VEX Robotics Competition Evaluation
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Report prepared for The Robotics Education & Competition Foundation by Cher Hendricks, Ph.D.

Evaluation Team

Meltem Alemdar, Ph.D.
Center for Education Integrating Science, Math, and Technology
Georgia Institute of Technology

Cher Hendricks, Ph.D.
Center for Education Integrating Science, Math, and Technology
Georgia Institute of Technology

Tamra Ogletree, Ph.D.
Department of Collaborative Support and Intervention
University of West Georgia

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Introduction

The focus of this initial VEX Robotics Competition (VRC) evaluation was on the program's impact on its student participants. According the VEX Robotics website[i]:

> *The VEX Robotics Competition is the largest and fastest growing middle and high school robotics program globally with more than 3,500 teams from 20 countries playing in over 250 tournaments worldwide…Students, with guidance from their teachers and mentors, aim to build the most innovative robots possible and work together to obtain the most points possible. In addition to just having a great time and building amazing robots, through their participation in the VEX Robotics Competition and their work within their team, students will learn many academic and life skills.*

Because Competition goals focus on teambuilding and teamwork, academic skills, and life skills (such as communication and sportsmanship), the evaluation was focused in those areas. Additional factors of interest were (a) interest and engagement in science, technology, engineering, and mathematics (STEM), and (b) 21st century skills such as problem solving, communication, collaboration, adaptability, and leadership. These are important aspects of the Competition, as explained in the VEX Robotics Competition Gateway manual[ii], which explains:

> *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*

[i] Information obtained 05/26/11 at http://www.vexrobotics.com/competition/

[ii] VEX Robotics (2011). *VEX Robotics Competition-Gateway Manual (v.04/05/11)*. © VEX Robotics. Available at: http://www.vexforum.com/wiki/index.php/Gateway

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)

We also investigated VRC's impact on student self-efficacy (i.e., self-confidence) related to doing well in school and STEM classes, 21st century skills, and perceived ability in a STEM or STEM-related career. As explained by Pajares[iii], self-efficacy impacts the choices people make (such as choosing a STEM career), how much effort they put into tasks, and their perseverance and resilience in difficult situations. Given the ways high self-efficacy may impact student choice and effort, we chose to measure this self-referent belief as part of the evaluation.

In summary, this evaluation is focused on the ways in which participation in VEX Robotics Competition impacts its student participants in the areas of

- Teamwork and sportsmanship
- Interest and engagement in STEM areas and careers
- 21st century skills and engineering habits of mind
- Self-efficacy

The evaluation of these factors relied on survey, focus group, and interview data from VRC students and their Team Leaders. In the next section, we describe the evaluation plan in greater detail.

[iii] Pajares, F. (1997). Current directions in self-efficacy research. In M. Maehr & P. R. Pintrich (Eds.). *Advances in motivation and achievement*, v.10 (pp. 1-49). Greenwich, CT: JAI Press.

Evaluation Plan

In February 2011, the *Robotics Education and Competition Foundation (RECF)* contracted with our evaluation team to complete the first external evaluation of VEX Robotics Competition. In consultation with RECF, we completed the concept development stage in March 2011, focusing the evaluation on the ways in which VRC impacts the middle and high school students who participate in the program. Because of the short timeframe for this project, we chose to limit participation to students and Team Leaders in North America. The evaluation had two main questions.

Question 1. What changes do students report, based on their participation in VRC, in the areas of:

(a) Teamwork
(b) Sportsmanship
(c) Engagement in school
(d) Engagement in school-based STEM activities
(e) 21st century skills such as problem solving, communication, collaboration, adaptability, and leadership
(f) Interest in STEM
(g) Self-efficacy related to school achievement, doing well in STEM coursework in high school and college, succeeding in a STEM career, 21st century skills, and teamwork

Question 2: What changes in students, due to their participation in VRC, do Team Leaders report in the areas of:

(a) Teamwork
(b) Sportsmanship
(c) Engagement in school
(d) Engagement in school-based STEM activities
(e) 21st century skills such as problem solving, communication, collaboration, adaptability, and leadership
(f) Interest in STEM
(g) Self-efficacy related to school achievement, doing well in STEM coursework in high school and college, succeeding in a STEM career, 21st century skills, and teamwork
(h) Engineering habits of mind, as outlined in the *Standards for K-12 Engineering Education*[iv], including systems thinking, creativity, optimism, collaboration, and communication

[iv] Committee on Standards for K-12 Engineering Education (2010). *Standards for K-12 Engineering Education?* Washington, DC: The National Academies Press.

Team Leaders who are also teachers were asked to compare VRC students to their non-VRC peers in categories a, b, c, d, e, f, and g above. Team Leaders were also asked about ways VRC may be able to reach a more diverse population.

Data collection involved surveying students and Team Leaders as well as conducting interviews and focus groups with students and Team Leaders at VEX Robotics Competition events. Our initial step was to work with RECF during the survey development process. The evaluation team first developed a survey matrix for the student survey and the Team Leader survey, focusing on the main categories of student impact (e.g., teamwork, sportsmanship, engagement, interest in STEM, 21st century skills, self-efficacy, etc.). Next, we operationally defined these categories/ variables, reviewing the literature to further clarify definitions. During this process, we identified a number of subcategories in some variables, including:

- *Sportsmanship*, with subcategories

    (a) respect
    (b) fairness
    (c) honesty
    (d) responsibility
    (e) civility

- *Engagement*, with subcategories

    (a) behavioral engagement: participation in school-related activities, involvement in academic and learning tasks, positive conduct
    (b) cognitive engagement: investment in learning

- *21st Century Skills*, with subcategories

    (a) learning and innovation skills including creativity/innovation, critical thinking/problem-solving, and communication/ collaboration
    (b) life and career skills including flexibility/adaptability, initiative/self-direction, and productivity/accountability

- *Interest in STEM*, with subcategories

    (a) desire to study STEM in high school
    (b) desire to study STEM in college
    (c) desire to pursue a STEM career

- *Self-Efficacy* in the areas of

    (a) school success
    (b) current STEM achievement

(c) predicted STEM achievement in college
(d) predicted STEM achievement in a career
(e) problem solving
(f) leadership
(g) communication
(h) teamwork

After identifying these subcategories, we developed items to measure perceptions of impact in each of the areas. Online surveys for students and Team Leaders were then developed and pilot tested with approximately 30 students and 9 Team Leaders, both online and face-to-face at a VEX Robotics competition. Feedback was used to clarify items and to add logic to the Team Leader survey so that only Team Leaders who were teachers completed items comparing VRC students to their non-VRC peers. Most items were on a Likert scale, but open-ended questions were also included to gather additional information. The student survey is provided in Appendix 1, and the Team Leader survey is provided in Appendix 2.

The online surveys were opened in early April 2011 and remained open through May 2011. Team Leaders were contacted via email and notified about the surveys, and links to both the Team Leader and student surveys were included in the email. Team Leaders forwarded the student survey link to their team members. These email notifications were sent three times during the open survey period, and participation was incentivized by offering a random drawing from the student and Team Leader participant pools to receive a $100 VEX credit. One credit was awarded to a student, and one was awarded to a Team Leader.

Focus group and individual interviews with students and Team Leaders were conducted at the Mid-Atlantic VEX Competition in March 2011 and the 2011 VEX Robotics World Championship in Orlando, Florida, in mid-April. Themes from interviews, focus groups, and open-ended survey items were qualitatively analyzed and triangulated with quantitative survey data to provide answers to the key evaluation questions. In the next section, key findings are presented.

Key Findings

In analyzing student and Team Leader surveys, interviews, and focus groups, several key findings emerged. Based on student and Team Leader self-report perception data, students and Team Leaders overwhelmingly reported positive student effects, in all areas evaluated, due to participation in VEX Robotics Competition. Positive benefits were greatest in the areas of teamwork, interest in STEM, 21st century skills, and self-efficacy. Key findings are presented in this section, and more detailed results for each area, including descriptive statistics and qualitative data, are presented in the remainder of this document.

TEAMWORK

Whether reviewing survey or interview/focus group data, gains in teamwork were cited more often than other factor as a benefit of VRC participation. The areas of teamwork where students noted the most growth were (a) taking individual responsibility for doing one's part on the team, (b) solving difficult problems with teammates, and (c) being a good teammate. Team Leaders reported the most student growth in (a) coming up with ideas and sharing them with the team, (b) solving difficult problems with teammates, and (c) being a good teammate.

In each of the teamwork areas evaluated, Team Leaders perceived a more positive impact on students' teamwork due to their VRC participation than did the students themselves, though high percentages of students (between 37% and 55%) strongly agreed VRC helped them grow a great deal in various areas of of teamwork. High percentages of Team Leaders who are also teachers agreed or strongly agreed that VRC students demonstrate greater teamwork skills than do their non-VRC counterparts, and 66% of Team Leaders, when asked on the survey to describe the greatest benefit to students of VRC, provided a response related to teamwork. Teamwork was also the most often cited benefit of VRC during Team Leader focus group interviews as well.

INTEREST IN STEM

A large majority of students and Team Leaders agreed that VRC participation positively impacted students' interest in STEM. Students reported (a) wanting to learn more about robotics (92%) and engineering (90%), (b) becoming more interested in having a job in a STEM or computer field (87%), (c) becoming more interested in taking engineering courses in college (83%) and (d) becoming more interested in taking additional math or science classes in high school or college (75%). Team Leaders also perceived increased student interest in STEM areas due to their participation in VRC, and increases were greatest in (a) wanting to learn more about robotics (95%), (b) wanting to learn more about engineering design (91%), and wanting to learn more about computer programing (87%).

Higher percentages of males than females agreed that VRC had made them more interested in taking engineering classes in college, having a STEM career, learning more about computer programming, and learning more about engineering design. However, a higher percentage of girls than boys reported that VRC made them want to learn more about robotics and made them more interested in taking additional math and science classes in high school and college. When factoring out gender, at least 70% of all student participants indicated that participation in VRC had made them more interested in each of the STEM areas evaluated on the survey.

Team Leaders who are also teachers reported that VRC students are (a) more comfortable using computers (81% agreed) and (b) more interested in taking additional or harder computer classes (70%), math classes (72%), or science classes (70%) than are their non-VRC peers. Students and Team Leaders provided stories, anecdotes, and experiences in focus groups and

interviews that illustrated the ways student interest in STEM increased due to VRC participation.

21ST CENTURY SKILLS

Large percentages of students and Team Leaders perceive that VRC participation positively impacts students in 21st century skills such as accepting and using feedback, goal setting, and using time effectively. Over 90% of students and Team Leaders reported positive gains in students' ability to accept and use feedback, and approximately 90% of students and 85% of Team Leaders reported positive gains in the areas of goal setting and using time effectively.

When asked to compare VRC students to their non-VRC peers, large percentages of Team Leaders who are teachers (>70%) agreed that VRC students demonstrate (a) better leadership qualities, (b) better communication skill, and (c) more perseverance. Just under 90% of Team Leaders reported VRC students demonstrate higher problem solving ability than do their peers.

Team Leaders and students provided a wealth of qualitative data to support student gains in 21st century skills due to VRC participation, not only in the areas listed above, but also in collaboration, self-direction and motivation, and learning from failure.

SELF-EFFICACY

A large majority of students at both the middle and high school levels reported that VRC participation increased their confidence in each of the areas surveyed. The areas where students and Team Leaders perceived the most impact were (a) teamwork, (b) problem solving, and (c) leadership, though they also noted positive gains in confidence related to asking questions and presenting ideas/communicating. Students and Team Leaders perceived the least impact in the areas of confidence in general school achievement and science achievement.

When Team Leaders who are also teachers were asked to compare VRC students to their non-VRC peers, 82% agreed or strongly agreed that VRC students have higher confidence in their abilities in STEM areas than do their non-VRC peers. Just under 74% of Team Leaders agreed or strongly agreed that VRC students have higher confidence in their general academic abilities.

The areas of self-efficacy growth Team Leaders mentioned most, whether on open-ended survey items or in interviews and focus groups, were self-efficacy in teamwork, self-efficacy in communication, and self-efficacy in leadership. A number of Team Leaders also commented on the positive social aspects of VRC, which impact students' social skills and interactions with peers.

SPORTSMANSHIP

Team Leaders and students reported the greatest area of growth in sportsmanship as being honest and fair in competitive situations. Over 60% of Team Leaders reported that students

demonstrated a lot of growth in this area as a result of VRC participation, and 48% of students reported VRC had helped them grow a lot in this area. Over half of both Team Leaders and students reported significant growth in the area of treating teammates respectfully, and about 38% of students and 50% of Team Leaders reported significant growth in valuing each team member's contributions. Further, most Team Leaders reported observing a great deal of growth in students treating opponents respectfully. In focus groups and interviews, Team Leaders and students provided a number of examples of the ways teams supported each other during competitions and the friendliness and helpfulness of competing teams.

ENGINEERING HABITS OF MIND

Approximately 95% of surveyed Team Leaders perceived VRC to positively impact student growth in (a) coming up with creative solutions to difficult problems and (b) seeing possibilities and opportunities in design challenges. Between 87% and 93% of Team Leaders perceived VRC to positively impact students in (a) communicating to explain and justify ideas and (b) engaging in systems thinking. The engineering habit of mind area in which most Team Leaders perceived a positive impact due to VRC was understanding that every technology can be improved. Almost 97% of Team Leaders agreed or strongly agreed students grew in this area as a direct result of VRC participation.

ENGAGEMENT

Students and Team Leaders perceived VRC participation to be less influential in the area of engagement than of any other area evaluated in this project. In all engagement areas evaluated, fewer than 40% of participants strongly agreed VRC had an impact on engagement. The one engagement area where larger percentages of students (74%) and Team Leaders (82%) perceived some level of positive benefit was in interest in school or education.

Large percentages of Team Leaders who are teachers, when asked to compare VRC students to their non-VRC peers, agreed that VRC students are better behaved in school than are their non-VRC peers and have better attendance than their non-VRC peers. However, a number of Team Leaders suggested that students who are drawn to VRC are typically more engaged in school than are their peers.

Some Team Leaders did indicate their belief that VRC can give students who don't "fit in" to school cultures (such as those associated with athletics or non-academic clubs) a place to excel, which allows them to feel part of the school and thus increases their engagement.

