense of STEM identity ("I am a science person"), and an understanding of the role of science and technology in everyday life. As shown in Table 4, *FIRST* participants score significantly higher than comparison students on all five STEM-related measures after controlling for baseline scores and participant characteristics.

There were no significant differences, however, between *FIRST* participants and comparison students for non-STEM measures used in the study, including academic self-concept, college support, self-efficacy and prosocial behavior, 21st century skills, and the 21st century skill subscales for teamwork, problem solving, and communication. These results are consistent with those found in earlier analyses for the broader sample of all participants.

The positive impact on STEM-related measures is also evident when the data are broken down by gender. Table 5 shows the impact of program participation on STEM measures for male and female *FIRST* alumni, relative to comparison group males and females. Both male and female *FIRST* alumni show significantly higher scale scores at 48 months than their counterparts in the comparison group. An additional analysis that includes the interaction of gender and program participation shows that the impacts for females in the *FIRST* programs were significantly larger than those for male participants for all of the measures except STEM identity (Table 6).

Table 4
Impact on STEM and non-STEM attitudes.

| | Marginal means at 48 months | | | |
|---|---|---|---|---|
| **STEM measures** | ***FIRST* participants** | **Comparison group** | **Difference** | **Sig.** |
| STEM interest | 4.25 | 3.73 | 0.52 | ***0.000*** |
| STEM activity | 3.45 | 3.08 | 0.36 | ***0.000*** |
| STEM careers | 4.40 | 3.64 | 0.76 | ***0.000*** |
| STEM identity | 3.20 | 3.03 | 0.17 | ***0.000*** |
| STEM knowledge | 5.91 | 5.28 | 0.63 | ***0.000*** |
| **Non-STEM measures** | ***FIRST* participants** | **Comparison group** | **Difference** | **Sig.** |
| Academic self-concept | 5.82 | 5.88 | -0.07 | 0.397 |
| College support | 2.65 | 2.62 | 0.02 | 0.547 |
| Self-efficacy/prosocial | 5.83 | 5.83 | 0.00 | 0.985 |
| 21st century skills | 3.27 | 3.31 | -0.03 | 0.406 |
| Teamwork | 3.45 | 3.51 | -0.06 | 0.127 |
| Problem solving | 3.16 | 3.16 | 0.00 | 0.975 |
| Communication | 3.25 | 3.28 | -0.03 | 0.646 |

*Note.* Mixed analysis, controlling for gender, race, honors courses at baseline, family income, and parental support for STEM. $N = 451$. Bold italics are statistically significant at $p \leq 0.05$.

Table 5
STEM measures by gender.

| | Marginal means at 48 months | | | |
|---|---|---|---|---|
| **STEM measures** | ***FIRST* participants** | **Comparison group** | **Difference** | **Sig.** |
| **Males** | | | | |
| STEM interest | 4.49 | 4.13 | 0.36 | ***0.000*** |
| STEM activity | 3.63 | 3.48 | 0.15 | ***0.029*** |
| STEM careers | 4.98 | 4.62 | 0.36 | ***0.007*** |
| STEM identity | 3.27 | 3.14 | 0.13 | ***0.002*** |
| STEM knowledge | 6.04 | 5.75 | 0.28 | ***0.021*** |
| **Females** | ***FIRST* participants** | **Comparison group** | **Difference** | **Sig.** |
| STEM interest | 4.05 | 3.41 | 0.64 | ***0.000*** |
| STEM activity | 3.33 | 2.78 | 0.55 | ***0.000*** |
| STEM careers | 3.95 | 2.79 | 1.16 | ***0.000*** |
| STEM identity | 3.16 | 2.93 | 0.23 | ***0.000*** |
| STEM knowledge | 5.88 | 4.96 | 0.92 | ***0.000*** |

*Note.* Mixed analysis, controlling for gender, race, honors courses at baseline, family income, and parental support for STEM. Bold italics are statistically significant at $p \leq 0.05$.

