AC 2012-2994: THE IMPACT OF PARTICIPATION IN VEX ROBOTICS COMPETITION ON MIDDLE AND HIGH SCHOOL STUDENTS' INTEREST IN PURSUING STEM STUDIES AND STEM-RELATED CAREERS

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The Impact of Participation in VEX Robotics Competition on Middle and High School Students' Interest in Pursuing STEM Studies and STEM-related Careers

VEX Robotics Competition (VRC) is an international program for middle and high school students that has as its goal to engage student participants in the study of science, technology, engineering, and math (STEM) through a competition in which students build innovative robots to solve a challenge. Currently, over 3500 teams representing 20 countries compete globally each year in VRC. Through the competition, students are expected to devise creative solutions to difficult problems, work as a team, learn sportsmanship, communicate effectively, and build leadership skill.

An important objective of VEX Robotics Competition is to inspire students to pursue STEM-related education and career paths. As explained in the VEX Robotics Competition Gateway manual[7],

> *The world needs the students of today to become the scientists, engineers, and problem solving leaders of tomorrow. The constant breakthroughs in chemistry, medicine, materials and physics reveal a new set of challenges and create an even greater opportunity for problem solving through technology. These problems are not academic; the solutions could help save the world and those technology problem solvers will be the ones to make it possible.*
>
> *This underscores the dramatic challenge we face: there are not enough high school graduates choosing technology related disciplines in college. This does not reflect a lack of capacity for new students on the part of technical schools and universities, but a lack of interested and qualified applicants. In short, we will not have the people we require in the next generation to solve the problems of tomorrow unless the shortage is directly addressed today. Who will solve the world's next great crisis?*
>
> *Recognizing this dilemma, scores of organizations are creating programs designed to attract and engage young students in the study of science and technology. Many have found that robotics is a very powerful platform to attract and hold the attention of today's multi-tasking, connected youths. Robotics has strong appeal to this intensely competitive generation and represents the perfect storm of applied physics, mathematics, computer programming, digital prototyping and design, integrated problem solving, teamwork and thought leadership. Students with a previously undiscovered aptitude for STEM (Science, Technology, Engineering, and Math) curriculum are flourishing in growing numbers due to the efforts of schools, volunteer organizations, corporations, and governments internationally.*
>
> *The VEX Robotics Competition, operated by the Robotics Education and Competition Foundation, is a program that inspires thousands of students worldwide to pursue STEM-related education and career paths.* (p. 1)

In order to determine whether VRC was meeting its goal of inspiring students to pursue STEM education and career paths, the *Robotics Education and Competition Foundation* contracted with our team to conduct an external evaluation of the competition. This research paper describes findings from the evaluation, which was completed in May 2011. Three hundred forty-one (341) middle and high school students and 345 VRC Team Leaders completed online surveys that measured perceptions of the impact of VRC participation on student interest in STEM education and STEM careers. In addition, 70 students were interviewed in focus groups, and 37 Team Leaders were interviewed one-on-one and in focus groups, which allowed participants to provide in-depth responses about ways VRC participation impacted student interest in STEM education and careers. Although the evaluation covered a much broader set of outcomes (e.g., teamwork, sportsmanship, engagement, self-efficacy), only the results related to STEM interest are included in this paper.

Review of Literature

Though there is no published research on the effects of robotics competitions, several evaluations have been conducted, including studies of *FIRST* LEGO® League (FLL), *FIRST* VEX Challenge (FVC), and *FIRST* Robotics Competition (FRC). A study by Melchior, Cutter, and Cohen (2005a)[3] of FLL that focused on low income, urban participants (ages 9-14) found increases in student interest in science and technology. Survey data indicated that 94% of coaches reported gains in interest in science and technology, and 50% reported increased interest in math and science classes. In addition, over 90% of surveyed students said participating in FLL had increased their interest in learning about computers, robotics, science, and technology. Over 70% said their interest in science and technology careers had increased.