INCREASING PARTICIPATION FOR UNDERREPRESENTED STUDENTS

Over 75% of surveyed Team Leaders indicated that girls have shown interest in being on their VRC teams, and about 83% indicated they currently have girls on their teams. However, only 45% of Team Leaders said students in racial groups typically underrepresented in STEM have shown interest in being on their teams. When asked their perception about how well VRC

reaches out to underrepresented students, 58% of Team Leaders agreed VRC does a good job reaching out to girls, and 43% agreed VRC does a good job reaching out to students who are racial minorities.

Team Leaders suggested (a) using more female engineering role models to increase the number of girls participating and (b) lowering costs to teams to increase minority participation. A number of Team Leaders suggested VEX offer grants to teams with high numbers of minority students.

IMPROVING VRC FOR STUDENTS

Suggestions for improving VRC for students included keeping costs low, improving software and hardware, and improving competitions by simplifying and clarifying rules and ensuring fair judging at events.

PARTICIPANTS

Both the student and Team Leader surveys included demographic items. On the student survey, students provided their age, gender, years in VRC, race, language spoken at home, and parents' education level, as well as average grades in school and college plans. On the Team Leader survey, respondents provided number of years coaching VRC, gender, race, and profession. Team Leaders who were also teachers were asked to provide grade level and subject taught as well as years teaching experience. We collected demographic data from participants in order to determine whether responses differed across participants.

STUDENTS

Surveyed Students. Three hundred forty-one (341) students completed the survey. Of those who provided a grade level, 210 were high school students, and 78 were middle school students. Of the middle school students, most were 8th graders (53%), but there were also 6th (18%) and 7th (29%) graders who completed the survey. At the time of this survey, just under 3% of these students had not yet competed in a VEX competition, 46% had competed in 1-4 competitions, 34% had competed in 5-9 competitions, and 17% had competed in 10 or more competitions.

The high school students included 51 9th graders (23.8%), 56 10th graders (26.2%), 50 11th graders (26.6%), and 57 12th graders (26.6%). Just under 6% of these students had not yet competed in a VEX competition, 56.1% had competed in 1-4 competitions, 21.1% had competed in 5-9 competitions, and 17.2% had competed in 10 or more competitions.

Most students, both middle and high school, reported that their parents had completed college, with 71% reporting one parent completed college and 68% reporting both parents had. Of these students, 39% also reported one parent earned a graduate degree, and 31% reported

both parents had. About 6% reported one or both parents did not complete high school. Table 1 provides demographic data on these students.

Table 1. Demographics of Student Survey Participants

		Middle School Grades 6-8	High School Grades 9-12	All Students
Age	11 or younger	2.6% (2)[v]	---	2.3% (7)
	12	26.3% (20)	---	7.3% (22)
	13	32.9% (25)	1.0% (2)	9.3% (28)
	14	38.2% (29)	11.4% (24)	18.3% (55)
	15	---	22.4% (47)	15.9% (48)
	16	---	27.6% (58)	19.6% (59)
	17	---	20.5% (43)	14.6% (44)
	18	---	15.7% (33)	11.6% (35)
	18 or older	---	1.4% (3)	1.0% (3)
Gender	Male	73.3% (55)	74.2% (155)	73.6% (220)
	Female	26.7% (20)	25.8% (54)	26.4% (79)
Ethnicity	African-American/Black	1.3% (1)	3.4% (7)	2.7% (8)
	Asian/Pacific Islander	18.4% (14)	18.3% (38)	18.1% (54)
	Hispanic/Latino	11.8% (9)	9.1% (19)	10.0% (30)
	Native American/Alaskan	---	---	---
	White/Caucasian	51.3% (39)	61.5% (128)	58.9% (176)
	Multiracial	13.2% (10)	5.3% (11)	7.4% (22)
	Some other race	3.9% (3)	2.4% (5)	3.0% (9)
Language Spoken at Home	English	89.3% (67)	84.5% (174)	85.1% (252)
	Non-English	10.7% (8)	15.5% (32)	14.9% (44)
Team Type	Public School Team	61.8% (47)	60.5% (127)	59.1% (178)
	Private School Team	17.1% (13)	16.7% (35)	17.3% (52)
	Homeschool Team	14.5% (11)	7.1% (15)	10.0% (30)
	Club Team	5.3% (4)	8.1% (17)	7.6% (23)
	Other	1.3% (1)	7.6 % (16)	6.0% (18)
Years in VRC	First Year	61.3% (46)	45.2% (95)	49.7% (149)
	1 Year	6.7% (5)	9.0% (19)	8.3% (25)
	2 Years	21.3% (16)	31.4% (66)	28.3% (85)
	3 Years	10.7% (8)	11.4% (24)	11.3% (34)
	4 Years	---	2.9% (6)	2.3% (7)

Students self-reported the grades they typically earn in math and science. Most students reported earning mostly A's or A's and B's in math (85%) and science (86%). For middle school students, 78% reported earning mostly A's or A's and B's in math, and 81% reported earning A's or A's and B's in science. Percentages of high school students who reported earning these high grades were slightly higher (87% earning A's or A's and B's in math and science). Most respondents reported they were college-bound, with fewer than 1% reporting they had no plans to go to college. Just over 14% said the highest degree they planned to earn was a Bachelors degree, 33% plan to pursue a Masters, and almost 38% are planning to earn a more

[v] Numbers in parentheses represent the number of participants in each category.

advanced degree such as a Ph.D., MD, or JD. When asked what major they planned to pursue, 298 respondents wrote responses, including:

- General engineering 18% (n=53)
- Computer science 11% (33)
- Mechanical engineering 8% (23)
- Medical or biomed field 7% (21)
- Aerospace engineering 4% (11)
- Mathematics 3% (10)
- Electrical engineering 3% (9)
- Robotics 2% (7)
- Liberal Arts 2% (7)

These percentages include respondents who chose more than one major, thus a few respondents are in multiple categories.

When comparing male and female student respondents by college plans, there was little difference in percentages of students who were unsure about their major or who plan to earn nothing higher than an Associates or Bachelors degree. However, a slightly higher percentage of females plan to earn beyond a Masters degree (see Table 2).

Table 2. Gender Comparisons of Students' Highest Degree Sought

	Highest Degree Student Plans to Earn					
	Unsure	**Associates**	**Bachelors**	**Masters**	**Beyond Masters**	**Not going**
Males	14.2% (31)	1.4% (3)	13.3% (29)	34.9% (76)	35.8% (78%)	<1% (1)
Females	14.1% (11)	1.3% (1)	12.8% (10)	29.5% (23)	42.3% (33)	---

There were also differences in students' choice of college major. As indicated in Table 3, more males than females plan to pursue a degree in engineering or computer science, and more females plan to pursue a degree in a medical or biomedical field. No girls reported an interest in majoring in robotics. In taking a closer look at differences in engineering fields, most students, both male and female, reported interest in general engineering, with about 18% of males and females choosing general engineering as a major. There was no difference between percentages of males and females interested in aerospace, electrical, or mechanical engineering.

Table 3. Gender Comparisons of Students' Plans for College Major

	Major Student Plans to Pursue in College			
	Engineering	**Computer Science**	**Medical/ Biomedical**	**Robotics**
Males	34.4% (75)	12.8% (28)	<1% (10)	2% (7)
Females	26.9% (21)	<1% (4)	14.1% (11)	---

Participants were compared across racial categories to determine whether differences existed due to race. Table 4 provides percentages of male and female students in each racial category.

Table 4. Gender and Race of Student Survey Respondents

	Student Race					
	African-American/Black	**Asian/Pacific-Islander**	**Hispanic/ Latino**	**Caucasian/ White**	**Multi-Racial**	**Other**
Males	3.2% (7)	13.3% (29)	11.5% (25)	63.3% (138	6.4% (14)	2.3% (5)
Females	1.3% (1)	30.4% (24)	6.3% (5)	46.8% (37)	10.1% (8)	5.1% (4)

Because numbers in some racial categories are low (there were only 8 African-American/Black respondents), caution must be taken in interpretations. General findings indicated:

- Asian/Pacific Islander students reported the most years experience in VRC with 1.5 years, followed by Caucasian/White students (1.4 years), African-American/Black students (1.2 years), and Hispanic/Latino students (1.1 years).

Years in VRC:	Asian → 1.5 years	White → 1.4 years	Black → 1.2 years	Hispanic 1.1years

- Asian/Pacific Island students reported parents with the highest educational attainment with 94% reporting parents with a college or graduate degree, followed by Caucasian/White students (75.9% with parents with a college or graduate degree), and African-American students (62.5%). Just over 40% of Hispanic/Latino students reported one or both parents had completed a college or graduate degree.

Parents' w/college or graduate degree:	Asian → 94%	White → 76%	Black → 63%	Hispanic 40%

- Asian/Pacific Islander and Caucasian/White students slightly outperformed African-American/Black students in science with 92% of White and 90% of Asian, compared to 88% of Black students, reporting earning A's or A's and B's.

Science Grades A's or A's & B's:	White → 92%	Asian → 91%	Black → 88%	Hispanic 69%

- All racial groups reported earning higher grades in math than did their Hispanic/Latino counterparts, with 72% of Hispanic students reporting earning A's or A's and B's in math. [**Note:** These are self-reported grades]

Math Grades A's or A's & B's:	Asian → 89%	Black → 88%	White → 87%	Hispanic 72%

- Degree level students plan to pursue differed across racial groups with Caucasian/White students reporting uncertainty more often (17% of the time) than other groups. Regardless of race, a majority of students in each racial group reported they planned to earn a graduate degree. [**Note:** These are self-reported grades]

Plans to pursue a graduate degree:	Asian → 90%	White → 82%	Hispanic → 81%	Black 75%
Plans to pursue degree greater than Masters	Asian → 52%	Hispanic → 48%	White→ 41%	Black 13%

Differences across races also existed in the type of team students were on. As illustrated in Table 5, most African-American/Black students were on public school teams, and none were on homeschool, club, or other types of teams. Only Caucasian/White and Hispanic/Latino students reported being on homeschool teams. With the small respondent sizes in some racial categories, interpretations should be made with caution.

Table 5. Racial Comparisons across Team Types

	Type of Team				
	Public School	**Private School**	**Homeschool**	**Club**	**Other**
Asian/Pacific Islander	51.9% (28)	27.8% (15)	---	14.8% (8)	5.6% (3)
African-American/Black	87.5% (7)	12.5% (1)	---	---	---
Caucasian/White	60.2% (106)	10.2% (18)	14.8% (26)	6.8% (12)	8.0% (14)
Hispanic/Latino	56.7% (17)	33.3% (10)	10.0% (3)	---	---

In summary, the average respondent on the survey was a 15-year old Caucasian male on a public school team whose parents completed a college degree with at least one parent earning a graduate degree. The typical respondent had been competing in VRC for just over a year and had competed in 5 competitions, was an A/B student in school, was college bound, and planned to pursue a graduate degree in a STEM field.

The typical female student respondent was just under 15 years old, Caucasian, with parents who had completed an undergraduate or graduate degree, and was in her first year in VRC. The typical female respondent was a straight-A student who planned to attend college and earn at least a Masters degree in a STEM field.

Interviewed Students. A total of 70 students—33 at the high school level and 37 at the middle school level—were interviewed in focus groups at both a regional competition in Maryland and at the World Championship in Orlando. Students were interviewed with their teammates, and a total of 19 teams participated. There was wide diversity in the focus groups, as indicated in Table 6, with larger percentages of African-American and Native American students participating in interviews than they did in completing surveys.

Table 6. Demographics of Student Focus Group Participants.

		Middle School Grades 6-8	High School Grades 9-12	All
Gender	Male	70.3% (26)	54.5% (18)	62.9% (44)
	Female	29.7% (11)	45.5% (15)	37.1% (26)
Ethnicity	African-American/Black	16.2% (6)	12.1% (4)	14.3% (10)
	Asian/Pacific Islander	3.0% (1)	9.1% (3)	5.7% (4)
	Hispanic/Latino	8.1%% (3)	6.0% (2)	7.1% (5)
	Native American/Alaskan	5.4%% (2)	3.0% (1)	4.2% (3)
	White/Caucasian	67.6% (25)	69.7% (23)	68.6% (48)
Team Type	Public School Team	89.2% (33)	42.4% (14)	67.1% (47)
	Private School Team	---	21.2% (7)	10.0% (7)
	Homeschool Team	10.8% (4)	9.1% (3)	10.0% (7)
	Club/Community Team	---	27.3% (9)	12.9% (9)

TEAM LEADERS

Surveyed Team Leaders. The Team Leader Survey was completed by 345 coaches, mentors, and parent mentors. Of these participants,

- 35.3% described themselves as ***coach***, defined as someone who helps students with design, building, and planning related to competition;
- 7.4% described themselves as a ***mentor***, defined as a someone sharing his or her specific expertise in engineering, robotics, computer programming, and/or technological areas who serves as an expert advisor to teams;
- 13.9% described themselves as a ***parent or other adult, non-technical mentor***, defined as someone who helps coordinate travel, chaperones students, or does event planning or other similar activities; and
- 43.5% described themselves a combination of two or more of these roles.

Of those Team Leaders with combined roles, 32% spent more than half their time in the coach role, whereas only 18% spent more than half their time in the mentor role. On the whole, most Team Leaders spent the majority of their time coaching their teams. About 13% of parent/non-technical mentors spent about a quarter of their time coaching students, and over 25% reported spending some amount of time sharing their STEM expertise with students. In addition to serving as a mentor or coach, 61.1% indicated they were the parent of a current or former VRC participant.

When analyzing roles by gender of the Team Leader, important differences were noted, as illustrated in Table 7. In particular, a greater percentage of women defined themselves as non-technical or parent mentors (almost 39%) than did men (4%).

Table 7. Team Leader Roles by Gender

	Team Leader Role			
	Coach	**Mentor**	**Parent/ Non-Technical**	**Coach/Mentor Combination**
Male	40.3% (73)	9.4% (17)	3.9% (7)	46.4% (84)
Female	26.7% (24)	3.3% (3)	38.9% (35)	31.1% (28

Analysis of demographic data of Team Leaders indicated:

- Overall, most respondents were male (67%), with higher percentages of male Team Leaders at the high school level. At the middle school level, however, half were male and half were female.

