

Do After-school Robotics Programs Expand the Pipeline into STEM Majors in College? (RTP)

Dr. Cathy Burack, Brandeis University

Dr. Cathy Burack is an Associate Director and Senior Fellow for Higher Education at the Center for Youth and Communities in the Heller School for Social Policy and Management at Brandeis University. For the past twenty-five years Cathy has focused on two interrelated areas: access to higher education, especially by students who are among the first in their families to attend; and the ways in which colleges and universities engage with their communities. Cathy works with colleges, universities, and community organizations to use evaluation to both "prove" and "improve" their programs. Her research and capacity-building efforts attend to both outcomes and systemic change. To that end Cathy has conducted evaluations of campus-based change initiatives including conducting a national evaluation of institutional support for civic engagement, developing indicators associated with student success, helping to set up the Corporation for National and Community Service Learn and Serve America LASSIE national data collection system, and conducting multi-site evaluations on campus-wide change initiatives. Cathy recently was co-Principal Investigator of the evaluation of the Campus Compact Connect to Complete (C2C) initiative, a pilot peer-support program for low income and first generation students at nine community colleges, funded by the Bill and Melinda Gates Foundation. Cathy's recent work includes investigating pathways to post-secondary majors in STEM. She was an evaluation partner to Girls Who Code, and is currently the co-Principal evaluator of the longitudinal evaluation of the FIRST robotics program.

Mr. Alan Melchior, Brandeis University

Alan Melchior is a Senior Fellow at the Center for Youth and Communities at Brandeis University's Heller School for Social Policy and Management. He brings over twenty-five years of experience evaluating a wide variety of initiatives in the fields of youth, workforce, and community development.

Mr. Melchior has served as the lead evaluation partner for the FIRST robotics programs since 2002 and has conducted more than a dozen studies of FIRST's national after-school robotics programs. He is currently the co-Principal evaluator on the multi-year longitudinal impact study of FIRST programs.

Matthew Hoover, Brandeis University

Matthew Hoover is a Senior Research Associate at the Center for Youth and Communities at Brandeis University.

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Majors in College?

I. 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 [1], [2], [3]. These concerns have led to the development of new standards for science and technology education [4], [5], [6], policy initiatives aimed at promoting science and technology education [7], [8],[9], and to a growing body of research on math and science learning and the pathways leading to STEM-related careers [10], [11]. 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 [12], [13], [3], 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 [3], [14].

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 is 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 [15], [16]. Though there are scattered studies of individual after-school programs and summer science enrichment efforts [17], [18], [19],[20], [21], [22], [23],[24], 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 [25]. 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>.

II. 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"[26]. 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 [27], [28], [26], [29].

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 [30], [31]. 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 [32], [29]. 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 [21], [22]. The Social Cognitive Career Theory developed by Lent, Brown and Hackett suggests that these kinds of learning experiences can influence the sense of self-efficacy, outcomes expectations, interests and goals that inform the career choices that young people make [33]. Maltese and Tai 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 [34]. 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 [35], [36], [37]. 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 [38], [39]. 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 [40], [41],[42], [4].

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 [30]. 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 [13]. 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 et al 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 [43]. 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 [44]. 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 [45], [27], [46], [47], [14], [48]. 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 [49], [30], and experiences that highlight the social utility of engineering [31]. 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 ([50], [51], [52], [53]). 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.

III. *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 ages 6-18 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.

IV. 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 afterschool 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 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). Exhibit 1 shows the survey response rates for the study through 48 months.

Exhibit 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
<i>FIRST</i> 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%

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*. Exhibit 2 provides an overview of the key outcome measures.

Exhibit 2: Key Outcome Measures

STEM-Related Interest and Attitude Scales	Personal Development and Workplace-Related Scales	Behavioral Measures
<ul style="list-style-type: none"> • 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). 	<ul style="list-style-type: none"> • 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) 	<ul style="list-style-type: none"> • 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

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 [54]. 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 female. 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. Exhibit 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.

Exhibit 3: Demographic Characteristics of Sample

Characteristic	N	Percent of Total
<i>Total Sample</i>	451	
<i>FIRST</i> Participant	289	64.1%
Comparison Group member	162	35.9%
<i>Gender</i>		
Male	265	59.3%
Female	182	40.7%
Missing	4	
<i>Race/Ethnicity</i>		
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	

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 [55][56]. 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.

V. Findings

Data from prior years surveys (24 and 36 months) has 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 points 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 Exhibit 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.