These results were comparable to the initial 2003 evaluation of FLL, which used the same surveys and data collection techniques but with a larger, more representative group of participants. A 2009 study of FLL (Melchior, Cutter, & Deshpande[5]) found similar results. For example, 80% of coaches indicated their students were more interested in science and technology careers because of their FLL participation. Approximately 90% reported increased interest in computers and technology. Students reported that their participation in FLL increased their desire to learn about science and technology (89%) and computers and robotics (93%). Additionally 77% of students said they were more interested in a science or technology career, including 63% who indicated they wanted to become engineers. In both the 2005a[3] and 2009[5] studies, parent respondents also indicated that their children's interest in science, technology, computers, robotics, and STEM careers had increased due to FLL participation.

A 2006 evaluation of *FIRST* VEX Challenge (Center for Youth Development[1]), a competition for high school students, reported similar findings, with 90% of coaches reporting their students were more interested in science and technology careers and over 80% of students reporting the same. In addition, 93% of students said participation in FVC made them want to learn more about science and technology.

Finally, a 2005 evaluation[4] of *FIRST* Robotics Competition provided a retrospective view of FRC's impact on students who had graduated from the program. Results revealed that respondents perceived their participation in FRC increased their interest in science and

technology (86%) and science and technology careers (69%). For the 89% of respondents who went on to college, 51% reported taking at least one engineering course, approximately 60% said they had at least one work experience that was science or technology related, and for those who had chosen a major, 41% selected an engineering field, making them seven times more likely than the average college student to become an engineering major. When comparing across races and genders, results revealed that 40% of female FRC participants took engineering classes and 59% had worked a job or internship that was science or technology related. Additionally, 46% of African-American and 53% of Hispanic respondents took engineering courses, and 64% of African-American participants had held a science or technology internship or job.

Evaluation Design and Methods

Utilization-focused evaluation, described by Patton[6] (2008) as "evaluation done for and with specific intended primary users for specific, intended uses" (p. 37), was the framework for this investigation. Serving as external evaluators, our purpose was to provide data to the *Robotics Education and Competition Foundation* (RECF) about whether VRC students and Team Leaders perceived that VRC participation was affecting students in the areas articulated in RECF's vision. This purpose aligns with Patton's broader definition of program evaluation as a "systematic collection of information about the activities, characteristics, and results of programs to make judgments about the program, improve or further develop program effectiveness, information decisions about future programming, and/or increase understanding" (p. 39).

We collected survey and interview/focus group data from VRC student participants and Team Leaders. Early in the evaluation process, we collaborated with RECF to develop the survey, first creating survey matrices for the student and Team Leader surveys. The matrices included the main categories of student impact (e.g., interest in STEM, self-efficacy, engagement, teamwork and sportsmanship). Initially, we operationally defined each category, reviewing pertinent literature as part of the process. Review of the literature helped to identify subcategories in each area, which we used to develop survey items to be added to the matrices. The evaluation team as well as RECF reviewed the items to ensure they measured what we intended to measure. Surveys were then developed and pilot tested with approximately 30 students and 9 team leaders, both in an online format and with a paper-pencil version provided at a VRC event. Feedback from the pilot test was used to clarify items and add logic to the Team Leader survey so that only Team Leaders who were also teachers completed the survey section on comparing VRC students to their Non-VRC peers. The majority of survey items were on a Likert scale, but demographic and open-ended items were also included.

We conducted semi-structured focus group and one-on-one interviews with students and Team Leaders at two events: a regional competition of middle and high school students that took place in March, 2011, in Maryland and the 2011 VEX Robotics World Championship, which took place in April in Florida. We began the interviews/focus groups with a grand tour question (*Tell me about your experience in VEX Robotics Competition*), and then asked more specific follow-up questions (*What's it like working with your team?*) and probing questions (*When you say it was challenging working with your team, what do you mean? Can you describe one of the challenges?*). All interviews were recorded on digital audio recorders and transcribed. Data from interviews and focus groups, as well as from open-ended survey items, were qualitatively

analyzed using open-coding and axial coding, as described by Corbin and Strauss[2] (2008), to uncover themes, categories, and patterns.

There were several limitations of this first wave evaluation. First, due to the limited budget and short time frame given for the evaluation, the study was small in scale. The brief time frame allowed only a one-month window for collecting data via the online surveys, and we had to rely on Team Leaders to provide the surveys to students. At the time of the study, there was no existing database with student information, demographics, or contact information. This prevented us from contacting all students and from determining how representative the sample was of the larger population of VRC participants. It should be noted that although these limitations prevent broad generalizations of results, our findings replicate those from earlier studies of FRC, FLL, and FVC.