- Races of Team Leaders were similar across team level, with most Team Leaders reporting they are Caucasian/White (85%).

Team Leader Race:	White → 85%	Asian → 6%	Hispanic → 4%	Multiracial/other→ 3%	Black 1%

- Most Team Leaders who completed the survey coach public school teams (63%), including 5% in public charter schools and 7% in public STEM-focused schools.

Team Type:	Public School → 63%	Private → 16%	Homeschool → 9%	Other→ 7%	Club Team 5%

- Team Leaders who are also parents of VRC students work with homeschool teams, club teams, and other types of teams (e.g., community teams) in greater percentages than do Team Leaders who are not VRC parents.

Table 8 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 8. 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% (29)	73.5% (114)	69.9% (37)	67.0% (183)
	Female	50.0% (29)	26.5% (41)	30.2% (16)	33.0% (90)
Ethnicity	African-American/Black	1.7% (1)	---	3.9% (2)	1.1% (3)
	Asian/Pacific Islander	10.2% (7)	5.8% (9)	2.0% (1)	6.2% (17)
	Hispanic/Latino	1.7% (1)	3.8% (6)	5.9% (3)	3.7% (10)
	Native American	---	---	2.0% (1)	<1% (1)
	White/Caucasian	81.4% (48)	87.2% (136)	84.3% (43)	85.3% (233)
	Multiracial	1.7% (1)	1.9% (3)	2.0% (1)	1.8% (5)
	Some other race	3.4% (2)	1.3% (2)	---	1.5% (4)
Years as Team Leader	First year	49.2% (29)	35.0% (55)	20.8% (11)	35.0% (96)
	1 year	8.5% (5)	13.4% (21)	11.3% (6)	11.7% (32)
	2-3 years	33.9% (20)	32.5% (51)	35.8% (19)	33.6% (92)
	4-5 years	5.1% (3)	13.4% (21)	15.1% (8)	12.4% (34)
	More than 5 years	3.4% (2)	5.7% (9)	17.0% (9)	7.3% (20)
Profession	Middle School Teacher	33.9% (20)	1.9% (3)	5.7% (3)	9.6% (27)
	High School Teacher	1.7% (1)	66.5% (105)	28.3% (15)	44.1% (124)
	Engineer	8.5% (5)	1.3% (2)	9.4% (5)	8.9% (25)
	STEM/Computer Field	11.9% (7)	4.4% (7)	17.0% (9)	8.2% (23)
	Other	44.1% (26)	16.5% (26)	39.6% (21)	28.1% (79)
Team Type	Public School Team	57.6% (36)	71.3% (110)	35.8% (19)	63.0% (215)
	Private School Team	11.9% (7)	15.3% (24)	18.9% (10)	15.5% (53)
	Homeschool Team	15.3% (9)	5.1% (8)	17.0% (9)	9.1% (31)
	Club Team	6.8% (4)	3.8% (6)	7.5% (4)	5.0% (17)
	Other	8.5% (5)	4.5% (7)	18.9% (10)	7.3% (25)

*combined middle school and high school team

Interviewed Team Leaders. A total of 37 Team Leaders were interviewed in one-on-one and in focus groups at both a regional competition in Maryland and at the World Championship in Orlando. The average Team Leader was a white male who coached a public high school team. Demographic data for Team Leader interviewees are provided in Table 9.

Table 9. Demographics of Team Leader Interviewees

		Participants
Gender	Male	73.0% (27)
	Female	27.0% (10)
Ethnicity	African-American/Black	2.7% (1)
	Asian/Pacific Islander	2.7% (1)
	Hispanic/Latino	2.7% (1)
	Native American/Alaskan	2.7% (1)
	White/Caucasian	86.5% (32)
	Multiracial	2.7% (1)
Team Type	Public School Team	59.5% (22)
	Private School Team	18.9% (7)
	Homeschool Team	16.2% (6)
	Club Team	5.4% (2)

VEX Robotics Competition Impact on Students

In the following sections, results are provided in each of the major areas evaluated. Data are presented from the student survey, the Team Leader survey, student focus groups, and Team Leader interviews and focus groups. Descriptive statistics are reported for the Likert survey items within tables and the text, and narrative responses from open-ended survey items, focus groups, and interviews are provided to triangulate data sources and provide a rich description of student and Team Leader perceptions about VRC.

SELF EFFICACY

Student and Team Leader participants responded to 7 self-efficacy items on the Student and Team Leader surveys that measured self-efficacy (confidence) in school, problem-solving, leading, presenting ideas, asking questions, and working with a team. On the Team Leader Survey, the question was worded this way: *In which of these areas, if any, have you observed changes in students' CONDFIDENCE IN THEIR ABILITIES as a direct outcome of participation in VRC?*

The majority of students, regardless of school level, reported they strongly agreed or agreed that participation in VRC had increased their confidence in each of the areas measured, and Team Leader responses were similar. In addition to percentage of responses in each category, means for the Student Survey were derived for each item, where *Strongly Agree* was coded as a 4, *Agree* was coded as a 3, *Disagree* was coded as a 2, and *Strongly Disagree* was coded as a 1. On the Team Leader Survey, responses were *VRC students confidence becomes much higher* (coded as a 4)*, VRC students' confidence becomes somewhat higher* (coded as a 3)*, VRC students' confidence becomes a little higher* (coded as a 2), or *There's really no change* (coded as a 1). Thus, a score of 3.50 would indicate a response between *Strongly Agree* and *Agree* on the Student Survey or between *much higher confidence* and *somewhat higher confidence* on the Team Leader Survey.

The top three categories in which middle and high school students strongly agreed or agreed their self-efficacy had increased were in teamwork, problem solving, and leadership. Overall, school and science self-efficacy were ranked lowest for students and Team Leaders, except for those Team Leaders who coach both middle and high school teams. Self-efficacy scores, on the 1 – 4 scale described in the previous paragraph, are ranked for students and Team Leaders in Table 10. Additional disaggregated self-efficacy data are included in Appendix 3.

Table 10. Self-Efficacy Rankings for Students and Team Leaders

	Self-Efficacy Categories						
	1st Ranked	2nd Ranked	3rd Ranked	4th Ranked	5th Ranked	6th Ranked	7th Ranked
MS Students	Teamwork 3.57	Problem Solving 3.42	Leadership 3.39	Asking Questions 3.39	Presenting Ideas 3.38	School Achieve. 3.36	Science Achieve. 3.24
HS Students	Teamwork 3.52	Problem Solving 3.48	Leadership 3.41	Presenting Ideas 3.41	Asking Questions 3.33	Science Achieve. 3.28	School Achieve. 3.26
MS Team Leaders	Asking Questions 3.23	Teamwork 3.18	Presenting Ideas 3.18	Problem Solving 3.17	Leadership 3.05	School Achieve. 2.98	Science Achieve. 2.96
HS Team Leaders	Teamwork 3.41	Leadership 3.25	Problem Solving 3.22	Presenting Ideas 3.19	Asking Questions 3.18	School Achieve. 3.15	Science Achieve. 3.01
MS/HS Leaders	Problem Solving 3.49	Leadership 3.45	Science Achieve. 3.43	Teamwork 3.41	School Achieve. 3.36	Asking Questions 3.31	Presenting Ideas 3.31

On average, self-efficacy scores for middle school and high school Team Leaders, except for those who coach both team levels, were lower than scores for students, meaning students more often strongly agreed or agreed that VRC had a positive impact on their self-efficacy than did their Team Leaders. Still, over all, most Team Leaders agreed to some degree that participating VRC had a positive impact on students' self-efficacy.

Team Leaders also responded to questions about VRC students' self-efficacy compared to their non-VRC peers. As illustrated in Table 11, 70% of middle school Team Leaders, 84% of high school Team Leaders, and 83% of MS/HS Team Leaders agreed or strongly agreed that VRC students have higher confidence in their STEM abilities than do their non-VRC counterparts. About one-quarter of middle school coaches disagreed that VRC students have higher confidence in their general academic abilities than non-VRC students, but percentages of disagreement were much lower for high school and MS/HS coaches.

Table 11. Teacher/Team Leader Self-Efficacy Comparisons of VRC Students to their Non-VRC Peers

VRC students…		Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure	Mean	N
have higher confidence in their abilities in STEM areas than their peers.	MS	35.0%	35.0%	20.0%	---	---	3.17	20
	HS	35.0%	48.5%	1.9%	1.9%	9.7%	3.00	103
	MS/HS	22.2%	61.1%	---	---	11.1%	2.88	18
have higher confidence in their general academic abilities than non-VRC peers.	MS	35.0%	30.0%	25.0%	---	5.0%	2.95	20
	HS	24.3%	49.5%	9.7%	1.9%	12.6%	2.72	103
	MS/HS	17.6%	58.8%	5.9%	---	17.6%	2.59	17

Areas of self-efficacy growth also were analyzed in Team Leaders' open-ended response to the question that followed the Likert items: *How does participation in VEX Robotics Competition DIRECTLY INFLUENCE students' confidence in these areas? What have you observed?* The area of teamwork was most often mentioned (44 times, or in 27% of the responses), followed by communication (29 times, or in 18% of the responses), changes in social skill (16 times or 10% of responses), and leadership (14 times or 9% of responses).

Self-efficacy in Teamwork. In analyzing Team Leaders' open-ended responses about increases in self-efficacy, 44 included comments about teamwork. A common theme in self-efficacy responses related to the way the nature of VEX Robotics Competition required teams to work together in order to be successful. As one Team Leader succinctly explained it, "Because there are so many factors involved in producing a successful robots, all of the students must learn to rely on each other." Another provided a more in-depth response:

> *I find it fascinating that 15-year-olds go through the same work team forming dynamics that adults do. They form as a group, have struggles over leadership and role assignments, they start to create standard procedures, and then they start to really perform as a team. This feedback of stress-to-success informs their character and their plans. For many students, this is the first real chance they've been given to succeed without adults standing over them telling them what to do. They have more poise, confidence, and skills that will all be useful in college and as adults. I sometimes think this work group experience is more important than the STEM exposure they receive*.

Another Team Leader also expressed the real-world skills VRC students develop in competition:

> *The process of solving problems often involves seeking out information via discussion with others. Asking for help and considering if the information is applicable to their problem is quite different from what they get in the traditional classroom setting but more like what happens in the real world.*

Though teamwork will be described in greater detail later in this report, other comments are included to illustrated the common types of responses Team Leaders provided regarding the positive benefits of VRC on students' self-efficacy in teamwork. On surveys, Team Leaders wrote comments such as:

- *Our students have learned to work together in order to get the job done. Contributions from each and every person are respected.*

- *My students understand that they may not have all the answers, but by working together the sum is greater than their parts.*

- *Their ability to work well as a team has been greatly improved. Students show large growth in sharing their ideas and working with everyone regardless of whether they are their friends or not.*

- *The requirement of teamwork with split responsibilities makes students more accountable for their work. As a result they ask more questions and strive to work together well.*

Self-efficacy in Communication. On the survey, 29 Team Leaders wrote responses about confidence increasing in the area of communication. According to the data, one way this confidence builds is due to the fact that students must present their ideas to judges during competition. As one Team Leader explained, "Judging sessions (having to speak directly to judges, using eye contact, communicating effectively) are excellent opportunities for personal growth and boosting confidence." Another Team Leader suggested that talking with judges also helps students gain skills needed to obtain scholarships, writing, "Talking to judges about their designs can greatly affect their abilities to talk to people and overcome shyness. This really helps for scholarship interviews." Communicating in competition goes beyond simply communicating with judges, however. Another Team Leader who also mentioned the powerful experience of preparing to speak to judges further explained, "I have seen students struggle with the ability communicate their ideas effectively. They struggle with the engineering notebook in the beginning, but if they stick with it they can really improve communicating their ideas."

Another way students' self-efficacy in communication develops is in sharing ideas with teammates. One Team Leader expressed, "The team interaction forces them to communicate and encourage each other to participate and contribute towards the success of the goal." Another wrote, "It allows students to gain experience in interpersonal interaction and problem solving on a personal level, as they must communicate and work together to create a working robot that meets their own criteria." Additional comments referred to the accountability students feel to their teammates, which pushes them to communicate ideas. As another Team Leader explained,

> *I have observed students being better able to communicate their ideas and working together as a team. People in the club all contribute their ideas and turns out to be great usually. If their idea isn't taken, they don't mind too much as they are trying to make the robot as good as it can be and learn from their mistakes.*

Being part of VRC also provides students with additional opportunities, outside of competition, to gain confidence in communication. Team Leaders described interviews students provided, informational presentations made to local community groups, and fundraising presentations to local businesses. Survey comments included:

- *I was fortunate enough to have one team qualify for the World Championships. In order to raise funds for the trip they have had to reach out to local businesses. Their confidence in this area has skyrocketed. They are now at the point of contacting the businesses, scheduling the meeting and demonstrating their product all on their own.*

- *My team has made numerous presentations to local service clubs such as Kiwanis and Rotary. They are now making these presentations without the coach being present and the reports have been outstanding.*

- *Our team has been interview many times within our school and presented in front of groups many times. This has improved their presentation skills and confidence about their work.*

Growth in self-efficacy in communication was also described by several Team Leaders during focus group interviews. As one Team Leader explained about his all-girls' team:

> *I have students who come in and I can barely hear them talk. I mean, I've had them in class and they're silent, and [VRC] gets them to a point where they're in front of a news camera giving an interview at a normal volume…that's a huge change that I see, especially with the students I keep [on my team] over multiple years. They really build confidence, and they really start to realize they know what they're talking about, and they understand what they're doing. They can talk to adults. They can talk to judges. They can talk to adults who are interested in what they are doing. It really changes a lot.*

One coach of a team that was completely made up of underrepresented students (racial minority and mostly girls), also explained in his interview how his students had grown in communication and their confidence to communicate effectively. He stated, "*…communication skills…allow them to be a leader…it's the most important thing, more important that the math and science skills*."

In focus groups, students also described changes in their confidence related to communication. As one female minority student stated about growth in confidence in areas that include and extend past communication,

> *You have to learn how to deal with different personalities. You have to speak to people and you have to be patient. You have a lot of people who want to be leaders, and you have to listen. You have to work on your communication skills.*

A male teammate added to this comment, "*Yeah, programmers and builders do two different things and they have to communicate their ideas in order to get a robot to actually work. You have a lot of meetings to make sure everybody is on the same page*." To this, a third teammate added, "*And that's how we keep our team together*."

