The Impact of After-School Robotics Programs on STEM Interests

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Introduction[1]

Over the past two decades, 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 et al. 2002; TAP Campaign 2005; Committee on Prospering in the Global Economy of the 21st Century 2006; National Science Board 2012). These concerns have led to the development of new standards for science and technology education (National Committee on Science Education Standards and Assessment 1996; International Technology Education Association 2000; National Research Council 2012), new policy initiatives aimed at promoting science and technology education (U.S. Department of Education 2006; America Competes Act 2007; White House Office of Science and Technology Policy 2013), and a growing body of research on math and science learning and the pathways leading to STEM-related careers (Jacobs 2005; Cannady et al. 2014).[2] While some have challenged the picture of looming shortages of scientists and engineers and recent studies have indicated that American students are taking more science and advanced science courses in high school (Lowell 2007; Dalton 2007; National Science Board 2012), concerns persist that in an increasingly knowledge-driven global economy, the United States needs to expand the pipeline into STEM-related careers (National Science Board 2006;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 programs can play to reinforce STEM learning and help engage young people in educational pathways leading to STEM careers. Though there are scattered studies of individual after-school programs and summer science enrichment efforts (Fancsali 2002; Gibson and Chase 2002; Chacon and Soto-Johnson 2003; Markowitz 2004; Weinberg *et al* 2007; Barker and Ansorge, 2007; Welch 2010; Barnett et al 2011), most of the existing studies focus on shorter-term outcomes and/or are based on self-reported impacts, and few incorporate a control or comparison group design (Whitehurst 2004, National Research Council 2015). 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.

FIRST®

This paper presents interim findings from a multi-year longitudinal impact study aimed at assessing the effectiveness of one group of after-school STEM programs – after-school robotics competitions – in increasing STEM interest and attitudes and encouraging students to pursue STEM-related education and career trajectories. The study focuses on students involved in three of the four robotics programs operated by *FIRST*, a nonprofit that provides hands-on STEM learning challenges for students in grades K-12. The three competitive programs –*FIRST®* LEGO® League (grades 4-8), *FIRST®* Tech Challenge (grades 7-12) and *FIRST®* Robotics Competition (grades 9-12) – are among the world's largest robotics programs, engaging over 430,000 middle and high school-aged youth worldwide in annual robotics competitions aimed at strengthening their interest in science and technology while building teamwork,

[1] Portions of this paper have been presented at the 2018 American Educational Research Association Conference (New York, NY, April 2018) and the 2018 American Society for Engineering Education annual conference (Salt Lake City, June 2018).

[2] The website for the University of Michigan's Gender & Achievement Research Program also provides an extensive bibliography of math and science achievement articles at http://www.rcgd.isr.umich.edu/garp/.

project management, communications, and other life skills. While differing in their specific designs and target age groups, all three programs are built on a common model: In each, teams of school-aged youth work together under the guidance of two or more adults (an adult team leader plus technical mentors and other volunteers) to design and build robots that compete with other teams in completing a set of prescribed tasks.[3]

The primary goal of all three programs is to promote increased interest in science and technology and inspire innovation 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 events. 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.

Background

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.

The central hypothesis for the study is that involvement in organized after-school STEM programs like *FIRST* positively influences participants' education and STEM-related attitudes, leading to increased involvement in STEM-related courses and activities in high school and involvement in STEM-related studies and career plans in college. Three major questions guide the study:

- **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 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?

- **What is the relationship between program experience and impact?** To what extent are differences in program experience – such as time in the program, role on the team, quality of the program experience – associated with differences in program outcomes?

- **To what extent are there differences in experiences and impacts among key subpopulations of *FIRST* participants?** In particular, are there differences in impacts by race, gender, family income or among those from urban, rural and suburban communities?

[3] While the focus of this paper is on after-school programs, *FIRST* teams can be school-based or community-based, and meet regularly before, during, or after school.

To address these questions, the *FIRST* Longitudinal Study is tracking 1,273 students (822 *FIRST* participants and 451 comparison students) over five or more years beginning with entry of the *FIRST* participants into the program. *FIRST* participants were recruited to the study from a nationally representative sample of over 200 experienced teams in 10 states from the *FIRST* LEGO League, *FIRST* Tech Challenge, and *FIRST* Robotics Competition. 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. Recruitment took place in two waves, with recruitment of initial group of students in Fall 2012 and recruitment of additional participants in Fall 2013 to increase the overall sample for the study.