Participants

Evaluation participants included students and Team Leaders in the United States and Canada. Team Leaders were contacted via email and asked to (1) complete the online Team Leader survey and (2) provide the students on their teams with the link to the online survey. Email notifications were sent three times during the open survey period. To incentivize participation, all participants were entered into a random drawing to win a $100 VEX credit, which could be used to purchase VEX materials. In addition, the evaluators attended a regional VRC competition and the VEX World Championship for the purpose of observing the competition, making field notes, and interviewing students and Team Leaders.

Student Participants. Three hundred forty-one (341) students completed the online survey, including 210 high school students and 78 middle school students (some students did not provide their grade level). Table 1 provides demographic information for students who completed the survey. The typical male survey respondent was a 15-year old Caucasian on a public school team who had been competing in VRC for a little over a year and had competed in 5 competitions. Based on other student supplied information, the typical male respondent was also an A/B student in school, was college bound, planned to major in a STEM field, and had at least one parent who had earned a graduate degree. The typical female student respondent was Caucasian, was in her first year of VRC, was just under 15 years old, was a straight-A student who planned to attend college and earn at least a Masters degree in a STEM field, and had parents who had completed an undergraduate or graduate degree.

A total of 70 students, representing 19 teams, were interviewed in focus groups at a regional competition in Maryland and at the VEX Robotics Competition World Championship in Orlando. Thirty-three (33) students were at the high school level, and 37 were at the middle school level. Students were interviewed with their teammates. There was wide diversity in the focus groups, as indicated in Table 2, with larger percentages of African-American and Native American students participating in interviews than they did in completing surveys.

Table 1. Demographics of Student Survey Respondents

		Middle School Grades 6-8	High School Grades 9-12	All Students
Age	11 or younger	2.6%	---	2.3%
	12	26.3%	---	7.3%
	13	32.9%	1.0%	9.3%
	14	38.2%	11.4%	18.3%
	15	---	22.4%	15.9%
	16	---	27.6%	19.6%
	17	---	20.5%	14.6%
	18	---	15.7%	11.6%
	Over 18	---	1.4%	1.0%
Gender	Male	73.3%	74.2%	73.6%
	Female	26.7%	25.8%	26.4%
Ethnicity	African-American/Black	1.3%	3.4%	2.7%
	Asian/Pacific Islander	18.4%	18.3%	18.1%
	Hispanic/Latino	11.8%	9.1%	10.0%
	White/Caucasian	51.3%	61.5%	58.9%
	Multiracial	13.2%	5.3%	7.4%
	Some other race	3.9%	2.4%	3.0%
Language Spoken at Home	English	89.3%	84.5%	85.1%
	Non-English	10.7%	15.5%	14.9%
Team Type	Public School Team	61.8%	60.5%	59.1%
	Private School Team	17.1%	16.7%	17.3%
	Homeschool Team	14.5%	7.1%	10.0%
	Club Team	5.3%	8.1%	7.6%
	Other	1.3%	7.6 %	6.0%
Years in VRC	First Year	61.3%	45.2%	49.7%
	1 Year	6.7%	9.0%	8.3%
	2 Years	21.3%	31.4%	28.3%
	3 Years	10.7%	11.4%	11.3%
	4 Years	---	2.9%	2.3%
	Total number	**78**	**210**	**341**

Table 2. Demographics of Student Focus Group Participants (n=70)

		Middle School Grades 6-8	High School Grades 9-12	All
Gender	Male	70.3%	54.5%	62.9%
	Female	29.7%	45.5%	37.1%
Ethnicity	African-American/Black	16.2%	12.1%	14.3%
	Asian/Pacific Islander	3.0%	9.1%	5.7%
	Hispanic/Latino	8.1%	6.0%	7.1%
	Native American/Alaskan	5.4%	3.0%	4.2%
	White/Caucasian	67.6%	69.7%	68.6%
Team Type	Public School Team	89.2%	42.4%	67.1%
	Private School Team	---	21.2%	10.0%
	Homeschool Team	10.8%	9.1%	10.0%
	Club/Community Team	---	27.3%	12.9%
	Total Number	**37**	**33**	**70**

Team Leader Participants. The Team Leader survey was completed by 345 coaches, mentors, and parent volunteers. The typical Team Leader respondent was a white male with three or fewer years experience in VRC who was a middle or high school teacher and coached a public school team. Table 3 provides additional demographic data on Team Leaders disaggregated by team level coached (middle, high school, or both) as well as aggregated across team level.