Table 6
Additional impact of interaction effect for female *FIRST* participants.

| **Measure** | ***FIRST* participants compared to comparison students** | **Sig.** | **Female × program interaction** | **Sig.** |
|---|---|---|---|---|
| STEM interest (5 point scale) | 0.346 | ***0.000*** | 0.370 | ***0.007*** |
| STEM activity (5 point scale) | 0.199 | ***0.026*** | 0.416 | ***0.000*** |
| STEM careers (7 point scale) | 0.343 | ***0.023*** | 0.859 | ***0.000*** |
| STEM identity (4 point scale) | 0.130 | ***0.003*** | 0.090 | 0.152 |
| STEM knowledge (7 point scale) | 0.282 | ***0.046*** | 0.743 | ***0.000*** |

*Note.* Mixed analysis, controlling for gender, race, honors courses at baseline, family income, and parental support for STEM with added interaction variable for female program participants. Bold italics are statistically significant at $p \leq 0.05$.

### *B. Interest in Majoring in STEM-Related Fields*

The positive impacts on STEM-related attitudes were also reflected in reported interest in STEM majors at college, though with a clear distinction between engineering and technology-related majors and other STEM fields. Table 7 shows the percent of all first-year college students who are "very interested" in majoring in the specified field (i.e., reporting a 6, 7, or "already declared" on a 7-point scale measuring interest in specific college majors). The calculations of statistical significance and the odds ratios are based on a logistic regression analysis that calculates

Table 7
Interest in college majors (percent highly interested).

| | Percent highly interested (unadjusted) | | Relative likelihood of being interested (logit) | |
|---|---|---|---|---|
| | *FIRST* participants | Comparison | Sig. | Odds ratio |
| Arts and humanities | 12.3% | 23.1% | 0.461 | 0.763 |
| ***Biological sciences*** | ***15.6%*** | ***31.2%*** | ***0.000*** | ***0.301*** |
| Business | 21.8% | 21.4% | 0.626 | 1.165 |
| ***Computer science*** | ***44.0%*** | ***22.2%*** | ***0.037*** | ***1.824*** |
| Education | 7.9% | 13.3% | 0.380 | 0.672 |
| ***Engineering*** | ***59.9%*** | ***25.5%*** | ***0.004*** | ***2.322*** |
| ***Health professions*** | ***15.1%*** | ***33.3%*** | ***0.002*** | ***0.351*** |
| Mathematics | 21.4% | 19.2% | 0.361 | 0.746 |
| Physical sciences | 25.5% | 24.4% | 0.284 | 0.718 |
| Social sciences | 15.5% | 29.3% | 0.585 | 0.837 |
| Technical/vocational | 13.5% | 10.8% | 0.378 | 0.704 |
| Other professional | 9.0% | 19.1% | 0.174 | 0.586 |
| ***Robotics*** | ***40.2%*** | ***10.8%*** | ***0.000*** | ***3.875*** |

*Note.* Logit regression controlling for gender, race, honors courses at baseline, family income, and parental support for STEM and baseline STEM interest. Bold italics are statistically significant at $p \leq 0.05$. "Highly interested" is based on responding 6, 7, or "already declared" on a scale of 1 to 7 for each major field.

the relative likelihood of majoring in each field after adjusting for baseline difference. In this instance, an odds ratio of 1 indicates an equal likelihood of being highly interested in majoring in a field between the program participants and comparison students; a ratio above 1 indicates that program participants are *more* likely to be interested; a ratio below 1 indicates that program participants are *less* likely to be interested.

Among the first-year college-goers, *FIRST* alumni reported statistically significant higher interest in majoring in computer science, engineering, and robotics in their first year in college than comparison students. *FIRST* alumni are nearly twice as likely (1.8 times) to be interested in majoring in computer science, are 2.3 times more likely to be interested in engineering, and 3.9 times more likely to be interested in robotics than comparison students. Overall, 60% of *FIRST* alumni report being "very interested" in majoring in engineering; 40% report high interest in computer science and 40% are interested in majoring in robotics during their first year of college.