Data Collection

Once recruited into the study, team members and comparison students were surveyed at baseline and post-program in their first year, with annual follow-up surveys each spring thereafter. A baseline survey of parents provided additional background information on the family context for team members and comparison students, and Team Leader surveys at the end of the first year of team involvement in the study provided additional contextual data on the *FIRST* teams. Annual surveys have also been supplemented by interviews and focus groups with team members and comparison group students. The initial baseline surveys were administered in Fall 2012 (Wave 1) and Fall 2013 (Wave 2), with annual follow-up surveys each spring thereafter.

As of the Spring 2017 surveys, complete data have been collected through 48 months of follow-up (baseline, post-program, and three annual follow-up surveys). As Exhibit 1 shows, the response rate has been positive: overall 80% of study participants have continued through 48 months, including 74% of program participants and 90% of comparison students.

Exhibit 1: Response Rates Through 48 Months

	Baseline	12 Month Follow-Up (Post-Program)		24 Month Follow-Up		36 Month Follow-Up		48 Month Follow-Up	
	N	N	% of baseline	N	% of baseline	N	% of baseline	N	% of baseline
FIRST Participants	822	677	82.4%	665	80.9%	636	77.4%	611	74.3%
Comparison Students	451	259	57.4%*	411	91.1%	409	90.7%	406	90.0%
Total	**1273**	**936**	**73.5%**	**1076**	**84.5%**	**1045**	**82.1%**	**1017**	79.9%

NOTE: Because the recruitment of Wave 1 comparison students extended until early 2013, the decision was made to not administer Post-Program surveys to Wave 1 comparison students in Spring 2013 and to wait until the next round of surveys (Spring 2014) to conduct a follow-up with that group. Wave 1 comparison students have been included in all subsequent data collections.

Outcome Measures

The major focus of the study is on the impact of program participation on STEM-related interests, attitudes, and behaviors. Key outcomes were developed in collaboration with staff at *FIRST* and with program and technical advisory groups during the planning phase of the study. They 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 behavioral measures such as increased STEM-related course-taking in high school, postsecondary STEM course-taking, selection of college majors, and involvement in STEM-related activities in college. Exhibit 2 provides an overview of the key outcome measures for the study.

Exhibit 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) • STEM Activity (involvement in non-school STEM activities) • STEM Careers (interest in STEM-related careers, such as scientist, engineer, computer specialist, etc.) • STEM Identity (extent to which students see themselves as science, math or technology people) • 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) • College Support (adult support for college readiness/knowledge) • Self-Efficacy/Prosocial Values (self-confidence, sense of belonging and contribution) • 21st Century Skills (Self-assessed life and workplace skills, includes teamwork, problem-solving and communications subscales)	• STEM Course-Taking (High School) • Interest in STEM Majors in College/Declared Majors • STEM-Related College Course-taking • Involvement in College STEM-Activities (Clubs, competitions, internships, summer jobs) • STEM-related College Grants and Scholarships

This paper provides interim (48 month) findings on the impacts on the STEM-related interest and attitude scales and on college-related outcomes for the subgroup of 451 study participants who had at least one year of college as of Spring 2017. Data on impacts on STEM course-taking in high school and longer-term term college outcomes are not yet available. The measures of STEM-related interests and attitudes 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.[4]

Participant and Comparison Group Characteristics

As noted above, 1273 students agreed to participate in the study. Among the *FIRST* participants, 68% were males and 32% females. Approximately 68% of *FIRST* participants were White, 18% were Asian, 9% were African-American; in a separate item, 16% reported that they were Hispanic. Program participants included a mix of students from urban (26%), suburban (51%) and rural (23%) communities; 27% were from families that might be classified as low income (below $50,000 in family income). (Exhibit 3).

Participants and comparison students were relatively well-matched at baseline in terms of basic demographic characteristics and academic background (Exhibit 3). Comparison group members were more likely to be female. Participants and comparison students included comparable proportions of African-American and Hispanic students, though a much higher percentage of program participants were Asian. The two groups had no significant differences in terms of community type and family income. Participants and comparison students reported similar academic backgrounds and aspirations, and there were no significant differences in baseline measures of academic self-concept, support for college-going, self-efficacy and workplace-related skills. There were, however, significant differences at

[4] More detailed information on the specific items and reliability measure for each scale are available in a technical note on the FIRST website: https://www.firstinspires.org/resource-library/first-impact.

baseline in initial interest and involvement in STEM. The parents of *FIRST* participants were more likely to be involved in STEM-related careers and report that they supported involvement in STEM for their children. Program participants also scored significantly higher on baseline measures of STEM-related attitudes. As discussed below, these baseline differences were taken into account in the analysis.