Table 3. Coach/Mentor Demographics of Team Leader Survey Participants

		Middle School Grades 6-8	High School Grades 9-12	MS/HS*	All Team Leaders
Gender	Male	50.0%	73.5%	69.9%	67.0%
	Female	50.0%	26.5%	30.2%	33.0%
Ethnicity	African-American/Black	1.7%	---	3.9%	1.1%
	Asian/Pacific Islander	10.2%	5.8%	2.0%	6.2%
	Hispanic/Latino	1.7%	3.8%	5.9%	3.7%
	Native American	---	---	2.0%	<1%
	White/Caucasian	81.4%	87.2%	84.3%	85.3%
	Multiracial	1.7%	1.9%	2.0%	1.8%
	Some other race	3.4%	1.3%	---	1.5%
Years as Team Leader	First year/1year	57.7%	48.4%	32.1%	46.7%
	2-3 years	33.9%	32.5%	35.8%	33.6%
	4-5 years	5.1%	13.4%	15.1%	12.4%
	More than 5 years	3.4%	5.7%	17.0%	7.3%
Profession	Middle School Teacher	33.9%	1.9%	5.7%	9.6%
	High School Teacher	1.7%	66.5%	28.3%	44.1%
	Engineer	8.5%	1.3%	9.4%	8.9%
	STEM/Computer Field	11.9%	4.4%	17.0%	8.2%
	Other	44.1%	16.5%	39.6%	28.1%
Team Type	Public School Team	57.6%	71.3%	35.8%	63.0%
	Private School Team	11.9%	15.3%	18.9%	15.5%
	Homeschool Team	15.3%	5.1%	17.0%	9.1%
	Club Team	6.8%	3.8%	7.5%	5.0%
	Other	8.5%	4.5%	18.9%	7.3%
	Total	**59**	**158**	**53**	**345**

*combined middle school and high school team

A total of 37 Team Leaders were interviewed one-on-one or in focus groups at two competition events. The majority of interviewed coaches were Caucasian, male, and from a public school team. Demographic data for Team Leader interviewees are provided in Table 4.

Table 4. Demographics of Team Leader Interviewees

Gender		Ethnicity		Team Type	
Male	73.0%	African-American/Black	2.7%	Public School Team	59.5%
Female	27.0%	Asian/Pacific Islander	2.7%	Private School Team	18.9%
		Hispanic/Latino	2.7%	Homeschool Team	16.2%
		Native American/Alaskan	2.7%	Club Team	5.4%
		White/Caucasian	86.5%		
		Multiracial	2.7%		

Results

Participants were asked the extent to which participation in VRC increased students' interest in STEM areas, including (1) taking additional math or science classes in high school/college, (2) taking engineering courses in college, (3) having a job in a STEM or computer field, and (4) learning more about computer programming, engineering design, and robotics. As shown in Table 5, most students and Team Leaders agreed that VRC participation made students more interested in STEM. Over 75% of students reported they were interested in taking additional math or science classes in high school or college, and almost 83% said they were interested in taking engineering courses in college. Also, 87% of students reported they were more interested in having a job in a STEM or computer field, and just under 75% of Team Leaders perceived students were more interested in pursuing these careers. Students said they wanted to learn more about robotics (92%), engineering (90%), and computer programming (89%) because of participation in VRC. Percentages were also high in these categories for Team Leaders.