It is important to note that there are significant differences in interest in the other direction in other STEM-related fields. While *FIRST* alumni are more interested in engineering and technology-related fields, comparison group members show greater interest in the biological sciences and health-related majors. Alumni from the *FIRST* programs were roughly a third as likely as comparison students to be interested in majoring in biology (odds ratio of .301) and health professions (odds ratio of 0.351). These differences were also statistically significant.

Majors were also analyzed to examine differences in program impact by gender (Table 8). Both male and female *FIRST* alumni were more likely to be highly interested in computer science, engineering, and robotics than comparable comparison students, and less likely to be highly interested in biology and health professions (males were also significantly less likely to be interested in education). The differences between female *FIRST* alumni and comparison women are particularly striking. Female *FIRST* alumni in their first year of college were 3 times more likely to be interested in majoring in computer science and engineering and 5 times more likely to be interested in majoring in robotics than female comparison students. The differences were also evident in the raw (unadjusted) percentages, with 47% of female *FIRST* alumni reporting being "very interested" in Engineering versus 16% of females in the comparison group.

### C. Participation in STEM-Related College Courses

A similar pattern was evident in first-year course-taking, with statistically significant results showing that *FIRST* alumni are more likely to take engineering courses in their first year at college than comparison students, and less likely to take courses in the non-engineering-related STEM field of biology, or in social science-related fields. As Table 9 shows, after-school *FIRST* program alumni were 2.3 times more likely to take engineering courses in their freshman year than comparison students, with 44% of program alumni reporting that they took an engineering course compared to 17% of the comparison students. At the same time, *FIRST* alumni were roughly half as likely as comparison students to take courses in the arts and humanities, biology, social sciences, and pre-professional courses in law or medicine.

Among women the difference is even more substantial: while male *FIRST* alumni are 2.3 times more likely to take a first-year engineering course, female alumni are 3.4 times more likely to take a first-year engineering course than

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Table 8
Interest in college majors by gender (percent highly interested).

| | **Percent highly interested (unadjusted)** | | **Relative likelihood of being interested (logit)** | |
|---|---|---|---|---|
| | ***FIRST* participants** | **Comparison** | **Sig.** | **Odds ratio** |
| ***Males*** | | | | |
| Arts and humanities | 9.8% | 18.8% | 0.955 | 1.031 |
| ***Biological sciences*** | ***11.6%*** | ***31.9%*** | ***0.000*** | ***0.181*** |
| Business | 22.7% | 22.9% | 0.924 | 1.039 |
| Computer science | 49.4% | 31.4% | 0.327 | 1.406 |
| ***Education*** | ***5.8%*** | ***14.9%*** | ***0.032*** | ***0.287*** |
| ***Engineering*** | ***66.9%*** | ***35.8%*** | ***0.050*** | ***2.071*** |
| ***Health professions*** | ***10.5%*** | ***25.8%*** | ***0.015*** | ***0.285*** |
| Mathematics | 23.3% | 26.5% | 0.249 | 0.633 |
| Physical sciences | 26.8% | 31.3% | 0.363 | 0.700 |
| Social sciences | 12.4% | 22.1% | 0.291 | 0.618 |
| Technical/vocational | 17.0% | 18.8% | 0.275 | 0.627 |
| Other professional | 8.3% | 15.9% | 0.325 | 0.592 |
| ***Robotics*** | ***45.0%*** | ***14.5%*** | ***0.003*** | ***3.460*** |
| ***Females*** | | | | |
| Arts and humanities | 17.9% | 27.4% | 0.245 | 0.533 |
| Biological sciences | 23.5% | 31.3% | 0.108 | 0.445 |
| Business | 20.0% | 19.8% | 0.503 | 1.387 |
| ***Computer science*** | ***33.3%*** | ***11.8%*** | ***0.036*** | ***3.053*** |
| Education | 12.5% | 12.3% | 0.365 | 1.902 |
| ***Engineering*** | ***46.9%*** | ***15.7%*** | ***0.017*** | ***3.159*** |
| ***Health professions*** | ***24.1%*** | ***39.5%*** | ***0.031*** | ***0.355*** |
| Mathematics | 17.5% | 12.9% | 0.784 | 1.169 |
| Physical sciences | 22.9% | 16.3% | 0.492 | 0.700 |
| Social sciences | 22.4% | 34.9% | 0.870 | 1.080 |
| Technical/vocational | 6.0% | 3.5% | 0.868 | 1.195 |
| Other professional | 10.7% | 21.2% | 0.269 | 0.518 |
| ***Robotics*** | ***30.1%*** | ***4.7%*** | ***0.011*** | ***5.057*** |