Exhibit 3: Participant and Comparison Group Characteristics at Baseline

Measure	*FIRST*	COMPARISON	ALL
Gender*			
Male	67.8%	41.5%	58.5%
Female	32.2%	58.5%	41.5%
Race/Ethnicity*			
Asian	17.9%	10.2%	15.2%
Black/African-American	8.5%	6.6%	7.8%
White	67.8%	82.9%	73.0%
Ethnicity (NS)			
Hispanic	16.0%	10.0%	14.5%
Geography (NS)			
Urban	26.0%	23.2%	25.0%
Suburban	51.3%	53.0%	51.9%
Rural	22.7%	23.9%	23.1%
Academic Performance - Grades (NS)			
Mostly A's	49.5%	49.4%	49.5%
A's and B's	34.0%	36.4%	34.9%
Student's Educational Aspirations (NS)			
BA Degree or More	95.2%	96.4%	95.7%
Family Income (NS)			
Under $50,000	26.9%	21.7%	25.2%
$50,000- $100,000	32.5%	34.8%	33.2%
$100,000 and over	40.5%	43.5%	41.6%
Parent Employment/Experience in STEM*			
At least 1 Parent ever employed as engineer, scientist, programmer or other STEM field.	49.3%	40.8%	46.3%
Parent Support for STEM*			
Importance of having child participate in STEM activities (Important/Very Important)*	91.5%	75.4%	86.0%
Survey Scales(average baseline scale score)			
STEM Interest*	4.1	3.7	
STEM Activity*	3.4	3.1	
STEM Careers*	4.5	3.7	
STEM Identity*	3.1	2.9	
STEM Knowledge*	5.6	4.9	
Academic Self-Concept	5.71	5.71	
College Support	2.18	2.21	
Self-Efficacy/Prosocial	5.5	5.5	
21st Century Skills	3.1	3.2	
Teamwork/Collaboration subscale	3.3	3.4	
Problem-solving subscale	3.1	3.1	
Communications subscale	2.9	3.0	

Note: An asterisk (*) indicates differences between participants and comparison group members that are statistically significant at p≤.05. (NS) stands for not significant.

Analysis

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 estimates average gains for participants vs. comparison students taking into account differences between the groups at baseline and using data from all points in time (baseline, post-program, and follow-ups). One advantage of this type of analysis for longitudinal studies is that the mixed analysis makes full use of cases with missing data, rather than excluding them from dataset (O'Connell and McCoach 2008, and Singer 1998). The study also incorporates Logistic Regression analysis to examine binary outcomes (for example, increase/no increase in STEM attitudes). 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 (as a proxy for baseline STEM interest), and baseline parental support for STEM. The Mixed Models analysis of scale scores includes baseline scores for the scale being analyzed as a data point in the analysis (hence controlling for baseline differences); the Logit analyses include baseline scale scores as covariates for each scale being measured.

Findings

This paper focuses on the program's impact on a core set of STEM-related attitudinal measures at 48 months after program entry and and on college-related outcomes for the subgroup of 451 study participants who had at least one year of college as of Spring 2017. Analysis of the data from earlier surveys (24 and 36 months after program entry) had found positive impacts on STEM-related attitudes for program participants.[5] The questions for this paper include whether those positive impacts continued to persist as students continue through school and into 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. It is important to note that, as of the 48 month survey, less than half of the *FIRST* program participants responding to the survey were still actively involved in the program: 41.2% (252) of *FIRST* participants had graduated high school and were no longer eligible for *FIRST*, 20.9% (128) had left the program, and 37.8% (231) were still active participants. In that regard, the impacts at 48 months represent a mix of impacts for those still in the program and persisting impacts for those who had left *FIRST*, in some cases several years before.

Impacts on STEM-Related Attitudes and Interests

As Exhibit 4 shows, the 48 month survey data continue to show shows a consistent, positive impact for *FIRST* participants on all five of the STEM-related interest and attitude measures. Based on the "Mixed Models" analysis, *FIRST* participants showed significantly higher scale scores at 48 months than comparison group students on all five measures after adjusting for differences at baseline. In each case, the differences were significant at $p \leq .001$. The effect sizes for each impact were either "large" (the impact on STEM interest) or "medium," indicating that program impacts were not only statistically significant, but large enough to represent a meaningful difference in attitudes and interests.