Table 5. Student and Team Leader Comparisons on STEM Interest Items

Participating in the VEX Robotics Competition has made me		**Strongly Agree**	**Agree**	**Disagree or SD**	**Not sure**
more interested in taking additional math or science classes in high school	Students	43.0%	32.8%	16.4%	7.9%
		75.8%			
	Team Leaders	44.3%	38.8%	4.5%	12.4%
		83.1%			
more interested in taking math or science classes in college	Students	43.4%	34.9%	13.2%	8.6%
		78.3%			
	Team Leaders	42.3%	34.5%	4.5%	18.9%
		76.8%			
more interested in taking engineering classes in college	Students	56.1%	26.4%	12.6%	5.0%
		82.5%			
	Team Leaders	42.4%	37.8%	3.4%	16.4%
		80.2%			
more interested in having a job in a STEM or computer field	Students	61.7%	25.7%	9.2%	3.3%
		87.4%			
	Team Leaders	40.3%	33.4%	5.9%	20.3%
		73.7%			
want to learn more about computer programming	Students	58.2%	30.3%	8.9%	2.6%
		88.5%			
	Team Leaders	39.2%	47.9%	10.3%	2.6%
		87.1%			
want to learn more about robotics	Students	67.3%	25.1%	5.3%	2.3%
		92.4%			
	Team Leaders	66.6%	28.6%	2.2%	2.6%
		95.2%			
want to learn more about engineering design	Students	60.5%	29.3%	7.3%	3.0%
		89.8%			
	Team Leaders	53.5%	37.1%	5.8%	3.5%
		90.6%			

When comparisons were made between male and female students, higher percentages of males than females agreed that participation in VRC had made them more interested in (1) taking engineering classes in college, (2) having a career in a STEM field, (3) learning more about computer programming, and (4) learning more about engineering design. A higher percentage of girls (96.2%) than boys (91.8%) said VRC participation made them want to learn more about robotics, and a higher percentage of girls (78.5%) than boys (74.9%) said VRC made them more interested in taking additional math or science classes in high school and college. Table 6 provides detailed comparisons by gender.

Table 6. Student Comparisons on STEM Interest Items by Gender

Participating in the VEX Robotics Competition has made me		**Strongly Agree**	**Agree**	**Disagree or SD**	**Not sure**
more interested in taking additional math or science classes in high school	Males	41.6%	33.3%	18.2%	6.8%
		74.9%			
	Females	45.6%	32.9%	11.4%	10.1%
		78.5%			
more interested in taking math or science classes in college	Males	44.7%	35.2%	12.7%	7.3%
		79.9%			
	Females	39.2%	36.7%	13.9%	10.1%
		75.9%			
more interested in taking engineering classes in college	Males	60.6%	25.7%	10.1%	3.7%
		86.3%			
	Females	44.3%	29.1%	19.0%	7.6%
		73.4%			
more interested in having a job in a STEM or computer field	Males	65.1%	25.7%	6.9%	2.3%
		90.8%			
	Females	54.4%	24.1%	15.2%	6.3%
		78.5%			
want to learn more about computer programming	Males	60.3%	28.8%	7.3%	3.7%
		89.1%			
	Females	50.6%	36.7%	12.7%	---
		87.3%			
want to learn more about robotics	Males	67.0%	24.8%	5.5%	2.8%
		91.8%			
	Females	68.4%	27.8%	3.8%	---
		96.2%			
want to learn more about engineering design	Males	61.6%	30.1%	5.0%	3.2%
		91.7%			
	Females	58.2%	26.6%	12.6%	2.6%
		84.8%			

Approximately 60% of Team Leaders wrote responses on the open-ended survey item about ways participation in VEX Robotics Competition directly influenced student interest in STEM. Specifically, they noted changes in students' interest in taking additional STEM classes in high school and in pursuing a STEM college major or career. These areas are described more fully in the following sections.

Interest in Taking Additional STEM Classes in High School. Several respondents provided anecdotes that described how VRC participation influenced their students' interest in taking additional STEM courses in high school. As one Team Leader explained,

> *Because of our VEX participation this year, I have seen extremely bright students want to participate on a team...they have also worked on this project harder than anything else all year with great enjoyment especially with the programming...they realize how important and fun it can be and all will be enrolled in our AP computer course next year along with AP Physics course.*

Another Team Leader wrote that many of his students become interested in pursuing engineering in college and decide to take high school courses to prepare them for that major. He reported,