Exhibit 4: Impact on STEM and Non-STEM Attitudes

STEM measures	Marginal Means at 48 Months			
	<i>FIRST</i> 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	<i>FIRST</i> 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

The positive impact on STEM-related measures is also evident when the data are broken down by gender. Exhibit 5 below 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 (Exhibit 6).

Exhibit 5: STEM Measures by Gender

STEM measures	Marginal Means at 48 Months			
	<i>FIRST</i> 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				
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

Exhibit 6: Additional Impact of Interaction Effect for Female *FIRST* Participants

Measure	<i>FIRST</i> Participants compared to Comparison Students	Sig.	Female x 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.

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. Exhibit 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 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 indicated 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 .351). These differences were also statistically significant.

Majors were also analyzed to examine differences in program impact by gender (Exhibit 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 is 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 girls in the comparison group.

Exhibit 7: Interest in College Majors (Percent Highly Interested)

	Percent Highly Interested (Unadjusted)		Relative Likelihood of Being Interested (Logit)	
	<i>FIRST</i> Participants	Comparison	Sig.	Odds Ratio
Arts and Humanities	12.3%	23.1%	0.461	0.763
<i>Biological Sciences</i>	<i>15.6%</i>	<i>31.2%</i>	<i>0.000</i>	<i>0.301</i>
Business	21.8%	21.4%	0.626	1.165
<i>Computer Science</i>	<i>44.0%</i>	<i>22.2%</i>	<i>0.037</i>	<i>1.824</i>
Education	7.9%	13.3%	0.380	0.672
<i>Engineering</i>	<i>59.9%</i>	<i>25.5%</i>	<i>0.004</i>	<i>2.322</i>
<i>Health Professions</i>	<i>15.1%</i>	<i>33.3%</i>	<i>0.002</i>	<i>0.351</i>
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
<i>Robotics</i>	<i>40.2%</i>	<i>10.8%</i>	<i>0.000</i>	<i>3.875</i>

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 $p \leq .05$. “Highly Interested” is based on responding 6, 7, or “already declared” on a scale of 1 to 7 for each major field.

Exhibit 8: Interest in College Majors by Gender (Percent Highly Interested)

	Percent Highly Interested (Unadjusted)		Relative Likelihood of Being Interested (Logit)	
	<i>FIRST</i> Participants	Comparison	Sig.	Odds Ratio
<i>Males</i>				
Arts and Humanities	9.8%	18.8%	0.955	1.031
<i>Biological Sciences</i>	<i>11.6%</i>	<i>31.9%</i>	<i>0.000</i>	<i>0.181</i>
Business	22.7%	22.9%	0.924	1.039
Computer Science	49.4%	31.4%	0.327	1.406
<i>Education</i>	<i>5.8%</i>	<i>14.9%</i>	<i>0.032</i>	<i>0.287</i>
<i>Engineering</i>	<i>66.9%</i>	<i>35.8%</i>	<i>0.050</i>	<i>2.071</i>
<i>Health Professions</i>	<i>10.5%</i>	<i>25.8%</i>	<i>0.015</i>	<i>0.285</i>
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
Tech/ Vocational	17.0%	18.8%	0.275	0.627
Other Professional	8.3%	15.9%	0.325	0.592
<i>Robotics</i>	<i>45.0%</i>	<i>14.5%</i>	<i>0.003</i>	<i>3.460</i>

Exhibit 8: Interest in College Majors by Gender, continued

	Percent Highly Interested (Unadjusted)		Relative Likelihood of Being Interested (Logit)	
	<i>FIRST</i> Participants	Comparison	Sig.	Odds Ratio
<i>Females</i>				
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
<i>Computer Science</i>	33.3%	11.8%	0.036	3.053
Education	12.5%	12.3%	0.365	1.902
<i>Engineering</i>	46.9%	15.7%	0.017	3.159
<i>Health Professions</i>	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
Tech/ Vocational	6.0%	3.5%	0.868	1.195
Other Professional	10.7%	21.2%	0.269	0.518
<i>Robotics</i>	30.1%	4.7%	0.011	5.057

Logit Regression controlling for Program, Race, Honors Courses at Baseline, Family Income, Parental Support for STEM and Baseline STEM interest

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 Exhibit 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.

Exhibit 9: First Year Course-Taking

	Percent Taking at Least 1 Course (Unadjusted)		Relative Likelihood of Taking a Course (Logit)	
	<i>FIRST</i> Participants	Comparison Group	Sig.	Odds Ratio
<i>Arts and Humanities</i>	56.4%	66.0%	0.013	0.544
<i>Biological Sciences</i>	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
<i>Engineering</i>	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
<i>Social Sciences</i>	31.8%	51.9%	0.000	0.396
Technical/ Vocational	2.8%	2.5%	0.820	0.841
<i>Other Professional Fields (Law, medicine, etc.)</i>	2.1%	11.1%	0.019	0.284

Logit Regression controlling for Program, Race, Honors Courses at Baseline, Family Income, Parental Support for STEM and Baseline STEM interest

Among women the difference is even more substantial: while male *FIRST* alumni are 2.3 times more likely to take a 1st year engineering course, female alumni are 3.4 times more likely to take a first year engineering course than female comparison students (Exhibit 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 Exhibit 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.