[5] Earlier reports for the study are available on the FIRST website at: https://www.firstinspires.org/resource-library/first-impact.

Exhibit 4: Mixed Models Results: Impacts on STEM Measures at 48 Months, All Participants

STEM measures	Estimated Outcomes		Difference		Effect Size	
	FIRST	Comparison	Value	Sig.	ω^2	Strength
STEM Interest	4.13	3.70	0.37	0.000	0.15	Large
Involvement in STEM Activity	3.46	3.07	0.39	0.000	0.08	Medium
Interest in STEM Careers	4.33	3.71	0.62	0.000	0.09	Medium
STEM Identity	3.14	2.98	0.16	0.000	0.06	Medium
STEM Knowledge	5.63	4.99	0.64	0.000	0.07	Medium

Note: Controlling for Gender, Race, Honors Courses in HS, Family Income and parental support for STEM. Effect size measure is "Omega Squared" (ω^2). Effect size categories: Small >.01, medium >.06, large >.14

While the "Mixed Models" analysis indicated significantly greater gains in STEM-related attitudes for *FIRST* participants, a second analysis using logistic regression examined whether *FIRST* participants were more likely to show any gain between baseline and 48 months than comparison students. As Exhibit 5 shows, after adjusting for differences in baseline characteristics and baseline scale scores, *FIRST* participants were more likely to show gains on all five measures. The odds ratios from the Logit analysis show that *FIRST* participants were:

- 3.0 times more likely than comparison students to show gains on *STEM interest*;
- 2.2 times more likely to show gains in involvement in *STEM activity*;
- 3.0 times more likely to show gains on interest in *STEM careers*;
- 1.6 times more likely to show gains in *STEM identity*; and
- 2.2 times more likely to show gains in *understanding of STEM.*

All of those differences were highly significant at p≤.001.

Exhibit 5: Logistic Regression (Logit) Results for STEM Scale Scores at 48 Months, All Participants

		Pct. With Increased Scores Baseline to Follow-Up (Unadjusted)		Relative Probability of Increase	
Measure	N	*FIRST* % Increase	Comparison % Increase	Odds Ratio	Sig.
STEM Interest	801	40.6%	27.7%	3.0	0.000
Involvement in STEM Activity	799	47.8%	38.4%	2.2	0.000
Interest in STEM Careers	709	43.5%	26.1%	3.0	0.000
STEM Identity	784	45.8%	45.3%	1.6	0.000
STEM Knowledge	775	51.5%	47.1%	2.2	0.000

Note: Controlling for Gender, Race, Honors Courses in HS, Family Income, parental support for STEM and scale at baseline.

Based on the "Mixed Models" analysis, positive impacts were evident for participants from all three *FIRST* programs in the study (Exhibit 6). Across all three programs *FIRST* participants showed statistically significantly higher scale scores than comparison students at the 48 month follow-up. With the exception of interest in STEM careers among *FIRST* LEGO League participants (who were younger than participants in *FIRST* Tech Challenge and *FIRST* Robotics Competition) effect sizes were either "medium" or "large" (the effect size for the impact on interest in STEM careers for *FIRST* LEGO League participants was "small.")

Exhibit 6: Mixed Models Results: Impacts on STEM Measures at 48 Months, by Program

Measure	*FIRST* LEGO League (N=206)		*FIRST* Tech Challenge (N=248)		*FIRST* Robotics Competition (N=366)	
	Difference (Sig.)	Effect Size	Difference (Sig.)	Effect Size	Difference (Sig.)	Effect Size
STEM Interest	0.347***	Medium	0.457***	Large	0.522***	Large
Involvement in STEM Activity	0.398***	Medium	0.279***	Medium	0.368***	Medium
Interest in STEM Careers	0.363**	Small	0.637***	Medium	0.848***	Large
STEM Identity	0.170***	Medium	0.165***	Medium	0.142***	Medium
STEM Knowledge	0.566***	Medium	0.647***	Medium	0.660***	Large

Note: "Difference" is the difference in scale score between *FIRST* participants and comparable comparison students at 48 months. Analysis controls for Gender, Race, Honors Courses in HS, Family Income and parental support for STEM.
Significance: *p<.05, **p<.01, ***p<.001. Effect sizes (ω^2): Small >.01, medium >.06, large >.14

FIRST participants also showed significant impacts across all of the major population groups in the study and among participants from different types of communities. As Exhibits 7 and 8 show, male and female participants, White and students of color, higher and lower income *FIRST* participants, and those from urban, rural, and suburban communities, all showed significantly greater gains than those of comparable students in the comparison group. In most cases, effect sizes were "medium" or "large."