> *Our club members LOVE robotics. After a year on a team, most are ready to major in engineering, and sign up for the math and science courses which will get them there. We have former members at U Pitt (biomedical engineering), Embry-Riddle (aeronautical engineering), Cal Poly SLO (mechanical engineering), UC campuses (mechanical engineering), U Penn (computer engineering), USC (computer science) and Cal State (mechanical engineering). Graduating seniors this year have been accepted at MIT (materials science), Stanford (She's yet to decide which field of engineering), and schools to be determined.*

Along similar lines, a middle school Team Leader expressed,

> *My observation is that the kids who participate in VEX are attracted to the program because of their interest in the way machines work and the unique nature of the competition. I believe that once they have exposure to their coaches and mentors they quickly understand the role of STEM and the importance of good grades in math and science while in middle school and the need for an aggressive track of study in upper level courses in high school so that they are prepared for an engineering or science/math college career.*

Several Team Leaders reported that their students desired to learn additional math and science concepts so that they could more fully engage in their robotics work. One Team Leader, for example, wrote on his survey, "*Students become obsessed with Robotics and spend time looking for solutions to problems they encounter. I have witnessed students learning math well beyond their current class level in order to solve problems they are working on with VEX robots.*"

Another Team Leader, a female engineer who serves as a mentor, provided her opinion of the way VRC impacts girls in particular, stating,

> *With me being a woman in engineering, it has shown the girls that I coach that engineering and robotics is not just for 'nerds.' Specifically in the girls, I have seen interest in taking more science classes because they are shown in the VEX program that they are smart enough to succeed in these areas.*

A parent mentor also commented on the competition's impact on girls, providing this anecdote about her daughter, whom she believes was motivated to study in STEM areas because of her participation in VRC. On her survey the parent mentor wrote,

> *My daughter started being involved with VEX because she was interested in robotics …the VEX club and robotics competitions have been an overwhelmingly positive experience that will likely motivate her to commit to the work associated with study in the fields of Physics, Engineering, and higher math.*

Interest in computer courses or computer programming was another area in which Team Leaders reported changes in their students. A high school Team Leader explained, "*Some members on my team have sought out independent programming courses as a result of getting 'the bug' from work they have done on our robots.*" A middle school Team Leader reported:

> *We are in middle school, so I'm not sure how this affects students once they get in high school and college. Here our students have been very interested in design and how things work. There has also been a lot of interest in learning about programming and even though we had one main programmer, everyone tried to learn some. Students have also expressed an interest in doing more with programming next year.*

Another Team Leader wrote,

> *It's a very engaging process. Programming can be engaging to some, but with the VRC, it gives programming a contextual base—it isn't just data processing but gives control and interaction with the outside environment (outside of the computer) in a way that a teacher or coach can implement without an expensive machine shop or extensive experience in programming.*

Team Leaders who were also teachers were asked on the survey to compare VRC students to their non-VRC peers. High percentages of Team Leaders reported that their VRC students were more comfortable using computers (81% agreed or strongly agreed with this statement), more interested in taking additional or harder computer classes (70% agreed or strongly agreed), more interested in taking additional or harder math classes (72%), and more interested in taking additional or harder science classes (70%). Additional data are provided in Table 7.

Table 7. Teacher/Team Leader Comparisons of VRC Students to their Non-VRC Peers

VRC students are more	**Strongly Agree**	**Agree**	**Disagree or SD**	**Not Sure**	**Doesn't Apply**
comfortable using computers than their non-VRC peers.	34.5%	46.9%	7.6%	9.7%	1.4%
	81.4%				
interested in taking additional or harder math classes than their non-VRC peers.	21.4%	50.3%	10.4%	15.2%	2.8%
	71.7%				
interested in taking additional or harder science classes than their non-VRC peers.	20.7%	49.7%	11.1%	15.2%	3.4%
	70.4%				
interested in taking additional or harder computer classes than their non-VRC peers.	21.5%	48.6%	9.7%	16.7%	3.5%
	70.1%				

A few Team Leaders provided explanations about these differences on follow-up survey questions. For example, one Team Leader-teacher explained, "*Students at our school absorb more in the way of math and science when they participate in Robotics. It gives them a hands-on learning experience in the fields of Math, Science, and Engineering that they would not normally receive.*" Another Team Leader-teacher who coached a club team that drew students from several different schools wrote, "*I have been told on numerous occasions by math and science teachers in the local schools, that the kids in my program have made a marked improvement and actually tend to excel in their classes.*"