*Note.* Logit regression controlling for program, race, honors courses at baseline, family income, and parental support for STEM and baseline STEM interest. Bold italics are statistically significant at $p \leq 0.05$.

female comparison students (Table 10). Both male and female *FIRST* participants were less likely to take courses in non-technology science and social science fields.

### *D. Involvement in STEM-Related Internships and Other Activities*

Finally, the surveys for the study also asked college students about the kinds of co-curricular activities and opportunities they were engaged in during their first year at college. As Table 11 shows, *FIRST* program alumni were more likely than comparison students to engage in a variety of engineering and technology-related activities in their first year of college, and those differences were statistically significant. *FIRST* alumni were also more likely to have a STEM-related internship during their freshman year; to belong to a computer, engineering, or math club; to participate in computer or engineering competitions; and to receive an engineering-related grant or scholarship. *FIRST* alumni were less likely than comparison students to have a summer job (possibly because they had a STEM-related internship instead), but those with jobs were more likely to have one in a STEM-related field. Other types of activities (not shown in the table) such as participation in apprenticeship programs, science clubs, or math and science competitions, and participation in environmental clubs and programs showed no significant differences between program participants and comparison students.

## 6. Discussion

The data presented here represent an initial effort to assess the longer-term impacts of participation in after-school robotics programs like those provided through *FIRST* on the decisions that young people make about their education and careers. As the longitudinal study progresses, the numbers of study participants who enter and progress through college will increase: as of the 48-month survey data examined here, there were 451 first-time college-goers in the study sample. We estimate that the number will rise to over 600 for the spring 2018 survey and over 700 the following spring. As the study continues, we will have the opportunity to not only work with a larger sample, but to track progress through college (for example, looking at persistence in major) and at outcomes for other key subpopulations.

Table 9
First-year course-taking.

| | Percent taking at least 1 course (unadjusted) | | Relative likelihood of taking a course (logit) | |
|---|---|---|---|---|
| | *FIRST* participants | Comparison group | Sig. | Odds ratio |
| ***Arts and humanities*** | ***56.4%*** | ***66.0%*** | ***0.013*** | ***0.544*** |
| ***Biological sciences*** | ***20.1%*** | ***36.4%*** | ***0.003*** | ***0.465*** |
| Computer science/programming | 32.2% | 22.8% | 0.316 | 1.303 |
| Business | 9.3% | 16.0% | 0.111 | 0.573 |
| Education | 1.0% | 6.8% | 0.147 | 0.330 |
| ***Engineering*** | ***43.6%*** | ***16.7%*** | ***0.003*** | ***2.291*** |
| Health professions | 4.2% | 11.1% | 0.115 | 0.468 |
| Mathematics | 64.4% | 58.6% | 0.886 | 1.035 |
| Physical sciences | 50.5% | 39.5% | 0.229 | 1.330 |
| ***Social sciences*** | ***31.8%*** | ***51.9%*** | ***0.000*** | ***0.396*** |
| Technical/vocational | 2.8% | 2.5% | 0.820 | 0.841 |
| ***Other professional fields (law, medicine, etc.)*** | ***2.1%*** | ***11.1%*** | ***0.019*** | ***0.284*** |

*Note.* Logit regression controlling for program, race, honors courses at baseline, family income, and parental support for STEM and baseline STEM interest. Bold italics are statistically significant at $p \leq 0.05$.