Exhibit 7: Mixed Models Results: Impacts on STEM Measures at 48 Months, by Population Groups

	Males (N=738)	Females (N=521)	White (N=856)	Students of Color (N=315)	Low Income (N=420)	High Income (N=701)
Difference in Estimated Outcomes at 48 Months						
STEM Interest	0.282***	0.578***	0.453***	0.307***	0.404***	0.457***
Involvement in STEM Activity	0.265***	0.507***	0.386***	0.344***	0.441***	0.367***
Interest in STEM Careers	0.325***	0.928***	0.661***	0.460**	0.654***	0.614***
STEM Identity	0.114***	0.212***	0.170***	0.126**	0.155***	0.171***
STEM Knowledge	0.349***	0.927***	0.664***	0.453**	0.637***	0.667***
Effect Sizes						
STEM Interest	Large	Large	Medium	Medium	Large	Medium
Involvement in STEM Activity	Medium	Large	Medium	Medium	Large	Medium
Interest in STEM Careers	Medium	Large	Medium	Small	Medium	Medium
STEM Identity	Medium	Medium	Medium	Small	Medium	Medium
STEM Knowledge	Medium	Large	Medium	Medium	Large	Medium

Note: "Difference" is the difference in scale score between *FIRST* participants and comparable comparison students at 48 months. Analysis controls for Gender, Race, Honors Courses in HS, Family Income and parental support for STEM.
Significance: *p<.05, **p<.01, ***p<.001. Effect sizes (ω^2): Small >.01, medium >.06, large >.14

Exhibit 8: Mixed Models Results: Impacts on STEM Measures at 48 Months, by Community Type

	Urban (N=301)	Suburban (N=624)	Rural (N=277)
Difference in Estimated Outcomes at 48 Months			
STEM Interest	0.374***	0.458***	0.501***
Involvement in STEM Activity	0.422***	0.359***	0.449***
Interest in STEM Careers	0.730***	0.538***	0.778***
STEM Identity	0.202***	0.153***	0.175***
STEM Knowledge	0.706***	0.675***	0.618***
Effect Sizes			
STEM Interest	Large	Large	Large
Involvement in STEM Activity	Medium	Medium	Medium
Interest in STEM Careers	Large	Medium	Large
STEM Identity	Medium	Medium	Medium
STEM Knowledge	Large	Medium	Medium

Note: "Difference" is the difference in scale score between *FIRST* participants and comparable comparison students at 48 months. Analysis controls for Gender, Race, Honors Courses in HS, Family Income and parental support for STEM.
Significance: *p<.05, **p<.01, ***p<.001. Effect sizes (ω^2): Small >.01, medium >.06, large >.14

While both young women and men in *FIRST* showed significantly greater gains than their comparison group counterparts, the gains for female *FIRST* participants were significantly greater than those for program participants as a whole (Exhibit 9). That is, young women in *FIRST* showed additional, statistically significant gains beyond those for *FIRST* participants generally.

Exhibit 9: Mixed Models Results: Differential Impacts on Females in *FIRST*

Measure	Difference in Outcomes - *FIRST* vs. Comparison	Sig.	Additional Impacts for *FIRST* Females (Female**FIRST* interaction)	Sig.
STEM Interest	0.270	0.000	0.326	0.000
Involvement in STEM Activity	0.263	0.000	0.250	0.009
Interest in STEM Careers	0.311	0.024	0.626	0.000
STEM Identity	0.111	0.003	0.102	0.020
STEM Knowledge	0.340	0.041	0.608	0.000

Note: "Difference" is the difference in scale score between *FIRST* participants and comparable comparison students at 48 months. Analysis controls for Gender, Race, Honors Courses in HS, Family Income and parental support for STEM.

An analysis of impacts by length of time in the program (one year vs. two or more years) shows that young people who participated in *FIRST* for only a single year still showed statistically significant gains relative to comparison students that persisted at 48 months; those who stayed in the program for two or more years showed even greater gains (Exhibit 10). It is important to note that those who persisted in the program beyond the first year were self-selected (rather than randomly assigned), so it is difficult to draw conclusions about the value of one year vs. two years in the program based on this data.