Students also reported benefits of VRC participation in the areas of math and science. One student wrote on his survey, "[*VRC] helps me with school work in the fields of math and science*." And another commented, "*It has taught me how interesting science and technology can be*." Other comments included, "*[VRC] helps me so much in my science math and engineering workshop classes!*" and "*Things in math that I thought were useless suddenly become valuable skills to me.*"

Several other students wrote about how much they had learned about programming as a result of VRC participation. Student comments included:

- *It teaches me a lot about programming and robotics.*
- *It improved my programming.*
- *It helped me to learn how to program under stress.*
- *It taught me how to program on some basic level.*
- *Encouraged me to learn 2 more programming languages.*
- *I got interested in programming.*
- *I have also learned how much I enjoy computer programming and want to continue learning new things in that area.*

Interest in Pursuing a STEM as a College Major or Career. Several Team Leaders reported that their VRC students' interest in STEM majors or STEM fields had increased due to their participation in VEX Robotics Competition. One Team Leader commented, "*I have observed that participation in the competition directly influenced the students interest in these areas by exposing them to computer programming, logical thinking, engineering, team work, math, science, which pipes their interest in related career fields.*"

Several other Team Leaders also reported increased student interest in STEM fields due VRC participation. Some of the most salient of those comments are provided here:

- *I have seen Robotics change [a] student's choice of major in college. The juniors and seniors ask [prospective] colleges specific questions regarding robotics programs or other scientific practical applications/competitions. I have even seen veteran high school students give opinions and advice to college teams on their robots as they tour the university.*

- *I mostly see students who were vaguely interested in engineering and other technical areas become focused on it. I also see students who joined because their friends did go*

from being non-technical to having some affinity for it, even if they do not change career or educational plans because of their involvement.

- *When they have worked on a design and watched it compete with others, they take pride and ownership in their work. At that point they are hooked and desire similar experiences. For these reasons the experience has galvanized their desire to continue into an engineering field.*

- *One student was sure he wanted to do mechanical engineering because he loves to build, but since competing with VEX, his interests expanded to include electrical and computer engineering as well. His teammate has multiple talents (a lot of accomplishments in music and business) but didn't realize that he would enjoy engineering. His experience with VEX has shown him how much "fun" engineering is and it has opened up this field as an area of interest to him.*

Most of the 37 interviewed Team Leaders also described experiences with their students that indicated an increased interest in STEM areas due to VRC participation, usually in the area of engineering. One coach explained, "*About 60% [of our students] change their minds and want to go into STEM pathways…they get a much more in-depth view of [the kinds of] jobs [available to them]*."

A Team Leader from a team with 100% minority involvement [racial minority, all-girls team] said in his interview,

> *I have seen kids come out of our robotics program [and] take interest in numerous STEM disciplines of study. Traditionally, students say they want to be a nurse, policeman, [or something like that]. I talk to these same kids in fifth or sixth grade [and they want to go into the same kinds of trades their parents are in], like chicken catcher or factory worker. It's the mindset of the community. Until you change the mindset of the community, you can't change the mindset of the kids. Robotics is the "wow" factor to the community.*

Another Team Leader described the new opportunities his VEX students have due to their VRC participation, which encourages and prepares students to examine more college options. On his survey he explained,

> *Because of our involvement with VEX, our students have had many opportunities to visit the engineering departments at college campuses and they have made contact with a variety of interested adults who encourage their learning and give them a sense of community. They understand how they can further develop their interests and have learned about many options at the university level. This long term perspective helps give their current class work meaning and a sense of urgency, because they want to be prepared when someone is going to offer them another great opportunity to participate in something fun!*

Another Team Leader, who coaches minority students in an inner city school, explained in a focus group interview how VRC participation created new options for his students:

> *We're a Title I high school, 98% free and reduced lunch…and we talk to incoming 9th graders saying, "This is what we can help you do [to get into college]. Two of our students got accepted into Johns Hopkins last year; this could be you. They were both [in] robotics." …If you're on this team, you know, you've elevated yourself to having a better chance to go to a high quality college or university.*