Exhibit 10: First Year Course-Taking by Gender

	Percent Taking at Least 1 Course (Unadjusted)		Relative Likelihood of Taking a Course (Logit)	
	<i>FIRST</i> Participants	Comparison Group	Sig.	Odds Ratio
<i>Males</i>				
Arts and Humanities	53.1%	62.0%	0.135	0.621
<i>Biological Sciences</i>	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
<i>Education</i>	0.5%	5.6%	0.045	0.089
<i>Engineering</i>	49.0%	26.8%	0.051	1.861
<i>Health Professions</i>	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
<i>Social Sciences</i>	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
<i>Females</i>				
<i>Arts and Humanities</i>	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
<i>Engineering</i>	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
<i>Social Sciences</i>	28.7%	53.4%	0.004	0.348
Technical/ Vocational	3.2%	2.3%	0.672	0.626
<i>Other Professional Fields</i>	2.1%	13.6%	0.049	0.201

Logit Regression controlling for Program, Race, Honors Courses at Baseline, Family Income, Parental Support for STEM and Baseline STEM interest

Exhibit 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 bold indicates statistically significant at p=.05 or less, 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.

VI. Discussion

The data presented here represent an initial effort to assess the longer-term impacts of participation in afterschool 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.

The data currently in hand, however, strongly suggest that the afterschool 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 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 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 this type 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 the 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 findings 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 [57]. 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.

References

- [1] P. B. Campbell, E. Jolly, et al., "Upping the Numbers: Using Research-Based Decision Making to Increase Diversity in the Quantitative Disciplines," *A Report Commissioned by the GE Fund*, GE Fund. 2002.
- [2] TAP Campaign, *Tapping America's Potential: The Education for Innovation Initiative*. http://tapcoalition.org/resource/pdf/TAP_report2.pdf , 2005.
- [3] National Science Board, *National Science and Engineering Indicators 2012*. Arlington, VA, National Science Foundation, 2012.
- [4] National Committee on Science Education Standards and Assessment, N. R. C., *National Science Education Standards*, Washington, DC: National Academy Press, 1996.
- [5] International Technology Education Association, *Standards for Technological Literacy: Content for the Study of Technology*, Reston, VA: International Technology Education Association, 2000.
- [6] National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, Washington, DC: The National Academies Press, 2012.
- [7] America COMPETES Reauthorization Act. (P.L. 111-358), 2010.
- [8] U.S. Department of Education, Office of the Secretary, *Answering the Challenge of a Changing World: Strengthening Education for the 21st Century (American Competitiveness Initiative)*. Washington, DC: U.S. Department of Education, 2006.
- [9] White House Office of Science and Technology Policy, *Preparing a 21st Century Workforce*, from www.whitehouse.gov/ostp., 2013.
- [10] J.E. Jacobs and S. D. Simpkins, "Mapping leaks in the math, science, and technology pipeline," *New Directions for Child and Adolescent Development*, 2005(110):2005, pp. 3-6.
- [11] M. Cannady, E. Greenwald, and K. Harris, "Problematizing the STEM Pipeline Metaphor: Is the STEM Pipeline Metaphor Serving Our Students and the STEM Workforce?," *Science Education Policy*, 98: 2014, pp. 443-460.
- [12] B. L. Lowell and H. Salzman, *Into the Eye of the Storm: Assessing the Evidence on Science and Engineering Education, Quality, and Workforce Demand*, Washington, DC: The Urban Institute, 2007.
- [13] B. Dalton, S. J. Ingels, et al. *Advanced Mathematics and Science Coursetaking in the Spring High School Senior Classes of 1982, 1992, and 2004*. Washington, DC, National Center for Educational Statistics, Institute of Education Sciences, U.S. Department of Education: NCES 2007-312, 2007.