However, the fact that even those who participated for only a single year showed significant impacts is notable.

Exhibit 10: Mixed Model Results: Impacts on STEM Measures at 48 Months, by Time in Program

STEM measures	Marginal Means at 48 Months			Difference: 1 YR vs. Comparison		Difference: >1 YR vs. Comparison	
	1 Year in FIRST	2 or More Years in FIRST	Compar-ison Group	Value	Sig.	Value	Sig.
STEM Interest	4.06	4.20	3.69	0.37	*0.000*	0.50	*0.000*
Involvement in STEM Activity	3.37	3.52	3.06	0.32	*0.000*	0.46	*0.000*
Interest in STEM Careers	4.16	4.48	3.69	0.47	*0.000*	0.79	*0.000*
STEM Identity	3.11	3.17	2.97	0.13	*0.000*	0.19	*0.000*
STEM Knowledge	5.51	5.75	4.98	0.53	*0.000*	0.77	*0.000*

Note: Controlling for Gender, Race, Honors Courses in HS, Family Income and parental support for STEM.

College-Related Impacts

In addition to examining the 48 month impacts on the participant sample as a whole, this interim analysis also examined impacts on a subset of study participants who had enrolled in at least one year of college as of the summer of 2017. As noted above, that sample included 451 study participants: 289 *FIRST* program alumni and 162 comparison group members. For those students, the key question is whether the positive impacts on attitudes and interests carry forward into college, and whether participation in *FIRST* also resulted in increased interest in STEM-related majors, STEM course-taking, and involvement in other STEM-related activities in college.

For each of the measures examined, *FIRST* continued to show positive impacts into the first year of college. As Exhibit 11 shows, *FIRST*'s impacts in STEM-related interests and attitudes continued to persist among those program alumni who had entered college. On all five STEM-related measures, *FIRST* alumni in their first year of college continued to show higher scale scores than college-going comparison students. All of those differences were statistically significant at p≤ .001. The effect size for those impacts were substantial, with "large" effect sizes for the impacts on STEM interest, interest in STEM careers, and STEM knowledge, and "medium" effect sizes on STEM activity and identity.

Exhibit 11: Mixed Models Results: Impacts on STEM Measures at 48 Months, First-Year College-Goers

STEM measures	Estimated Outcomes		Difference		Effect Size	
	FIRST	Comparison	Value	Sig.	ω^2	Strength
STEM Interest	4.25	3.73	0.52	0.000	.21	Large
Involvement in STEM Activity	3.45	3.08	0.36	0.000	.10	Medium
Interest in STEM Careers	4.40	3.64	0.76	0.000	.14	Large
STEM Identity	3.20	3.03	0.17	0.000	.10	Medium
STEM Knowledge	5.91	5.28	0.63	0.000	.15	Large

Note: Controlling for Gender, Race, Honors Courses in HS, Family Income and parental support for STEM. Effect size measure is "Omega Squared" (ω^2). Effect size categories: Small >.01, medium >.06, large >.14. N=451.

Participation in *FIRST* also had a positive impact on reported interest in STEM majors at college, though with a clear distinction between Engineering and technology-related majors and other STEM fields. Exhibit 12 shows the percent of all first year college students who were "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 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 *FIRST* participants are *more* likely to be interested; a ratio below 1 indicated that *FIRST* 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 were nearly twice as likely (1.8 times) to be interested in majoring in Computer Science, 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 reported being "very interested" in majoring in Engineering; 40% reported high interest in Computer Science and 40% were interested in majoring in Robotics during their first year of college.

It is important to note that there were significant differences in interest in the other direction in other STEM-related fields. While *FIRST* alumni were more interested in Engineering and technology-related fields, comparison group members showed 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 .351). These differences were also statistically significant.

Exhibit 12: Interest in College Majors (Percent Highly Interested)

	Percent Highly Interested (Unadjusted)		Relative Likelihood of Being Interested (Logit)	
	FIRST	**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
Tech/ 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, Parental Support for STEM and baseline STEM interest. Bold italics are statistically significant at p≤.05. "Highly Interested" is based on responding 6, 7, or "already declared" on a scale of 1 to 7 for each major field.

FIRST alumni were statistically significantly 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 Exhibit 13 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.