In a focus group interview, a male Team Leader of an all-girls team provided additional evidence of the impact of VRC participation on the girls on his team:

> *I'm at a public, all girls' college preparatory high school, so it's a unique situation. My girls get a lot out of the science and math tie-ins…I have girls who didn't think they were good at science or math before they came in. Build that confidence…and a lot of the young girls from [my inner city school] who never would have thought of engineering as a career choice or any sort of math or science related major until they take robotics…a lot of them go to engineering-specific [universities] or they go to schools and they really want to become engineers. So I think that's a big thing, to open those opportunities and having them thinking about that...*

Students also provided comments about ways VRC participation increased their interest in pursuing STEM fields. On the survey, a student wrote, "*I started programming because my brother needed someone to program his robots. I am good at math so my mother elected me to figure it out. I will be majoring in computer science in college as a result*." A second student wrote, "*It has helped me learn about engineering which I want to learn about in college.*" Another student wrote, "*It has given me an idea of what I want to do during college and in life*," and a fourth responded, "*It has impacted me by wanting to take an engineering class in college*." An interviewed student stated, "*Because of VEX, I'm going to be a computer engineer [and study] at the [local] university*."

Three Team Leaders cautioned that many students who come into VRC are already interested in STEM fields. However, each Team Leader expressed his or her perceptions of the positive benefits for students. One Team Leader explained,

> *Most of the team members I have worked with were already interested in technology, it's hard to judge if the interest is increased because of the robotics, or if the interest in robotics is due to the members general interest in tech. Regardless, it's a great outlet and allows for practical application of concepts.*

A second Team Leader responded on the survey:

> *Since the program attracts students that would already be interested in STEM career fields, I can't say that the program is having a profound change in the students. But I DO see that the program has challenged them more than without it. They have better opportunities now than they did before. AND there are a few students that it does change their interests in STEM. Likewise there a few also that realize how hard they have to work to succeed in a STEM field, that it isn't just [playing with robots].*

Yet another gave a more detailed explanation of the types of kids who compete on his teams and the ways VRC participation may impact their future plans. He explained,

> *I have 3 main groups of students: the "science kids", who would have majored in some area of STEM without VRC, the "trade kids", who probably will attend junior college but never aspire to a BA/BS degree, and the "non-technical kids" who are generally good students, but without a specific plan. For the science kids, VRC sparks their interest in the applications of science. About 10-20% moved from pure science intended majors to engineering-based college majors based on robotics. For the trade kids, VRC encourages them to study things like auto/machine tool technology or electronics, and gives them motivation to do better in school (one moved from a 1.5 GPA to a 2.5 GPA after joining robotics). Some of these students have poor language skills and/or no family support for education (parents never finished high school). The non-technical kids tend to go to college locally without an intended major. They are likely to earn a BA in something like Liberal Studies or business. VRC has affected them in a more personal, but not necessarily professional way. Some have said things like, "I'd like to be a robotics mentor after I graduate." I have 2 college students in this category who currently mentor our high school robotics team. The main reason that they don't attempt engineering or a science-based career is that they struggle in math classes (attempted but did not pass calculus) but do very well in other classes (English, history, economics, psychology, etc.). They like robotics because they like to work with their hands.*

On a final note, one Team Leader did express a concern about the narrow path that some VRC students take, which can limit their options. As he explained, *"I have observed a focus on VEX Robotics to the exclusion of other pursuits and a path to an engineering career possibly without a wider evaluation of other career options that may be better suited to the student."* No other Team Leader expressed this concern on the survey, though one similar comment was made during a Team Leader interview.

Conclusions

Results of this study indicate that students who participate in VEX Robotics Competition, as well as their Team Leaders, perceive that participation positively affects student interest in STEM courses and careers. Quantitative survey data, as well as qualitative data from the survey and interview/focus groups, support the impact VRC has on student interest in taking additional STEM courses in high school and college, learning more about computer programming, and considering STEM college majors and careers. Although generalizability of the evaluation results are limited due to the small, non-random sample, results do replicate those found in other evaluations of robotics competitions, including FLL, FRC, and FVC and thus add to the growing knowledge base on the power of competitive robotics teams to inspire students to pursue STEM pathways.

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