Self-efficacy in Leadership. On the survey, 14 Team Leaders mentioned changes in students' confidence in leadership. The most prominent theme related to students with few leadership skills developing into confident leaders due to the need for a leader or leaders to emerge in order for the team to be successful. Within the comments there were two anecdotes about students reluctant to participate when they started on the team who moved into leadership roles within a year. Other comments related to the need for student leaders to understand group dynamics and work with the team accordingly. One Team Leader explained this, expressing the role a good mentor can play in helping students develop:

> *The need to be a team leader is particularly competitive and it fuels those that might otherwise be shy about this aspect to really step-up and find a valuable place for themselves on the team to prove that they can head-up a team. This also transfers outside of robotics into their daily lives. Learning how to develop in the group dynamic is often a hard lesson, one that I feel is very important for the adult leaders to guide. New members often come in feeling that they are smarter than any one else on the team and work outside the set structure to try and prove themselves. As the student approaches the end of his sophomore year, mentors are able to instill a better balance of respect and appreciation for the guidance that more experienced team members and mentors offer.*

In addition to the role mentors can play in helping students develop as leaders, other Team Leaders mentioned the types of leadership roles students take within their teams such as motivator, mentor, and mock judge. One Team Leader, describing the way "scrubs" (experienced team members) lead in the development of "newbies" (students new to VRC), wrote,

> *As students work with their VEX teammates, they grow as individuals. Newbies who may be shy and quiet, find that they are encouraged to speak up and join in. Experienced team members practice competition robotics, taking on the role of the judges, inviting the newbies to answer the "judges" questions about teamwork, individual contributions, how the team functions, etc. The "judges" then meet with the team as a whole and review lessons learned. The next mock competition finds the newbies with a bit more confidence, standing a bit straighter, and acting a bit more like a seasoned pro. The next year, those "scrubs" will take on leadership roles themselves. A number of parents have told us that after a year in robotics, their son (or daughter) has matured well beyond their expectations.*

When surveyed students were asked the areas in which VRC participation had impacted them the most, several wrote about the various areas of confidence in which they perceive they have grown. One student, for example, wrote, "*VEX has given me the confidence to think out-side the box and express my ideas to the team, as well as try my leadership skills*." Other student comments were:

- *Since I started with the VRC I feel more confident when expressing my ideas to a team. I also find it easier to assume the role of leader when I have to.*
- *I have more confidence and am more willing to take charge and lead.*
- *It has helped develop my sense of confidence, and how I work with other people and contribute to the big picture.*

A few students also mentioned their growth in leadership during the focus group interviews. One 12th grade male student, when asked what he liked best about being in VRC, said, "Learning leadership." He went on to say of his experience on the team, "I learned how to work with people…I learned responsibility to become a leader." Another student (a senior who also served as a student mentor to her team) explained, "The program has really helped students come into their own. Doing well in VEX helps you become a leader."

Other Changes in Student Self-efficacy. Other categories derived from Team Leaders' open-ended survey responses related to changes in shy students and changes in students typically underrepresented in STEM. Changes in shy students were mentioned by 16 Team Leaders. One Team Leader simply wrote, "*I have seen very shy students become more verbal and work together better due to participation in VEX*." This was expressed by other Team Leaders as "*getting over inhibitions*" and "*coming out of their shells*."

As explained by the Team Leaders, getting over shyness is necessary because students must communicate within their teams, with other teams, and with judges to be successful. One Team Leader stated, "I've watched kids come out of their shells and seen some turn-arounds that have surprised me. Some of it is the participation individually and some of it is the group interactions." During an interview, another Team Leader who works with a particular ethnic population (and is, himself, part of the same ethnic group) said of his students, [In our culture, students] "are naturally shy and not outgoing, but to see a student come into VEX—they start to become the total opposite of how they started because they see all the other students [at competition] and interact with them."

Yet another Team Leader wrote,

> *We have a small team (3) and they are very shy. However, they attended Worlds last year, too, which introduced them to other teams, working with people they have never met (and couldn't even communicate with—Chinese team), but still being able to work together to play the game. It gave them new experiences that they would never have had in their own state.*

Another wrote about the positive social aspects of this phenomenon, explaining,

> *Students that are normally quiet and non-social develop skills and gain confidence within themselves. I have a diverse group of kids ranging from Athletes to more academic driven students. In my class, these barriers are torn down and I see the kids working together instead of breaking each other down. Life long friendships have been made due to this type of class.*

An interviewed middle school coach explained his experiences this way: "*The kids become more outgoing. They're not afraid to address situations. [VRC] gets them out of their shells. VEX kids are either [naturally] outgoing or not at all [outgoing]. VEX brings them to the middle*."

Other similar comments included:

- *Students who were shy to begin their exposure in robotics seem to become more confident and outgoing after experiencing some successes among other teams as they see themselves as good or better in their performance against these teams. Also, they encourage themselves to be better and have the confidence to be as good as those teams they see as better than they are…*

- *The nature of the VEX competitions has forced my students to develop skills that enable them to approach other teams to ask questions that are related to problems that arise during the competition. Having shy students, this is a huge development and learning curve that will serve the students later in life.*

- *I have seen kids that were shy around others before now get excited as they explain their robot design to another team or adult.*

- *We also find that students who engage in the program often come in as loners, but find a comfortable social group within our club. As such robotics truly becomes part of their identity.*

A few other comments related to changes in confidence in students who Team Leaders perceive as not typical VRC students. For example, one Team Leader wrote:

> *My students are not the gifted and talented students in our school so they have really blossomed as a result of VEX. They are more confident in themselves and believe in their abilities as a result of VEX. My programmer knows she can compete against any high school student (she was so insecure when she first came she used to cry at failure). My students do well in school.*

Another Team Leader described differences in his students, who he views as atypical of others in VRC:

> *Most of my team members come from poor neighborhoods with a low self-esteem. Once they participate and collaborate with students from private and special schools as equals their confidence levels raise. We have to do fundraisers, like most teams, and they have to present the robotics project to people of different genders, age, and professions; this is a boost for their self-esteem.*

At the end of the survey, Team Leaders provided their explanations of the greatest benefits of VRC competition for students. Well over half of the participants wrote in responses, and of the 187 comments, 19 (10%) included comments about positive changes in student confidence. During interviews, Team Leaders frequently talked about ways students developed confidence due to VRC as well.

As one Team Leader explained, "*When students are placed in a position in which they can fail and they succeed, their confidence is boosted immensely*." Another listed, "*Building confidence in themselves and as part of a team*" as the greatest benefit of VRC for students.

TEAMWORK

Team Leaders and students were asked whether participation in VEX Robotics Competition helped students grow in the area of teamwork. On the student survey, participants responded to teamwork items on a 4-point scale where 4 = *Helped a lot*, 3 = *Helped*, 2 = *Helped a little*, and 1 = *Hasn't helped*. The Team Leaders survey items on teamwork required participants to answer the question *In which of these areas, if any, have you observed STUDENT GROWTH as a direct outcome of students' participation in VRC?* Because the Team Leader Survey items utilized a 3-point scale (where 3 = *a lot of growth*, 2 = *some growth*, and 1 = *not much growth*), two response categories on the Student Survey were collapsed into one category (*helped* and *helped a little*), thus means provided in the following tables are scaled on the 3-point scale for both the Student and Team Leader Surveys.

The teamwork item with the largest differences between Team Leader and student responses was in the area of *coming up with ideas and sharing them with the team*. Both Middle and High school students responded similarly on that survey item, with about 39% of students at each level reporting that VRC helped them a lot in this area. However, as illustrated in Table 12, a much higher percentage of Team Leaders reported students demonstrated growth in this area, with 74% of Middle School, 70% of High School, and 83% of MS/HS Team Leaders reporting students showed a lot of growth.

Table 12. Student and Team Leader Comparisons: *Coming up with ideas and sharing them*

Students: Has VRC helped you? Team Leaders: Have VRC students demonstrated growth?		**Helped a lot**	**Helped or Helped a little**	**Hasn't helped**	**Not sure**	**Mean**	**N**
Coming up with ideas and sharing them with team	MS Student	39.0%	54.6%	1.3%	5.2%	2.40	77
	HS Student	38.8%	57.9%	2.9%	<1%	2.36	209
		A lot of growth	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	74.1%	22.4%	1.7%	1.7%	2.74	58
	HS Team Leader	69.6%	29.7%	<1%	---	2.69	158
	MS/HS Leader	83.0%	17.0%	---	---	2.83	53

Means were similar on the item *solving difficult problems with teammates* among middle school students, middle school Team Leaders, and MS/HS Team Leaders (see table 13). However, the mean was lower for high school students and higher for high school Team Leaders, indicating a greater percentage of high school Team Leaders (71%) than high school students (40%) perceived that VRC was beneficial in the area of solving problems with teammates.

Table 13. Student and Team Leader Comparisons: *Solving difficult problems with teammates*

Students: Has VRC helped you? Team Leaders: Have VRC students demonstrated growth?		Helped a lot	Helped or Helped a little	Hasn't helped	Not sure	Mean	N
Solving difficult problems with teammates	MS Student	54.5%	41.6%	1.3%	2.6%	2.55	77
	HS Student	40.0 %	57.1%	1.9%	1.0%	2.38	210
		A lot of growth	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	57.6%	33.9%	6.8%	1.7%	2.52	59
	HS Team Leader	70.5%	27.6%	1.9%	---	2.69	156
	MS/HS Leader	56.6%	41.5%	1.9%	---	2.55	53

When making comparisons on the teamwork item *being a good teammate*, results indicated that a higher percentage of middle school students (53%) believed participation in VRC helped them a lot compared to high school students (44%). However, fewer middle school Team Leaders (46%) perceived that their middle school students demonstrate a lot of growth in being a good teammate. Data for this item are presented in Table 14.

Table 14. Student and Team Leader Comparisons: *Being a good teammate*

Students: Has VRC helped you? Team Leaders: Have VRC students demonstrated growth?		Helped a lot	Helped or Helped a little	Hasn't helped	Not sure	Mean	N
Being a good teammate	MS Student	53.2%	43.9%	---	2.6%	2.55	77
	HS Student	44.0%	52.7%	2.4 %	1.0%	2.42	207
		A lot of growth	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	45.8%	44.1%	8.5%	1.7%	2.38	59
	HS Team Leader	51.6%	44.6%	3.8%	---	2.48	157
	MS/HS Leader	52.8%	43.4%	3.8%	---	2.49	53

In the area of *setting team goals*, an almost equal percentage of high school students (37%) and their Team Leaders (39%) reported a lot of growth. There was a larger difference between middle school students (44%) and their Team Leaders (55%), with a higher percentage of Team Leaders than students reporting VRC impacted students in setting team goals (see Table 15).

Table 15. Student and Team Leader Comparisons: *Setting team goals*

Students: Has VRC helped you? Team Leaders: Have VRC students demonstrated growth?		Helped a lot	Helped or Helped a little	Hasn't helped	Not sure	Mean	N
Setting team goals	MS Student	44.2%	46.8%	3.9%	5.2%	2.42	77
	HS Student	37.1%	55.2%	5.7%	1.9%	2.32	210
		A lot of growth	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	55.2%	37.9%	5.2%	1.7%	2.51	58
	HS Team Leader	39.1%	54.5%	6.4%	---	2.33	156
	MS/HS Leader	45.3%	47.2%	7.5%	---	2.38	53

When examining VRC impact on students *taking individual responsibility for doing one's part on the team*, over 50% of middle school students (52%), high school students (55%), and middle school Team Leaders (55%) reported a high level of impact or growth in this area. Similar percentages of high school Team Leaders (55%) and MS/HS Team Leaders (51%) reported there was some growth in this area. Table 16 provides additional data.

Table 16. Student and Team Leader Comparisons: *Taking individual responsibility*

Students: Has VRC helped you? Team Leaders: Have VRC students demonstrated growth?		**Helped a lot**	**Helped or Helped a little**	**Hasn't helped**	**Not sure**	**Mean**	**N**
Taking individual responsibility for doing one's part on the team	MS Student	51.9%	42.5%	2.6%	2.6 %	2.51	77
	HS Student	55.0 %	40.6%	3.3%	1.0%	2.52	209
		A lot of growth	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	55.2%	37.9%	5.2%	1.7%	2.51	58
	HS Team Leader	39.1%	54.5%	6.4%	---	2.33	156
	MS/HS Leader	43.4%	50.9%	5.7%	---	2.62	53

Regardless of the slight differences on teamwork survey items (a) between high school and middle school students, (b) among middle, high, and MS/HS Team Leaders, and (c) across both groups, on average most students and Team Leaders reported that VEX Robotics Competition has helped them a great deal in developing teamwork skill. Higher percentages of middle school students than high school students, on every teamwork item except *taking individual responsibility for doing one's part on the team,* reported VRC helped them a great deal.

When analyzing teamwork items aggregated across students and aggregated across Team Leaders, results indicate that (1) higher percentages of Team Leaders than students believed that VRC helped students a lot (or that students demonstrated a lot of growth), and (2) when ranking items by mean, there were differences between Team Leader and student responses, as indicated in Table 17 As illustrated, the area in which Team Leaders reported the most student growth in teamwork was in *coming up with ideas and sharing them with the team*, the same item on which students reported the least growth.

Table 17. Student and Team Leader Comparisons of Ranked Areas of Growth in Teamwork

Student Teamwork Items	**Mean**	**Rank**	**Team Leader Teamwork Items**	**Mean**
Taking individual responsibility for doing one's part on the team	2.52	**1**	Coming up with ideas and sharing them with team	2.72
Solving difficult problems with teammates	2.46	**2**	Solving difficult problems with teammates	2.65
Being a good teammate	2.46	**3**	Being a good teammate	2.46
Coming up with ideas and sharing them with team	2.38	**4**	Setting team goals	2.41
Setting team goals	2.35	**5**	Taking individual responsibility for doing one's part on the team	2.37

Further, when Team Leaders who are also teachers were asked to compare teamwork skills of their VRC students to their non-VRC peers, 77% agreed or strongly agreed that VRC students

demonstrate greater teamwork skill than their peers. Disaggregated data are provided in Table 18, which shows that 40% of middle school, 33% of high school, and 39% of MS/HS Team Leaders strongly agreed VRC students demonstrate greater teamwork skill than do their non-VRC peers.