- [14] U.S. Congress Joint Economic Committee, *STEM Education: Preparing for the Jobs of the Future*. from https://www.jec.senate.gov/public/_cache/files/6aaa7e1f-9586-47be-82e7-326f47658320/stem-education---preparing-for-the-jobs-of-the-future-.pdf , 2012.
- [15] C. J. Chung, "Designing Robot Competitions," *2006 Robotics Education Symposium: Strengthening STEM Education Through the Use of Standards-Based Assessments for Robotics Competition*, Washington, DC., 2006.
- [16] Technology Student Association, "TSA Facts," from <http://www.tsaweb.org/TSA-Facts>, 2018.
- [17] M. Barnett, M. Vaughn, E. Strauss, & L. Cotter, "Urban environmental education: leveraging technology and ecology to engage students in studying the environment," *International Research in Geographical & Environmental Education*, 20(3), 2011. pp. 199-214. doi:10.1080/10382046.2011.588501
- [18] B. S. Barker and J. Ansorge, "Robotics as Means to Increase Achievement Scores in an Informal Learning Environment," *Journal of Research on Technology in Education*, 39(3), 2007, pp. 229-243. Retrieved from EBSCOhost.
- [19] P. Chacon and H. Soto-Johnson, "Encouraging Young Women to Stay in the Mathematics Pipeline: Mathematics Camps for Young Women," *School Science & Mathematics*, 103(6): pp. 274-284, 2003.
- [20] C. Fancsali, *What We Know about Girls, STEM, and Afterschool Programs*, *Science, Gender, and Afterschool: Creating a Research/Action Agenda*; Washington, DC, American Association for the Advancement of Science, Academy for Educational Development, 2002.
- [21] H. Gibson and C. Chase, "Longitudinal impact of an inquiry-based science program on middle school students' attitudes towards science," *Science Education* 86: 2002, pp. 693-705.
- [22] D. G. Markowitz, "Evaluation of the Long-Term Impact of a University High School Summer Science Program on Students' Interest and Perceived Abilities in Science," *Journal of Science Education and Technology*, 12(3): 2004, pp. 395-407.
- [23] A. G. Welch, "Using the TOSRA to Assess High School Students' Attitudes toward Science after Competing In the *FIRST* Robotics Competition: An Exploratory Study." *Eurasia Journal of Mathematics, Science & Technology Education*, 6(3), 2010, pp. 187-197.
- [24] J. Weinberg, J. Pettibone, S. Thomas, M. Stephen, and C. Stein, "The impact of robot projects on girls' attitudes toward science and engineering." Available at <http://www.siue.edu/engineering/pdf/WeinbergRSSWorkshop2007.pdf>. , 2007.
- [25] G. J. R. Whitehurst, "Research on Science Education," *Secretary's Science Summit, U.S. Department of Education*. Washington, DC 2004.
- [26] A. Wigfield and J. S. Eccles, "Expectancy-Value Theory of Achievement." *Contemporary Educational Psychology*, 25: 2000, pp. 68-81.

- [27] G. N. Crombie, N. Sinclair, et al. (2005). "Predictors of Young Adolescents' Math Grades and Course Enrollment Intentions: Gender Similarities and Differences." *Sex Roles*, 53(5/6): 2005, pp. 351-367.
- [28] A. Wigfield, "Expectancy-Value Theory of Achievement Motivation: A Developmental Perspective," *Educational Psychology Review*, 6(1): 1994, pp.49-78.
- [29] S. D. Simpkins, P. E. Davis-Kean, et al., "Math and Science Motivation: A Longitudinal Examination of the Links Between Choices and Beliefs," *Developmental Psychology*, 42(1): 2006, 70-83.
- [30] K. A. Updegraff and J. S. Eccles, "Course Enrollment at Self-Regulatory Behavior: Who Takes Optional High School Math Courses?," *Learning and Individual Differences*, 8(3): 239, 1996.
- [31] J. S. Eccles, "Where are all the Women? Gender Differences in Participation in Physical Science and Engineering," *Why Aren't More Women in Science?* S. J. Ceci and W. M. Williams. Washington, DC, American Psychological Association: 2007, pp. 199-210.
- [32] J. E. Jacobs, L. L. Finken, et al, "The Career Plans of Science-Talented Rural Adolescent Girls," *American Educational Research Journal*, 35(4): 1998, pp. 681-704.
- [33] R. Lent, S. Brown, and G. Hackett, "Toward a Unifying Social Cognitive Theory of Career, Academic Interest, Choice and Performance," *Journal of Vocational Behavior*, 45: 1994, pp. 79-122.
- [34] A. Maltese and R. Tai, "Pipeline Persistence: Examining the Association of Educational Experiences with Earned Degrees in STEM Among U.S. Students," *Science Education Policy*, 95: 2011, pp. 877-907.
- [35] J. P. Connell, "Educational Risk and Resilience in African American Youth: Context, Self, and Action Outcomes in School," *Child Development*, 65: 1994, pp. 493-506.
- [36] Institute for Research and Reform in Education, *Research Assessment Package for Schools (RAPS): Manual for Elementary and Middle School Assessments*, Institute for Research and Reform in Education, 1998.
- [37] E. A. Skinner, J. G. Wellborn, et al. "What It Takes to Do Well in School and Whether I've Got It: A Process Model of Perceived Control and Children's Engagement and Achievement in School," *Journal of Educational Psychology* 82(1): 1990, pp. 22-32.
- [38] R. Larson, R. Jarrett, et al. (2004). "Organized Youth Activities as Contexts for Positive Development," in *Positive Psychology in Practice: From Research to Application*, A. Linley and S. Joseph. New York, Wiley, 2004, pp. 540-560.
- [39] R. Larson, and K. Walker, "Learning about the 'Real World' in an Urban Arts Program," *Journal of Adolescent Research*, 21: 2006, pp. 244-268.