Table 10
First-year course-taking by gender.

| | Percent taking at least 1 course (unadjusted) | | Relative likelihood of taking a course (logit) | |
|---|---|---|---|---|
| ***Males*** | *FIRST* participants | Comparison group | Sig. | Odds ratio |
| Arts and humanities | 53.1% | 62.0% | 0.135 | 0.621 |
| ***Biological sciences*** | ***13.9%*** | ***29.6%*** | ***0.002*** | ***0.320*** |
| Computer science/programming | 34.5% | 28.2% | 0.943 | 1.024 |
| Business | 10.3% | 16.9% | 0.267 | 0.607 |
| ***Education*** | ***0.5%*** | ***5.6%*** | ***0.045*** | ***0.089*** |
| ***Engineering*** | ***49.0%*** | ***26.8%*** | ***0.051*** | ***1.861*** |
| ***Health professions*** | ***1.0%*** | ***8.5%*** | ***0.046*** | ***0.162*** |
| Mathematics | 64.4% | 66.2% | 0.624 | 0.848 |
| Physical sciences | 48.5% | 43.7% | 0.872 | 0.950 |
| ***Social sciences*** | ***33.0%*** | ***52.1%*** | ***0.011*** | ***0.447*** |
| Technical/vocational | 2.6% | 2.8% | 0.832 | 1.274 |
| Other professional fields | 2.1% | 8.5% | 0.157 | 0.355 |
| ***Females*** | *FIRST* participants | Comparison group | Sig. | Odds ratio |
| ***Arts and humanities*** | ***63.8%*** | ***69.3%*** | ***0.034*** | ***0.433*** |
| Biological sciences | 31.9% | 40.9% | 0.329 | 0.700 |
| Computer science/programming | 27.7% | 17.0% | 0.087 | 2.140 |
| Business | 7.4% | 15.9% | 0.208 | 0.482 |
| Education | 2.1% | 8.0% | 0.766 | 0.742 |
| ***Engineering*** | ***33.0%*** | ***8.0%*** | ***0.015*** | ***3.406*** |
| Health professions | 9.6% | 13.6% | 0.444 | 0.652 |
| Mathematics | 64.9% | 52.3% | 0.456 | 1.304 |
| Physical sciences | 54.3% | 35.2% | 0.051 | 1.933 |
| ***Social sciences*** | ***28.7%*** | ***53.4%*** | ***0.004*** | ***0.348*** |
| Technical/vocational | 3.2% | 2.3% | 0.672 | 0.626 |
| ***Other professional fields*** | ***2.1%*** | ***13.6%*** | ***0.049*** | ***0.201*** |

*Note.* Logit regression controlling for program, race, honors courses at baseline, family income, and parental support for STEM and baseline STEM interest. Bold italics are statistically significant at $p \leq 0.05$.

The data currently in hand, however, strongly suggest that the after-school STEM programs being studied do have a positive, longer-term impact on *FIRST* participant attitudes about STEM and on the decisions they make about what they will study in college. The program participants in this sample ended their participation in *FIRST* at least a year prior to taking the most recent survey for this study, yet they continue to show a significantly stronger interest in STEM and STEM careers and continue to think of themselves as "STEM people" to a greater degree than comparison students, even after taking into account baseline differences in interests and characteristics. Those differences

Table 11
First-year internships, clubs, and other STEM-related activities.

| Activity | Categories | *FIRST* participants | Comparison group |
|---|---|---|---|
| College: internships* | *STEM-related* | *19.0%* | *9.2%* |
| | Non-STEM related | 5.8% | 5.2% |
| | Did not have | 75.2% | 85.6% |
| Computer club* | *Yes* | *16.3%* | *7.4%* |
| | No or missing | 83.7% | 92.6% |
| Engineering club* | *Yes* | *30.8%* | *12.3%* |
| | No or missing | 69.2% | 87.7% |
| Math club* | *Yes* | *10.0%* | *4.9%* |
| | No or missing | 90.0% | 95.1% |
| Computer competition* | *Yes* | *10.0%* | *3.1%* |
| | No or missing | 90.0% | 96.9% |
| Engineering competition* | *Yes* | *11.8%* | *5.6%* |
| | No or missing | 88.2% | 94.4% |
| Engineering grants* | *Yes* | *8.7%* | *3.1%* |
| | No or missing | 91.3% | 96.9% |
| College: summer job* | *STEM-related* | *15.6%* | *7.2%* |
| | Non-STEM related | 40.1% | 57.5% |
| | Did not have job | 44.4% | 35.3% |