Table 18. Teacher/Team Leader Teamwork Comparisons of VRC Students to their Non-VRC Peers

VRC students…		Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure	Doesn't Apply	Mean	N
Demonstrate greater	MS	40.0%	40.0%	15.0%	---	---	5.0%	3.26	20
teamwork skill than	HS	33.0%	44.7%	5.8%	1.9%	11.7%	2.9%	2.88	103
their non-VRC peers.	MS/HS	38.9%	33.3%	---	5.6%	22.2%	---	2.61	18

At the end of the Team Leader Survey, Team Leaders were asked what the greatest benefit of VRC participation was for students, and answers related to teamwork far outnumbered all other answers. Of the 187 written responses, 124 (66%) included *teamwork* as a benefit. Some of these responses were specific to the teamwork skills built within teams, such as, "…*working as a team and knowing that they can solve real problems successfully*." As one Team Leader explained,

> *The team approach brings a completely different set of skills needed to project manage the design build and program and then actually enroll, lead and motivate in the competitions. I haven't seen this complexity of skills needed in usual sports teams. It allows for a greater diversity of students to contribute with a broad range of skills and it certainly encourages team playing rather than one-man teams.*

The benefits of intra-teamwork was described this way by another Team Leader:

> *If a team works together to solve a problem, in an organized, efficient manner, there is no end to what a young man/woman can accomplish. The whole is greater than individual contributions; but nothing can be accomplished unless the team "works together."*

Other Team Leaders described the ways teamwork across teams, or inter-teamwork, occurs and is beneficial for students. One Team Leader, for example, wrote that the greatest benefit of VRC for students was, "*Being able to apply theory to real life situations and share ideas with others who might not even be from the same team*," a second wrote, "*Learning from and interacting with other teams at the competition*," and a third responded, "*Seeing the cooperation between the teams in a competition*." Yet another Team Leader described the inter-teamwork benefit this way:

> *The students learn how to be competitive, yet encouraging to other teams/other students. The teams are forced to work through a design and make*

improvements throughout the year. They are invested in their solution to the competition challenge and want to see it succeed. Additionally, the students learn something new and are given many opportunities at competitions to collaborate with other teams and help those teams improve.

Students also wrote about the positive impact of VRC on their teamwork skills, commenting on the survey:

- *The VEX Robotics Competition has positively impacted me in the sense that I now understand that there is no "I" in team, and that the team as a whole is responsible for victory, not just the individual members.*

- *I've learned so much this year it would be hard to name one thing. I think one of the most important things I've learned is how to work in a team effectively.*

- *VEX Robotics has impacted me because it has taught me to be a team player and involve everyone.*

- *Vex competitions gave me a view that nothing really is impossible. My teammates and I really worked as a group and each did their role. We overcame obstacles, gave up a lot of time, and strategized our game. Though hard work and dedication we achieved many things we once saw impossible.*

- *The VEX robotics competition has made me into harder working, more capable person. It has taught me to have a work ethic, and it also has taught me how to work together in a team.*

- *I have become a better team member through having to collaborate so intensively with an often highly strung group of teammates.*

- *Vex has taught me to lead a team, work with their morale, and to solve problems as a group.*

- *In all ways shape and form, these competitions have positively impacted me. I have improved in the forms of cooperative teamwork, engineering, the design process, testing and revising, competitive spirit and creative inspiration.*

- *I've worked on hands-on engineering with a team. This is something that you can't learn in school (normal classes I mean).*

- *I enjoy working with my team to solve different engineering problems.*

- *It made me more team-oriented.*

In interviews, students also discussed the ways VRC participation impacted their teamwork skill. As one middle school student (male, minority) from a pubic school stated,

> *We have to build things together and share tools and help each other. That is our main goal to get here, to participate. You have to have teamwork on the field. If you do not have teamwork, people are going to be insane and you lose your focus. It helps when you build your robot. We have to help each other. Everyone has a different [type of] coordination, and you use it all together.*

In several focus groups, students described how difficult it was, at first, to work together as a team. As one middle school student explained, "*We all have to work together. We've gotten better at it, but it was really hard at first, but we have to work together*." This comment was confirmed by this student's teammates, who nodded in agreement as the student spoke. In another middle school focus group with 4 girls and 1 boy, several students commented about VRC impacting teamwork skills. As one female student explained, "*You have to work in a group to succeed*." Another girl from the team added, "*and it helps with teamwork at school and in group work [at school]*."

Interviewed Team Leaders also explained how students grew in teamwork, and throughout the interviews, they consistently talked about teamwork being one area in which students grew the most. As one Team Leader explained in her focus group interview,

> *I've definitely seen them grow over the years in teamwork. I don't think it was something they were good at, at first. And we've had a lot of….some talk, especially at the beginning, like, "Well,* I *did this on the robot, and* I *did this on* my *robot." [But then the talk changes to], "No, this is* our *robot and* our team *did this."*

Another Team Leader, in his focus group interview, explained the importance of building teamwork skills for VRC participants:

> *I think for some of the students, it's really an experience for them to work as a team instead of doing everything all by themselves. They have to learn to relinquish control of certain aspects of construction or programming, and they have to focus in on what they're doing and allow someone else to help and do something else rather than just build it all themselves. Working with a team and interacting with others is very significant with a robotics team like this. It's not just the technical aspects of the engineering part or the programming part. It's the interaction, the human aspect, which is sometimes not thought of initially.*

A number of other interviewed Team Leaders responded with *teamwork* when asked what the greatest benefit of VRC participation was for students. Other Team Leaders responded *seeing the kids work together in teams* when asked what they liked best about being a coach or mentor.

SPORTSMANSHIP

As was the case with teamwork survey items, when analyzing sportsmanship items, student response categories were collapsed to create a 3-point scale in order to make comparisons to the Team Leader survey.

The sportsmanship area in which both Team Leaders and students reported VRC helped them the most was *being honest and fair in competitive situations*. As illustrated in Table 19, over 60% of Team Leaders in each category reported that students demonstrated a lot of growth in this area due to VRC participation. Percentages of students who believe VRC helped them in this area were smaller with 48% of middle school and 48% of high school students reporting a lot of growth in being honest and fair in competition.

Table 19. Student and Team Leader Comparisons: *Being honest and fair in competition*

Students: Has VRC helped you? Team Leaders: Have VRC students demonstrated growth?		**Helped a lot**	**Helped or Helped a little**	**Hasn't helped**	**Not sure**	**Mean**	**N**
Be honest and fair in competitive situations	MS Student	48.1%	45.5%	2.6%	3.9%	2.47	77
	HS Student	48.3%	47.8%	2.4%	1.4%	2.47	209
		A lot of growth	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	62.7%	33.9%	1.7%	1.7%	2.62	59
	HS Team Leader	60.9%	32.7%	5.1%	1.3%	2.56	156
	MS/HS Leader	64.2%	34.0%	1.9%	---	2.62	53

Slightly smaller percentages of Team Leaders responded that VRC participation resulted in growth in the area of *treating teammates respectfully* with about 53% of middle and MS/HS Team Leaders and 55% of high school Team Leaders reporting students demonstrated a lot of growth in this area. As illustrated in Table 20, percentages of middle school students (47%) and high school students (46%) who reported VRC had helped them a lot in the area of treating teammates respectfully were slightly smaller.

Table 20. Student and Team Leader Comparisons: *Treating teammates respectfully*

Students: Has VRC helped you? Team Leaders: Have VRC students demonstrated growth?		**Helped a lot**	**Helped or Helped a little**	**Hasn't helped**	**Not sure**	**Mean**	**N**
Treating teammates respectfully	MS Student	46.8%	48.1%	2.6%	2.6%	2.45	77
	HS Student	45.7%	45.7%	5.8%	2.9%	2.41	208
		A lot of growth	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	52.5%	37.3%	6.8%	3.4%	2.47	59
	HS Team Leader	54.5%	39.7%	5.8%	5.8%	2.49	156
	MS/HS Leader	52.8%	35.8%	11.3%	---	2.42	53

The sportsmanship area where students and Team Leaders reported the least growth was *valuing each team members' contributions*, though mean values were still high for this item. As

indicated in Table 21, a higher percentage of students at both the middle and high school levels reported VRC helped them or helped them a little, with fewer than 40% reporting participation had helped them a lot in valuing team members' contributions.

Table 21. Student and Team Leader Comparisons: *Valuing each team members' contributions*

Students: Has VRC helped you? Team Leaders: Have VRC students demonstrated growth?		**Helped a lot**	**Helped or Helped a little**	**Hasn't helped**	**Not sure**	**Mean**	**N**
Valuing each team members' contribution	MS Student	37.7%	57.2%	1.3%	3.9%	2.38	77
	HS Student	39.5%	55.7%	3.8%	1.0%	2.36	210
		A lot of growth	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	49.2%	37.3%	10.2%	3.4%	2.40	59
	HS Team Leader	46.2%	49.4%	4.5%	---	2.42	146
	MS/HS Leader	52.8%	39.6%	7.5%	---	2.45	53

Team Leaders were also asked to respond to an item that measured perceptions of student growth in *treating opponents respectfully*. A majority of Team Leaders at each level reported that students demonstrated a lot of growth in this area due to VRC participation. As indicated in Table 22, 59% of middle school Team Leaders, 53% of high school Team Leaders, and 62% of MS/HS Team Leaders reported a lot of growth for students in treating opponents respectfully.

Table 22. Team Leader Responses to *Treating opponents respectfully*

Have students demonstrated growth in		**A lot of growth**	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
Treating opponents respectfully	MS Team Leader	59.3%	39.0%	-	1.7%	2.60	59
	HS Team Leader	52.5%	41.3%	5.2%	-	2.48	155
	MS/HS	62.3%	32.1%	5.7%	-	2.57	53

When analyzing sportsmanship items aggregated across students and aggregated across Team Leaders, results indicate that (1) slightly higher percentages of Team Leaders than students believed that VRC helped students a lot (or that students demonstrated a lot of growth), and (2) when ranking items by mean, there were no differences between students and Team Leaders, as indicated in Table 23 [**Note:** an additional item is included in the rankings for Team Leaders that was not available on the student survey. When this item is removed, rankings are the same for both groups].

Table 23. Student & Team Leader Comparisons of Ranked Areas of Growth in Sportsmanship

Student Sportsmanship Items	**Mean**	**Rank**	**Team Leader Sportsmanship Items**	**Mean**
Being honest and fair in competitive situations	2.47	**1**	Being honest and fair in competitive situations	2.58
		-*	Treating opponents respectfully	2.53
Treating teammates respectfully	2.41	**2**	Treating teammates respectfully	2.47
Valuing each team members' contribution	2.37	**3**	Valuing each team members' contribution	2.44

*item not available on Student Survey

Team Leaders were asked what the greatest benefits of VRC were for students, and a few provided answers related to sportsmanship. For example, one Team Leader wrote that VRC is "*better than athletics at developing teamwork, communication, and sportsmanship*."

Sportsmanship was also described by some Team Leaders during focus group interviews. One Team Leader said there were many VRC teams in her home state (which is very small). She said, "*There are many teams there. We found that there is a lot of collaboration among teams. If anyone needs help, [other teams] will help*."

Students also commented on the student survey about the positive impact VRC has on sportsmanship. As one student explained, "*It's taught me how to be a good competitor, and that helping other teams out and getting to know about their design is more important than winning*." Another wrote, "*Vex competitions have taught me gracious professionalism*." When asked what they liked best about VEX Robotics Competition, several students provided these comments related to sportsmanship:

- *The idea that you not only compete with the robot you designed but the opportunity to learn, collaborate and ultimately become friends with your alliances and competitors.*

- *I like that even though individual competitions are competitive, teams from different schools and clubs still remain completely respectful and friendly towards each other.*

- *How friendly everyone at the meet is to everyone else is even during the competitions. All of the teams are willing to give you items if you need them and everyone is courteous to one another.*

- *The friendship between the teams even though they are against each other.*

- *The robot designs, and the shared creativity from the teams*

One student wrote this response about what was the best part of the competition:

> *The camaraderie and friendliness between teams. Most everyone at the competitions act with the utmost of dignity and respect, and treat each other like they would want themselves to be treated. Examples of this include: - Teams lending a hand to other teams for programming - Teams sharing VEX parts with other teams - Teams shaking hands with the other teams before and/or after matches to congratulate and thank the other teams for playing - The Fellowship after the competitions are over (playing games and such) - Getting to know one another better I also enjoy being able to just be myself, without having to put on a facade to impress other people.*

Another student (a high schooler in a minority group) stated in his focus group interview:

> *We do not focus on winning. It's all about working together to make something work. I just want to make sure it gets better each year. It is not about winning. In the other teams, it's not much about competition. Everyone has respect for each other. We [all] try to show professionalism.*

As opinion expressed by several Team Leaders in both interviews and on the survey was that VRC is set up to encourage sportsmanship, as described by one Team Leader who stated in a focus group, "*…the way VEX sets up the competition really fosters the sportsmanship conduct and the helping of other teams*." In fact, another interviewed Team Leader told this story about his team:

> *…a couple of guys on the team do a lot of competitive sports, soccer, and their first [VRC] tournament, they were brain-fried in the very first match, and the team they'd just played came over and helped them problem-solve and figure out what to do, and since that point on, it's just been so obvious it's about creating professionalism in the VEX competition….sportsmanship has been big.*

Observations at the two competitions further indicated a spirit of sportsmanship during the events. Teams were observed helping other teams in the pit areas, sharing tools and parts, and problem solving through programming issues and equipment malfunctions.

INTEREST IN STEM

Team Leaders and students were asked the extent to which participation in VEX Robotics Competition made students interested in STEM areas, including (1) interest in taking additional math or science classes in high school or college, (2) interest in taking engineering courses in college, (3) interest in having a job in a STEM or computer field, and (4) interest in learning more about computer programming, engineering design, and robotics.

As illustrated in Table 24, a large majority of students and Team Leaders strongly agreed or agreed that VRC participation made students more interested in STEM. Results indicated:

- Over 75% of students reported they were interested in **taking additional math or science classes in high school or college** because of participation in VRC.