Exhibit 13: 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, Parental Support for STEM and Baseline STEM interest

The positive impacts on interest in engineering and technology majors and course-taking were also evident when the results are broken down by gender. In particularly, female *FIRST* alumni were more than 3.2 times more to be interested in majoring in engineering, 3.1 times more likely to be interested in majoring in computer science, and 5.1 times more likely to be interested in majoring in robotics than female comparison students. Female FIRST alumni were also 2.3 times more likely to take an engineering course in their first year of college than female comparison students. All of those results were statistically significant at $p \leq .05$.

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 Exhibit 14 shows, *FIRST* 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.

Exhibit 14: 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 bold indicates statistically significant at p≤.05, based on Chi Sq. analysis. For summer jobs, comparison group was more likely to have a summer job; *FIRST* alumni were more likely to have a STEM-related summer job.

Discussion

A key question for this study is whether after-school robotics programs like *FIRST* are effective in promoting and supporting the kinds of interests and attitudes likely to lead to sustained involvement in STEM. The work of multiple scholars suggests that increased interest in STEM, a sense of STEM identity, an understanding of the relevance and utility of STEM in the real world, and the kinds of career opportunities available all promote increased involvement in STEM-related education and careers.

The data presented here suggests that these types of intensive, hands-on afterschool STEM experiences do have a positive impact on STEM-related attitudes and interests for middle and high school aged youth and that these impacts persist beyond secondary school and into college. Longitudinal survey data collected over a 4-year period from *FIRST* participants and comparison students show positive, statistically significant impacts on a core set of STEM-related attitudes for program participants as a whole and for each of a number of key subgroups in the study sample, including both male and female participants, White students and students of color, low and higher income participants, and students from urban and rural, as well as suburban communities. In most cases, not only were the differences in STEM-related attitudes and interests statistically significant, but the effect size measures indicate that the differences were large enough to represent a meaningful difference in attitudes and interests.

The data from first-year college students in the study demonstrate that the positive impacts persist beyond high school and into college. At this point in time the data on college students must be seen as preliminary as the number of study participants who had entered college by the time of the 48 month

survey is limited. However, the initial college data reported here suggest that not only do the impacts on STEM-related attitudes persist into college, but that they are reflected in the choices that *FIRST* alumni make about college majors, first-year courses, and engagement in STEM-related co-curricular activities.

In one of the more exciting findings, the data also indicate that this type of after-school STEM program can have a particularly powerful impact on female participants. While the recruitment of young women into robotics programs like *FIRST* remains a challenge (approximately a third of *FIRST* participants are female), the young women who participated showed significantly greater impacts on STEM-related attitudes than the male participants in the program. Female alumni also showed strong, statistically significant impacts on interest in engineering-related majors and first year college course-taking. Interviews with female program participants and responses to open-ended questions in the annual surveys suggest that many young women felt that *FIRST* had provided a unique opportunity to be exposed to engineering and robotics and to discover their own talents in what are traditionally seen as male-dominated fields.

There are some important limitations to the study. The study uses a comparison group design (random assignment was not feasible) and there are significant differences in baseline attitudes between *FIRST* participants and comparison students. While the statistical analysis takes those differences into account, it is possible that there are unmeasured differences that are not reflected in the analysis. We continue to look for ways to further test our findings in that regard. The study also focuses on one particular group of programs (*FIRST*) in one STEM area of interest (robotics). Other robotics programs and other types of after-school STEM activities may have different outcomes. Ideally, other researchers can begin examining the broader array of after-school STEM programming. Finally, the 48 month data presented here represent interim findings for the study. Current plans call for collection of survey data for at least another year and likely beyond. With that additional data, we should be able to continue to examine even longer-term impacts on STEM-related attitudes as well as impacts on longer-term educational and career decisions.

Within those limitations, however, the data currently in hand strongly suggest that the afterschool STEM programs like *FIRST* can have a positive, long-term impact on participant attitudes about STEM and on the decisions they make about what they will study in college. It is worth noting that the study continues to show positive impacts on STEM attitudes and interests at 48 months despite the fact that, at the time of the 48 month surveys, more than half of the *FIRST* participants had ended their participation in the program. For the college-level sample, the *FIRST* alumni had left high school and *FIRST* least a year prior to taking the most recent survey for this study. In both cases, program participants continued to show a significantly stronger interest in STEM and STEM careers and continued to think of themselves as "STEM people" to a greater degree than comparison students. Those differences in attitudes were 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.

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