*Note.* Based on raw percentages with no baseline adjustments. Asterisk (*) and italic indicates statistically significant at $p = 0.05$ or less, based on chi square analysis. For summer jobs, comparison group was more likely to have a summer job; *FIRST* alumni were more likely to have a STEM-related

in attitudes are reflected in the differences in the respective levels of interest in technology-related majors (engineering, computer science, and robotics) and initial course-taking, and they appear to lead to a greater engagement in non-classroom-based STEM activities, including clubs, competitions, internships, and summer jobs. In that regard, the initial evidence presented here suggests that *FIRST*'s after-school robotics programs are meeting their primary goal of generating and helping to sustain interest in STEM and encouraging young people to pursue that interest in college.

It is also important to recognize those areas in which these types of after-school robotics programs appear to *not* have a significant impact. First, none of the measures of non-STEM-related attitudes showed any statistically significant impact: *FIRST* participants and comparison students show remarkably little difference on measures of academic self-concept, personal development, or 21st century workplace skills despite the fact that these outcomes are as much a focus of the *FIRST* program design as is interest in STEM. One likely explanation is that both in-school and community-based programs increasingly provide experiences aimed at building modern workplace skills (communications, problem-solving, teamwork, etc.) and that the opportunities to gain these and related developmental experiences through sports, music and theater, co-curricular programs, 4-H and scouting, or project-based learning in school abound. Telephone interviews with a sample of study participants tend to reinforce this hypothesis. Both *FIRST* participants and comparison group members pointed to a variety of settings in which they had opportunities to learn and practice an array of 21st century skills. Our conclusion was that the *FIRST* robotics programs did help teach those skills, but so did other resources in the community. What was unique about the *FIRST* programs was their emphasis on STEM.

Similarly, while after-school programs like those provided by *FIRST* often refer to their goals of increasing interest in STEM generally, the fact is that while STEM principles are integral to the programs (using math, trial and error, etc.), after-school robotics programs like *FIRST*'s are primarily focused on engineering and technology (the E and T in STEM). The positive impacts at the college level are clearly focused on areas such as computer science and engineering, with comparison group students significantly more likely to pursue majors in non-engineering STEM fields such as biology and health professions. One implication is that programs like those studied here may have a general influence on STEM attitudes, but they are likely to have the greatest impacts on areas directly related to their content.

There are some important limitations to the findings presented here. The results are based on initial college-level data from the study. Those finding could change as more of the longitudinal study sample enter college. Also, the results focus on the first year in college: we look forward to seeing whether the findings persist as students move through their college careers. The design of the study also presents challenges. Participants in *FIRST* programs, as with most after-school STEM programs, are largely self-selected, and the use of a comparison group design (as opposed to a randomized control trial) raises the question of whether the results are influenced by selection bias. We have tried to control for baseline differences by including a mix of demographic variables and baseline STEM measures, including participation in STEM honors courses at baseline, parental support for STEM, and measures of

STEM interest at baseline. The statistical procedures used, particularly the mixed methods analysis, provide robust controls for baseline differences. That said, it is possible that there are unmeasured differences between *FIRST* participants and comparison students that influence the results. We continue to look for ways to further test our findings in that regard.

A recent National Science Board report estimates that 7.5% of all entering college freshmen intend to major in engineering, including 13.7% of the men and 2.6% of women entering college (National Science Foundation, 2016). The comparable rates for the alumni of the *FIRST* robotics programs in this study are 67% for male participants and 47% for female participants suggesting that, at the very least, these types of after-school robotics programs help those who are interested in engineering stay engaged and interested to the point where they can pursue those interests in college.

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