- [40] Partnership for 21st Century Skills, *21st Century Skills, Education and Competitiveness: A Resource and Policy Guide*, 2008.
http://www.p21.org/storage/documents/21st_century_skills_education_and_competitiveness_guide.pdf
- [41] North Central Regional Educational Laboratory and the Metiri Group, *enGauge 21st Century Skills: Literacy in the Digital Age*, 2003. <http://pict.sdsu.edu/engauge21st.pdf>
- [42] Accreditation Board for Engineering and Technology, E. A. C. *2016-2017 Criteria for Accrediting Engineering Programs*, Baltimore, MD, 2015.
- [43] A. Melchior, F. Cohen, T. Cutter and T. Leavitt. "More than Robots: An Evaluation of the FIRST Robotics Competition, Participant and Institutional Impacts." Waltham, MA: Center for Youth and Communities, Brandeis University. Prepared for FIRST, April 2005.
- [44] X. Chen, *STEM Attrition: College Students' Paths Into and Out of STEM Fields (NCES 2014-001)*, National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, Washington, DC., 2013.
- [45] S. Catsambis, "The Path to Math: Gender and Racial-Ethnic Differences in Mathematics Participation from Middle School to High School," *Sociology of Education*, 67: 1994. pp. 199-215.
- [46] J. S. Eccles, "Understanding Women's Educational and Occupations Choices," *Psychology of Women Quarterly* 18: 1994, pp. 585-609.
- [47] National Science Board, *Science and Engineering Indicators 2006*. Arlington, VA: National Science Foundation, 2006.
- [48] U.S. Department of Education, Office for Civil Rights, *Gender Equality in Education: A Data Snapshot*, Washington, DC: U.S. Department of Education, 2012.
- [49] V. E. Lee. and D. T. Burkam, "Gender Differences in Middle Grade Science Achievement: Subject Domain, Ability Level, and Course Emphasis," *Science Education*, 80(6): 1996, pp. 613-650.
- [50] M. M. Bleeker and J. E. Jacobs, "Achievement in Math and Science: Do Mothers' Beliefs Matter 12 Years Later?," *Journal of Educational Psychology*, 96(1): 2004, pp. 97-109.
- [51] K. Dabney, D. Chakraverty, D., and R. Tai, R. "The Association of Family Influence and Initial Interest in Science." *Science Education*, 97:2013, pp. 395-409.
- [52] J.E. Jacobs and M. M. Bleeker, "Girls' and boys' developing interests in math and science: Do parents matter?," *New Directions for Child and Adolescent Development*, 2004(106): 2004, pp. 5-21.
- [53] S. D. Simpkins, P. E. Davis-Kean, et al., "Parents' Socializing Behavior and Children's Participation in Math, Science and Computer Out-of-School Activities," *Applied Developmental Science*, 9(1): 2005, pp. 14-30.

[54] U.S. Department of Education, National Center for Educational Statistics (n.d). *High School Longitudinal Study of 2009. Student Questionnaire, Base Year*, Available at: <http://nces.ed.gov/surveys/hsls09/questionnaires.asp>, 2009.

[55]A. A. O'Connell and D.B. McCoach, eds., *Multilevel Modeling of Educational Data*, Charlotte, NC: Information Age Publishing, 2008.

[56]J. D. Singer, "Using SAS PROC MIXED to Fit Multi-Level Models, Hierarchical Models, and Individual Growth Models," *Journal of Educational and Behavioral Statistics*, 24(4), 1998, pp. 323-355.

[57] National Science Foundation, National Science Board, Science and Engineering Indicators 2016 (NSB-2016-1), Alexandria, VA: National Science Foundation, Figure 2.1, January 2016.