- Almost 83% of students reported they were interested in **taking engineering courses in college** because of participation in VRC, a slightly higher percentage than Team Leaders who reported the same (80%).

- Over 87% of students reported they were **more interested in having a job in a STEM or computer field** because of participation in VRC; Under 75% of Team Leaders perceived their students were more interested in pursuing a career in these fields.

- Large percentages of students reported they were **more interested in wanting 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.

- When results were disaggregated for students and responses were compared between middle school and high school students, differences in responses were minimal. The same was true when middle school Team Leader, high school Team Leader, and MS/HS Team Leader responses were compared, as illustrated in Appendix 4.

Table 24. Student and Team Leader Comparisons on STEM Interest Items

Participating in the VEX Robotics Competition has made me		Strongly Agree	Agree	Disagree	Strongly Disagree	Not sure	Mean	N
interested in taking additional math or science classes in high school	Students	43.0%	32.8%	12.5%	3.9%	7.9%	3.25	305
		75.8%						
	Team Leaders	44.3%	38.8%	3.9%	<1%	12.4%	3.45	307
		83.1%						
more interested in taking math or science classes in college	Students	43.4%	34.9%	10.9%	2.3%	8.6%	3.31	304
		78.3%						
	Team Leaders	42.3%	34.5%	3.9%	<1%	18.9%	3.47	307
		76.8%						
more interested in taking engineering classes in college	Students	56.1%	26.4%	10.6%	2.0%	5.0%	3.44	303
		82.5%						
	Team Leaders	42.4%	37.8%	3.0%	<1%	16.4%	3.46	304
		80.2%						
more interested in having a job in a STEM or computer field	Students	61.7%	25.7%	6.9%	2.3%	3.3%	3.52	303
		87.4%						
	Team Leaders	40.3%	33.4%	4.9%	1.0%	20.3%	3.42	305
		73.7%						
want to learn more about computer programming	Students	58.2%	30.3%	7.6%	1.3%	2.6%	3.49	304
		88.5%						
	Team Leaders	39.2%	47.9%	9.6%	<1%	2.6%	3.29	311
		87.1%						
want to learn more about robotics	Students	67.3%	25.1%	4.0%	1.3%	2.3%	3.62	303
		92.4%						
	Team Leaders	66.6%	28.6%	1.6%	<1%	2.6%	3.65	311
		95.2%						
want to learn more about engineering design	Students	60.5%	29.3%	5.3%	2.0%	3.0%	3.53	304
		89.8%						
	Team Leaders	53.5%	37.1%	4.8%	1.0%	3.5%	3.48	310
		90.6%						

When student results were disaggregated by gender, higher percentages of males than females agreed or strongly agreed participation in VRS 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. As illustrated in Table 25, regardless of gender, in each area, high percentages (> 70%) of boys and girls reported an increase in STEM interest due to VRC participation.

Table 25. Student Comparisons on STEM Interest Items by Gender

Participating in the VEX Robotics Competition has made me		Strongly Agree	Agree	Disagree	Strongly Disagree	Not sure	Mean	N
interested in taking additional math or science classes in high school	Males	41.6%	33.3 %	13.2 %	5.0%	6.8 %	3.20	219
		74.9%						
	Females	45.6%	32.9%	11.4%	---	10.1%	3.38	79
		78.5%						
more interested in taking math or science classes in college	Males	44.7%	35.2%	10.0%	2.7%	7.3%	3.32	219
		79.9%						
	Females	39.2%	36.7%	13.9%	---	10.1%	3.28	79
		75.9%						
more interested in taking engineering classes in college	Males	60.6%	25.7%	8.3%	1.8%	3.7%	3.50	218
		86.3%						
	Females	44.3%	29.1%	17.7%	1.3%	7.6%	3.26	79
		73.4%						
more interested in having a job in a STEM or computer field	Males	65.1%	25.7%	4.6%	2.3%	2.3%	3.57	218
		90.8%						
	Females	54.4%	24.1%	13.9%	1.3%	6.3%	3.41	79
		78.5%						
want to learn more about computer programming	Males	60.3%	28.8%	5.9%	1.4%	3.7%	3.54	219
		89.1%						
	Females	50.6%	36.7%	12.7%	---	---	3.38	79
		87.3%						
want to learn more about robotics	Males	67.0%	24.8%	4.1%	1.4%	2.8%	3.62	218
		91.8%						
	Females	68.4%	27.8%	3.8%	---	---	3.65	79
		96.2%						
want to learn more about engineering design	Males	61.6%	30.1%	3.2%	1.8%	3.2%	3.57	219
		91.7%						
	Females	58.2%	26.6%	11.4%	17.9%	2.6%	12.8%	3.12
		84.8%						

A number of Team Leaders (approximately 60%) wrote responses on the open-ended survey item about ways participation in VEX Robotics Competition directly influenced student interest in STEM. Descriptions follow.

Interest in Taking Additional STEM Classes in High School. Several respondents provided anecdotes regarding ways VRC participation influenced their students' interest in taking additional STEM courses in high school. As on 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 reported 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 wrote,

> *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.*

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.*

Further, some Team Leaders reported that their students learned additional math and science concepts in order to 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 perceptions 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.*"

In a focus group interview, a male Team Leader who coaches an all-girls team provided further evidence of the impact of VRC on girls. He explained,

> *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...*

A female Team Leader of a co-ed middle school team said in her focus group interview, "*Seeing girls get interested in VRC is definitely a benefit [of the program]*."

A parent mentor also commented on VRC's impact on girls, providing this information about her daughter, whom she believes has become more motivated to study in STEM areas because of her participation in the competition. On her survey she 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."*

Team Leaders also reported changes in students' interest in computer courses or programming as a result in participation in VRC. As one 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."* This Team Leader went on to explain the math and science support students on the team give one another, writing, *"There are a few cases of young students finding a comfortable niche on the team and getting support from others on their math and science work."* A middle school Team Leader has also seen interest in programming grow, explaining:

> *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.*

When asked on the survey to compare VRC students to their non-VRC peers in interest in STEM in high school, high percentages of Team Leaders reported that their VRC students, when compared to peers, were more comfortable using computers (81% agreed or strongly agreed with this statement) and more interested in taking additional or harder computer classes (70% agreed or strongly agreed). Further, 72% of Team Leaders agreed or strongly agreed VRC students were more interested than their non-VRC peers in taking additional or harder math classes, and 70% agreed or strongly agreed students were more interested in taking additional or harder science classes. Disaggregated data are provided in Table 26.

Table 26. Teacher/Team Leader Comparisons of VRC Students to their Non-VRC Peers

VRC students…		Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure	Doesn't Apply	Mean	N
are more comfortable	MS	50.0%	25.0%	20.0%	---	5.0%	---	3.15	20
using computers than	HS	32.7%	50.0%	2.9%	1.9%	10.6%	1.9%	2.94	104
their non-VRC peers.	MS/HS	22.2%	55.6%	11.1%	---	11.1%	---	2.78	18
are more interested in	MS	25.0%	45.0%	15.0%	---	10.0%	5.0%	2.79	20
taking additional or harder	HS	23.1%	46.2%	8.7%	2.9%	16.3%	2.9%	2.58	104
math classes than their non-VRC peers.	MS/HS	---	83.3%	---	---	16.7%	---	2.50	18
are more interested in	MS	20.0%	50.0%	10.0%	---	10.0%	10.0%	2.78	20
taking additional or harder	HS	23.1%	46.2%	9.6%	2.9%	15.4%	2.9%	2.60	104
science classes than their non-VRC peers.	MS/HS	---	72.2%	5.6%	---	22.2%	---	2.28	18
are more interested in	MS	25.0%	50.0%	15.0%	---	10.0%	---	2.80	20
taking additional or harder	HS	22.3%	46.6%	6.8%	2.9%	16.5%	4.9%	2.58	103
computer classes than their non-VRC peers.	MS/HS	5.6%	61.1%	5.6%	---	27.8%	---	2.17	18

On follow-up survey questions, some Team Leaders provided explanations about these differences. As 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 coaches a team that draws team members from 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 were:

- *Help me so much in my science math and engineering workshop classes!*
- *Things in math that I thought were useless suddenly become valuable skills to me.*

In addition, several other students wrote about how much they have learned about programming due to VRC participation. Students wrote:

- *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."* A number of other Team Leaders also have seen interest in STEM fields grow due VRC participation. Some of these comments are included 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.*

- *I have two high school seniors that are going into a college engineering program who previous felt they did not have the skills to do that.*

Most interviewed Team Leaders also provided responses or anecdotes that indicated an increased interest in STEM areas due to VRC participation, usually in the area of engineering. As 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].*" Another Team Leader from a team with 100% minority involvement [racial and gender minorities] 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.*

One Team Leader explained the new opportunities his VEX students have due to their involvement on the team, which encourages and prepares students to examine more college options, writing this survey response:

> *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 works with minority students in an inner city school, explained in a focus group interview how VRC participation created options for his students that they did not normally have:

> *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 [get into college]. Two of our*

> *students got accepted into Johns Hopkins last year; this could be you. They were both 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.*

Students also provided comments about ways VRC participation increased their interest in pursuing STEM fields. On the student survey, one 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*." Another 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 who stated that many students who come into VRC are already interested in STEM fields. However, in each case, the Team Leader expressed his or her belief about the positive benefits for students. As 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 robotic, 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 wrote:

> *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 impacts their future plans:

> *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.

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.

Using STEM to Solve Real World Problems. Finally, one additional item provided information on student and Team Leader perceptions of the extent to which participation in VEX Robotics Competition helped students understand how STEM is used to solve real world problems. Results indicated that 96% of middle school students and 93% of high school students strongly agreed or agreed that VRC participation had helped them in this area. This compares to 91% of middle school Team Leaders, 91% of high school Team Leaders, and 92% of MS/HS Team Leaders who reported students demonstrated at least some growth in this area due to VRC. Data are provided in Table 27.

Table 27. Student and Team Leader Comparisons on *Understanding how STEM is used to solve real world problems*

Participating in the VEX Robotics Competition has made me		Strongly Agree	Agree	Disagree	Strongly Disagree	Not sure	Mean	N
understand how STEM is used to solve real world problems	MS Student	62.2%	33.8%	2.7%	1.4%	---	3.57	74
	HS Student	56.9%	35.8%	5.9%	<1%	1.0%	3.50	204
		A lot of growth		**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	50.0%		41.4%	6.9%	1.7%	2.44	58
	HS Team Leader	47.1%		43.8%	8.5%	<1%	2.39	153
	MS/HS Leader	66.0%		26.4%	5.7%	1.9%	2.62	53

Several Team Leaders wrote about the power of VRC to illustrate to students how to solve real world problems. These comments included:

- *VRC bridges the classroom to the real world by taking concepts learned in the classroom and using them…to solve real life problems.*

- *We are a middle school team. I am not a teacher and we are not part of a school. What I have seen is students who have learned STEM subjects coming to the club and realizing they are capable of applying what they observe. This surprises them. This builds confidence. They feel that they have demonstrated that they are capable of doing something real with the knowledge they have. They start to think ahead to their adult life and being able to do this work in the real world. It becomes less a fantasy and more a reality. I would expect this has a positive impact on their schoolwork.*

- *I have observed that students doing robotics have a better understanding of math concepts; I attribute this to be able to see the math in action.*

- *Vex gives them real life examples of the skills needed programing, design, building driving etc. it's not just textbook stuff. Their learned math and science knowledge comes to life in a meaningful way.*

- *Provides a "real world" example of the skills they observe/learn in classrooms and allows them to see relevant applications of their knowledge.*

- *The program helps students by exposing them to basic design, build and programming skills. This in turn develops easily recognizable and direct applications of math and science.*

- *It allows hands on investigation and application of STEM principles. Through building and competing there is real accomplishment and that serves to show the students that the principles really do work and plants that seed of knowledge and curiosity that more is out there and that they can be a part of it.*

- *The design process gives the students a chance to see how his/her math/physics class is applicable to a real life situation.*

- *Gives them hands-on experience (as opposed to just book work) in engineering principles and design, pneumatics, physics, gear ratios, mechanical advantage, center of gravity....*

- *It gives them experiences that allow them to build their confidence, expand on designing ideas, and allows them to integrate concepts that are taught in their science, technology, and math classes.*

- *Having the 'hands on' experience demystifies science, math, and engineering. They do better in the academic studies of these areas because they have a practical basis to understand how they are applied.*

- *In general, the thing that is especially great is that so much technology in schools these days is about ticking off boxes so each thing is done the amount required for assessment, with very contrived exercises, and once the box is ticked the students move on. With vex robotics they get to experience real life hiccups, they learn through hours of hands on work, with a real investment of themselves (provided the teacher/guide gives the team space). This is much more like real life. Over time the students understand that they can try something out, and sometimes it works, and sometimes it doesn't, and that the process is as rewarding as the outcome.*

Students also commented about the ways participation in VRC helped them solve real world problems or see a connection to their schoolwork. As one student explained, "*I am the team programmer. I have learned more about programing with vex than in any other of my classes. Plus I remember what learned because a have practiced and used it in real world situations*." Another wrote, "*[VRC] has taught me more about how to apply the things I've learned in my science class in real life*." Other survey comments were:

- *VEX Robotics has had a positive impact on me by changing the way I look at robotics. It isn't as complicated or lofty as I imagined; it's a practical real world task that can be attained.*

- *It has impacted me positively alot. I now understand how math and science can help real world situations, and how to make things run efficiently.*

- *It's a way to apply technical learning. Things learned in school, or elsewhere can actually be used and applied. The fact that you can see a real-world application to learnt knowledge not only helps to understand, but also motivates to learn more.*

- *I like being able to apply skills that I learned in my science/math classes to robotics. Before VEX I did not know of many ways that I could apply these skills but now I feel like there are many real world applications for my education.*

In focus group interviews, several students described the way VRC participation helped them in this area. As one female high school student explained, "*It helped me learn problem solving and I'll be able to apply that to real-world situations*."

ACADEMIC ENGAGEMENT

In analyzing survey items on the perceived impact of VRC participation on students' academic engagement, it was apparent that students and Team Leaders believe VRC to be less influential in this area than in the other areas (e.g., teamwork, sportsmanship) examined. Though a majority of Team Leaders (82%) agreed or strongly agreed that VRC participation made students more interested in school or education, only 74% of students responded the same way. Further, though over half of student respondents agreed or strongly agreed that VRC participation made them want to go to school more/have better attendance or join more

clubs/teams at school, many said participation had no impact in these areas (see Table 28). Approximately 30% of students disagreed or strongly disagreed VRC participation made them want to join more clubs or teams, 24% disagreed or strongly disagreed VRC made them want to go to school more or have better attendance, and 19% disagreed or strongly disagreed participation made them more interested in school or education. Disaggregated data are provided in Appendix 5.

Table 28. Student and Team Leader Responses to Academic Engagement Survey Items

Participating in the VEX Robotics Competition has made me		Strongly Agree	Agree	Disagree	Strongly Disagree	Not sure	Mean	N
want to go to school more or have better attendance	Student	33.9%	31.6%	17.3%	6.6%	10.6%	3.04	301
		65.5%						
	Team Leader	35.7%	29.5%	11.4%	4.9%	19.5%	3.17	308
		65.2%						
want to join more clubs or teams at school	Student	26.7%	33.0%	25.4%	4.3%	10.6%	2.92	303
		59.7%						
	Team Leader	23.5%	29.1%	18.3%	5.9%	23.2%	2.91	306
		52.6%						
more interested in school or education	Student	34.4%	39.7%	16.2%	3.0%	6.6%	3.13	302
		74.1%						
	Team Leader	45.9%	35.8%	5.9%	1.3%	11.1%	3.42	307
		81.7%						

When Team Leaders who are also teachers were asked to compare VRC students to their non-VRC peers in the areas of academic engagement, large percentages agreed or strongly agreed that VRC students are better behaved in school and have better attendance, as illustrated in Table 29. When data were aggregated across all Team Leaders, equal percentages (77%) agreed or strongly agreed with these items, though around 10% also disagreed and another 10% were unsure.

Table 29. Teacher/Team Leader Comparisons of VRC Students to their Non-VRC Peers

VRC students…		Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure	Doesn't Apply	Mean	N
are better behaved in school than their non-VRC peers.	MS	25.0%	45.0%	20.0%	---	5.0%	5.0%	2.89	20
	HS	29.0%	55.2%	5.7%	1.0%	13.3%	1.9%	2.75	105
	MS/HS	5.6%	66.7%	11.1%	---	16.7%	---	2.44	18
have better attendance than their non-VRC peers.	MS	35.0%	35.0%	10.0%	---	10.0%	10.0%	2.94	20
	HS	25.7%	50.5%	6.7%	1.9%	11.4%	3.8%	2.80	105
	MS/HS	16.7%	66.7%	---	---	11.1%	5.6%	2.82	18

Some Team Leaders did express, both during interviews and on the survey, that students had to maintain a minimum GPA (usually a B or C average) and have good attendance in order to remain on the robotics team. One Team Leader explained, "*Their attendance in other classes and grades go up, I believe this is because they love to compete and if they do not maintain their grades they will not be competing.*"

As one parent mentor also commented,

> *Being a homeschool mom, in our first year with Robotics, I can only say for my kids. They have more interest in school so that they can attend practices. As with any student, on any team, if they want to remain a team member, they have to keep up the grades.*

Another Team Leader stated that the time-consuming nature of VRC could actually preclude students from being involved in other activities. He wrote:

> *Some students get too involved in multiple clubs/teams, and therefore, their grades suffer. We recommend that those students cut back on extra-curricular activities and remember that their future should be the most important consideration in what they do today.*

Yet another Team Leader described the impact of VRC on her at-risk students, expressing,

> *Our team is located in a district with a 45% poverty rate. We are a safe haven for homeless students and those that do not fit into other "clicks." We focus on academics, writing, teamwork and creative solutions. Our students maintain their GPA and attendance as part of being a team member. We currently have two talented students that plan on becoming engineers and are on the Honors track. We also have 3 students that are homeless or displaced. They also show up to school and practice while maintaining grade expectations.*

Additional school engagement comments included:

- *Vex has given several students a reason to pass their other classes and a reason to come in after school and eagerly solve problems and work as a team.*

- *It has given several students a strong desire to be in school, when in the past school was just "OK". One parent wrote just yesterday to a community organization: "I have to say that Robotics has been one of the most satisfying high school events I have been a part of in terms of growth and development of teens! "*

- *For several of my students, parents have reported that robotics is their child's "life", and at times, the only positive.*

- *Students who participate in our VEX Robotics program are all more likely to have above average attendance, higher grades and contribute significantly to bettering the culture of the school.*

- *The principal has told me that the Robotics Club has given a few students direction and helped with their overall academics. I see students who become interested in learning.*

Students also provided responses that indicated the impact VEX Robotics Competition has on engagement in school. One student wrote on his survey, "*I've made a lot of friends at robotics, I'm now also spending more time at school, and more willing to learn things. Things in math that I thought were useless suddenly become valuable skills to me*." Another student wrote, "*VEX Robotics has involved me in school more*." Additional comments were:

- *The VEX Robotics Competition positively impacted on me is it helps me in school by giving me ideas in all subjects.*
- *It has made school more enjoyable.*
- *It has helped me become more involved in school.*

It appears that one of the ways VRC increases students' engagement in school is by giving them a place where they "fit." Several Team Leaders described the positive benefits of giving kids who don't feel they fit into the school culture a place to succeed. As one Team Leader explained, "*Robotics provides a safe accepting atmosphere for students that don't fit in to other clicks*." Another Team Leader commented, "*Students who normally would not have a competitive outlet ([such as]sports) have one."* This perception was echoed by a number of other Team Leaders during interviews.

21st CENTURY SKILLS

A large percentage of students and Team Leaders perceive that participation in VEX Robotics Competition helps student grow in 21st century skills related to adaptability, goal setting, and self-direction [Note: other 21st century skill areas such as problem solving, communication, collaboration, and leadership are described in other sections of this report].

As illustrated in Table 30, 88% of middle school and 96% of high school students believe participation in VRC has helped them in accepting and using feedback and criticism, and 94% of Team Leaders believe students demonstrate growth in this area due to VRC participation. Higher percentages of middle school students and their Team Leaders reported that VRC helped them a lot in this area than did high school students and their Team Leaders.

Table 30. Student and Team Leader Comparisons: *Accepting and using feedback and criticism*

In which of these areas has participating in the VEX Robotics Competition helped you?		Helped a lot	Helped or Helped a little	Hasn't helped	Not sure	Mean	N
accepting and using feedback and criticism	MS Student	41.6%	46.8%	5.2%	6.5%	2.39	77
	HS Student	38.8%	57.4%	2.9%	1.0%	2.36	209
		A lot of growth	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	52.5%	39.0%	6.8%	1.7%	2.47	59
	HS Team Leader	39.1%	55.8%	4.5%	<1%	2.35	156
	MS/HS Leader	39.6%	52.8%	7.5%	----	2.32	53

On the student survey item about positive impacts of VRC participation, two students provided this feedback, which is related to the skill above:

- *I love working with the bot, making changes, and getting feedback from other students.*
- *It has improved my ability to better be able to accept other people's ideas and implement them.*

Approximately 94% of middle school and 91% of high school students reported that VRC helped them in setting individual goals, compared to 85% of Team Leaders who said students demonstrated growth in this area. As was the case in accepting and using feedback and criticism, a greater percentage of middle school students and their Team Leaders believed VRC helped students a lot in this area as compared to high school students and Team Leaders (see Table 31).

Table 31. Student and Team Leader Comparisons: *Setting individual goals*

In which of these areas has participating in the VEX Robotics Competition helped you?		Helped a lot	Helped or Helped a little	Hasn't helped	Not sure	Mean	N
	MS Student	47.4%	46.1%	3.9%	2.6%	2.45	76
	HS Student	36.2%	54.7%	6.7%	2.4%	2.30	210
setting individual goals		**A lot of growth**	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	37.9%	48.3%	8.6%	5.2%	2.31	58
	HS Team Leader	30.8%	53.2%	15.4%	<1%	2.15	156
	MS/HS Leader	34.0%	54.7%	9.4%	1.9%	2.25	53

All indicated in Table 32, in the 21st Century Skill area *using time effectively*, 90% of middle school and 92% of high school students reported that participation in VRC helped them develop in this area, as compared to 84% of Team Leaders. A much higher percentage of middle school students (almost 51%) reported VRC helped them a lot in using time effectively, compared to 34% of high school students and 29% of Team Leaders.

Table 32. Student and Team Leader Comparisons: *Using time effectively*

In which of these areas has participating in the VEX Robotics Competition helped you?		Helped a lot	Helped or Helped a little	Hasn't helped	Not sure	Mean	N
	MS Student	50.6%	39.0%	6.5%	3.9%	2.47	77
	HS Student	33.8%	58.6%	6.2%	1.4%	2.28	210
using time effectively		**A lot of growth**	**Some growth**	**Not much growth**	**Not sure**	**Mean**	**N**
	MS Team Leader	29.3%	46.6%	20.7%	3.4%	2.09	58
	HS Team Leader	28.2%	56.4%	14.1%	1.3%	2.14	156
	MS/HS Leader	30.2%	60.4%	9.4%	---	2.21	53

Table 33 provides ranked 21st century skill items for both students and Team Leaders. As indicated, means for *accepting and using feedback and criticism* were highest for both groups, followed by *individual goal setting* and *using time effectively*. Means were similar across groups for accepting and using feedback and criticism but were higher in the other two areas for students. This suggests students perceived VRC helped them more in these areas than was reported by their Team Leaders.

Table 33. Student & Team Leader Comparisons of Ranked Areas of Growth in 21st Century Skills

Student 21st Century Skills Items	Mean	Rank	Team Leader 21st Century Skills Items	Mean
Accepting and using feedback/criticism	2.37	**1**	Accepting and using feedback/criticism	2.38
Setting individual goals	2.34	**2**	Setting individual goals	2.21
Using time effectively	2.34	**3**	Using time effectively	2.14

As described in earlier sections of this paper, in other 21st century skills such as problem solving, taking responsibility, goal setting, communication, and collaboration, students and their Team Leaders reported growth due to participation in VRC. Additional data in these areas was collected from Team Leader surveys on items that asked Team Leaders who were also teachers to compare VRC students with their non-VRC peers in several 21st century skills areas. There was a high percentage of agreement among Team Leaders that their VRC students demonstrated greater 21st century skills than do their non-VRC peers. Results indicated that 89% of Team Leaders agreed or strongly agreed VRC students demonstrated higher problem solving ability, 79% agreed or strongly agreed VRC students demonstrated more perseverance, 77% agreed or strongly agreed VRC students demonstrated better leadership qualities, and 72% agreed or strongly agreed VRC students demonstrated better communication skill. Data, disaggregated by team level, is provided in Table 34.

Table 34. Teacher/Team Leader Comparisons of VRC Students to their Non-VRC Peers

VRC students…		Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure	Doesn't Apply	Mean	N
Demonstrate higher problem-solving ability than their non-VRC peers.	MS	35.0%	60.0%	5.0%	---	---	---	3.30	20
	HS	41.3%	44.2%	2.9%	1.9	8.7%	1.0%	3.09	104
	MS/HS	27.8%	55.6%	5.6%	---	11.1%	---	2.89	18
Demonstrate better leadership qualities than their non-VRC peers.	MS	30.0%	40.0%	15.0%	---	5.0%	10.0%	3.00	20
	HS	26.0%	50.0%	9.6%	1.9%	10.6%	1.9%	2.80	104
	MS/HS	5.6%	77.8%	---	5.6%	11.1%	---	2.61	18
Demonstrate better communication skill than their non-VRC peers.	MS	35.0%	40.0%	15.0%	---	5.0%	5.0%	3.05	20
	HS	23.3%	46.6%	11.7%	1.9%	13.6%	2.9%	2.66	103
	MS/HS	16.7%	61.1%	---	5.6%	11.1%	---	2.56	18
Demonstrate more perseverance than their non-VRC peers.	MS	42.1%	42.1%	10.5%	---	---	5.3%	3.33	19
	HS	44.1%	34.3%	5.9%	2.0%	11.8%	2.0%	2.99	102
	MS/HS	27.8%	50.0%	5.6%	5.6%	11.1%	---	2.78	18

In responding to open-ended survey items on differences between VRC students and their peers, a few Team Leaders expressed their belief that there is little difference between them. As one Team Leader commented, "*I do not see a significant difference between VRC students (generally better academic performers than average) and a comparable group on non-VRC*

students of similar academic achievements." A second Team Leader wrote, "*I see no difference. I see VRC as a competition that the kids try to win and not learn from*."

This was not the pervasive attitude, however. Several Team Leaders, in both interviews and on the survey, stated that typically, higher achieving students who have an interest in STEM are the ones who choose to participate, indicating that there are factors beyond VRC participation that impact student achievement, engagement, and STEM interest. As one Team Leader explained, "*I think our VRC students have more skills in many academic and social areas, but I also think the students who participate are self-selecting*." Another Team Leader wrote:

> *My current team consists of highly motivated, high achieving students who challenge themselves. They bring those qualities to the team already developed. The appreciate VRC because it lets them use and excel with skills they already have.*

Some Team Leaders described the differences they see between students who choose to participate in VRC and those who don't, as indicated in the comments below:

- *Most VRC students come to this program highly motivated to succeed. Non-VRC students would like to express their interest in these projects, but are lacking the motivation and commitment of time necessary to achieve success or are subject to peer disapproval.*

- *The VRC students by nature are students who are more academic and interested in math and science. They would typically be the students who would go on to STEM careers and would be successful. Not all of the students who showed an interested in being on the VRC team were these "good" students but the ones who stayed with the program, finished the robot and competed were.*

- *Students who are involved with robotics and robotics competitions enjoy and are interested in designing, engineering, problem solving, and advancing their understanding of science and math. Students who do not share these interests or are not confident in these areas seem to avoid such challenges.*

- *Students who are interested in VRC tend to be a better caliber of student.*

- *VRC students are drawn towards applications of what they already love: math, science, and building things (be it physical or programmed). VRC provides a great avenue for them to exercise and grow these abilities.*

Other comments seemed to indicate that some Team Leaders, while acknowledging that VRC students "*tend to be a better caliber of student*" still saw benefits for these students. For example, one Team Leader wrote, "*I think that Robotics inspires those with any STEM related aptitude to come out of their shell*," and another wrote

Students that participate in our robotics club are self-motivated to continue their passion for creating building and designing by getting together after school socially or communicating through texting, phone calls and video calls to continue their passion of learning. The more they communicate the more self confident they become and the more they want to succeed.

A final comment in this area was,

This program offers hands on problem solving in a game setting. Some of the kids we have out would love to be a great athlete and compete, but cannot. This venue gives these kids success and has also brought about a cognizance that it is pretty cool to do.

A number of Team Leaders did report gains in 21st century skills for VRC students that they attributed to participation in the competition. For example, when commenting on the gains VRC students made in comparison to their peers, Team Leaders who were also teachers provided detailed feedback about these gains, pointing to confidence, teamwork, and problem-solving as areas of growth. Comments supporting growth in these areas are provided in each of these areas.

In the area of **Problem Solving**, Team Leaders noted:

- *Confidence gained through teamwork and problem solving.*
- *Their ability to work together to compete and solve problems.*
- *Confidence in solving problems, project management, and utilizing computer skills and resources.*
- *Once a student completes my curriculum they have had to reach out to others for help, solved difficult problems that they would have never attempted, and gained confidence within themselves.*
- *After several years in the program, I have observed that VRC students learn to budget their time more effectively. They also feel more confident solving complex technical problems.*

A parent/coach who was interviewed also described changes in student confidence in problem solving, which he saw as specific to his homeschool team. As he explained about his students,

…they have the belief that they can problem solve and they can succeed with their brain, because, you know, coming from a homeschool, you're not seeing yourself with or against peers in the formal classroom and standardized testing

you don't really do, so there's this kind of uneasiness about "Am I capable?" and with VEX, [their confidence grows] in leaps and bounds.

In **Communication**, Team Leaders stated:

- *[Students] are more communicative and confident in their ideas and opinions within the group, and willing to speak to strangers about what they are doing.*
- *Students who participate in our VEX Robotics program always show improvement in leadership, communication and problem solving skills throughout their high school careers*.

In describing gains in **Self-Direction and Motivation**, Team Leaders commented:

- *I feel VRC students are more apt to jump right in an activity and figure it out rather than wait for the instructor to explain step-by-step instructions.*
- *The students on my robotics team flat out get their work done. If only the majority of my students were as productive.*
- *I would agree that VRC students have more perseverance than non-VRC students.*
- *VRC students are self-motivated and self-directed.*
- *The VRC students spend hours after school persisting in figuring out problems.*
- *VRC students are much more willing to commit time and effort to events outside of school.*
- *VRC team members are more motivated to work on their projects outside of class.*
- *The competitive nature of VRC forces students to make deadlines and get things done so they have to show perseverance become more confident, because they get things working one way or another.*
- *I believe that the competitive platform created by VRC motivates students to attend school, take an interest in STEM classes, and take personal pride in their work/achievements during the VRC season.*
- *VRC students are able to stay on task for long periods of concentration without stopping. They are also able to restart anew with less moaning when things don't go as planned. (But not always!)*

Along these same lines, in focus group interviews, Team Leaders often answered *responsibility* when asked what are the most significant gains students make due to their participation in VRC. As one Team Leader from a high minority, inner city school stated, "*They can take hold of their education and really do, really do go further*."

Regarding **Collaboration and Teamwork**, Team Leaders said:

- *By representing the school at various tournaments the students get to see how well they interact with each other. When our students hear that others schools actually have a budget they are proud that every penny that is invested in our robotics team is raised by the students themselves through various fundraisers. This in itself adds to their confidence and respect for the equipment and ability to be in competitions.*

- *The biggest difference is in their commitment and their understanding of teamwork since they know first hand how important each person is. Deadlines for competition force them to learn to follow thru on what they start.*

- *They value the need for teamwork more than the average students.*

- *VRC allows students from different areas to work together. I have students working together with students from other grades form strong bonds and partnerships. This allows them to help support each other in and outside of the classroom.*

In the area of **Learning from Failure**, Team Leader comments included:

- *The students who do VRC have to develop these skills in order to be successful in the competition. They also develop greater confidence to try things and seem less afraid of failure.*

- *The students get to know others well and are less self conscious about their achievement/ failure than others as they see the design process is never free of some mishaps.*

- *They are more willing to try. Even if it fails they are going to learn for the failure and fix the problem. Non-VRC [students] are afraid to fail and want to be guided through everything step by step.*

Students also commented about the ways VRC participation positively impacted them in the areas of problem solving, communication, leadership, collaboration, and learning from failure. When asked to explain the ways the competition had positively impacted them, 11 students (about 6% of those who provided a response) provided responses related to problem-solving. Some of these comments were:

- *Allowed me to use problem solving skills in a fun, creative way.*
- *VEX has taught me to…solve problems as a group.*
- *It has given me experience in problem solving.*
- *I enjoy working with my team to solve different engineering problems.*
- *Participating in VEX robotics has taught me the value of perseverance in regards to problem solving. Issues with designs crop up frequently, and persevering to solve these problems has helped me build.*
- *[How to] problem solve in general; actually thinking things through and not being hasty about it.*
- *It has also improved my creative and problem solving skills.*

Students also made several comments about **communication**. As one student explained, *"[VRC] has made me less nervous when talking to other people*." Another wrote, "*Since I started with the VRC I feel more confident when expressing my ideas to a team*." A third student commented, *"[VRC] has positively impacted me by learning how to communicate with others*."

In the area of **leadership**, 15 students (8% of those who answered the question about the ways VRC had positively impacted them) said VRC had positively impacted them in these areas of leadership. Some of these comments were, "*I find it easier to assume the role of leader when I have to,*" "*It has made me use my mind to develop new solutions for challenges ahead I never thought possible, but also made me grow as a leader, "It has made me a better leader while also teaching me programing and robotics,"* and "*I have more confidence and am more willing to take charge and lead."*

In explaining the leadership role he has taken with his team, one student wrote:

> *It has shown that I do have the leadership skills to start a new rookie team that we hope will be at worlds next year. I am currently mentoring a middle school team, which has also made me more involved in my community.*

Another student had similar experiences both leading his team and being a leader in the community. He wrote on his survey, "*It's given me opportunities to lead my own robotics team, and many others such as presenting to [a local business], the Kiwanis Club, and boards of directors*."

Another student explained,

> *The most gratifying change that the VEX Robotics Competitions has made are my leadership skills. Before beginning these competitions, I was terrified of competition. Thanks to this program, I was successfully able to lead our team through some troubling times and create a robot that we could all be proud of.*

Four students, in provided an answer to the survey question about the way VRC impacted them, gave responses related to **seeing failure as an opportunity to learn**. As one student wrote, "*The competitions are a good opportunity to learn from mistakes and make quick decisions when something goes wrong*." Other student comments were:

- *It has impacted me in allowing me to see my mistakes and see the consequences…like for example forgetting to tighten the motors resulting in a non running robot.*

- *VEX Robotics has impacted me because it has taught me to be a team player and involve everyone. VEX Robotics has also involved me in school more and I have e blast going to the competitions. I have a great time building and driving the robot. Also robotics is a challenging club. It has taught me that you will not get it right on the first try it is a sport that takes time and you can learn from your fails and try to fix it*

- *You learn the most when you fail. I have just learned to keep on trying again till I succeed.*

Finally, one Team Leader was able to express the way the team concept in VEX Robotics Competition helps students develop a variety of 21st century skills. He explained,

> *Working as a team for VRC students is not an option, in order to be competitive they have to work like a Swiss watch. Every team member should have one or multiple functions in the team. Solving problems is an everyday thing in robotics, and perseverance a must in order to survive. The commitment with the time is another earned asset; there's never enough time, so they have to make good use of it. These skills are transferable to different scenarios in the school, university and in the future in a job.*

When surveyed Team Leaders were asked the areas in which students benefit the most because of their participation in VEX Robotics Competition, a number of their responses (45%) included **problem-solving** as a benefit. Though many of these answers provided little more than general information about problem solving, some were more detailed. For example, one Team Leader described this benefit as, "*Developing multiple solutions to a problem, without the benefit of [knowing] what is the right answer*." Another wrote, "*We have a goal of problem solving at our school and I see [VRC] as the best tool we have to demonstrate us meeting that goal*." Other Team Leaders wrote:

- *VRC gives students the opportunity to think in-depth about a problem and work with others to solve it.*

- *Giving them the skills to be able to solve complex problems.*

- *Keeping at a problem until they optimize their solution.*

- *[Students] are given a problem and have the opportunity to solve it and test their idea against others. The ability to brainstorm and test ideas and then compare them to others is an invaluable experience. With my team, it's all about what the students are able to do, NOT me the teacher. I let them formulate the ideas and test them.*

In summary, Team Leaders and students, on both surveys and in interviews, described a number of ways students grow in 21st century skills due to their participation in VEX Robotics Competitions. Descriptive statistics from quantitative survey data indicate high levels of agreement that students are positively impacted in 21st century skill areas, and qualitative data describe in detail ways this growth is manifested.

ENGINEERING HABITS OF MIND

Only Team Leaders (and not students) were asked to respond to questions about student growth in engineering habits of mind, and overwhelmingly, large percentages of Team Leaders reported a positive impact on student growth as a result of participation in VRC. Table 35 displays data for the engineering habits of mind item, and as illustrated, Team Leaders perceive the greatest growth occurs in the area of *coming up with creative solutions to difficult problems* and *seeing possibilities and opportunities in design challenges.* In each of those areas, about 95% of Team Leaders said students exhibited growth in these areas. The area in which Team Leaders reported the least growth was *engaging in systems thinking,* but even in that category, approximately 88% of Team Leaders reported students demonstrated growth.

Table 35. Team Leader Responses to Engineering Habits of Mind Survey Items

In which of these areas, if any, have you observed STUDENT GROWTH as a direct outcome of students' participation in VRC?	A lot of growth	Some growth	Not much growth	Not sure	Mean	N
coming up with creative solutions to difficult problems	62.2%	33.3%	4.2%	<1%	2.58	288
seeing possibilities and opportunities in design challenges	60.5%	34.4%	4.8%	<1%	2.56	291
understanding that every technology can be improved	51.6%	45.3%	2.4%	<1%	2.49	289
communicating to explain and justify design solutions	45.5%	47.2%	6.6%	<1%	2.39	290
engaging in systems thinking (understanding that systems have unexpected effects that cannot be predicted from the behavior of individual subsystems).	41.0%	46.6%	8.3%	4.1%	2.34	290

When Team Leaders were asked on the survey to describe the greatest benefits to students for participating in VRC, 46 respondents (24% of those who wrote in an answer), included "engineering" in their response. As described by two Team Leaders, VRC participation provides "*engineering experience in an age appropriate setting*" and allows students to develop a "*basic understanding of the engineering process*."

Though the large majority of these responses simply listed engineering as a benefit, a few Team Leaders provided more depth in their answers. As one Team Leader commented, "*They directly see how their engineering decisions affect the performance of their robot. They learn many aspects of business and engineering*."

Several commented on the benefits of working through the engineering cycle. One Team Leader explained, "*[VRC] provides the opportunity to build robots that they don't normally get exposed to. It also shows the engineering cycle at its best. They design, build, and modify until they finally get the robot doing what they intended*." Other similar comments were:

- *The fun and competitive environment that allows for students to apply their ideas hands on. By trying out ideas in this way they learn not only the engineering principles but also the level of planning, work, and cooperation needed to be successful.*

- *Comprehensive experience of engineering design, construction, testing, improvement. Task is small enough for all to see from beginning to end and participate in multiple aspects. Time for rebuilding makes mistakes less costly and seen as learning opportunities. Excitement of competition drives students to achieve more.*

- *An extensive hands-on approach to solving engineering type problems that involves a multitude of engineering skills - mechanical, sensors, programming, hardware, etc. In addition, the involvement in the team problem solving approach is much more significant than can offered in a classroom or lab setting because all the students are INTERESTED in solving a common problem.*

- *Gives the team members a non-classroom area to learn about real-world engineering. The students do not see it as learning (although they certainly are); they are excited to build the best robot they can for the competition. The learning happens along the way.*

Two homeschool Team Leaders also provided comments on the way VRC benefits homeschooled students in particular. As one coach stated, "*I coach homeschoolers that generally have no other opportunities for teamwork or engineering design or competition, so there are lots of benefits*." Another VRC parent and coach wrote,

> *As a parent of homeschooled students, I see a lot of benefits of VRC. My children wouldn't have an opportunity to participate in this type of activity at all. They have not only learned about robotics, but about design, engineering, team work, helping others, leadership, communication, physical building skills, how to*

correctly use power tools, etc. The cost is reasonable for both the purchase of the robotics kits as well as going to the competitions (vs. the FIRST Robotics program). This was a huge factor in deciding to participate in VRC. Fun and Educational!

UNDERREPRESENTED STUDENTS IN VEX ROBOTICS COMPETITION

In order to determine the ways in which VRC currently reaches a diverse population, as well as to elicit suggestions for how to reach a broader student base, Team Leaders were asked to (1) respond to questions about the diversity of their teams, (2) provide their level of agreement with survey items about VRC's ability to reach out to students typically underrepresented in STEM (girls and minorities), and (3) give suggestions about how to reach a more diverse group of students.

Team Leaders reported some diversity on their teams. Of those Team Leaders who responded to the question[vi]:

- 18 Team Leaders (13.0%) reported they have 3 or more African-American/Black students on their teams and 59 (42.4%) reported they have none on their teams.
- 53 Team Leaders (33.5%) reported they have 3 or more Asian/Pacific Islander students on their teams and 41 (25.9%) reported they have none on their teams.
- 34 Team Leaders (26.2%) reported they have 3 or more Hispanic/Latino students on their teams and 49 (32.2%) reported they have none on their teams.
- 3 Team Leaders (3.3%) reported they have 3 or more Native American/ Alaskan/First Nations students on their teams and 78 (84.8%) reported they have none on their teams.
- 221 Team Leaders (85%) reported they have 3 or more Caucasian/White students on their teams and 4 (1.5%) reported they have none on their teams.
- 49 Team Leaders (38.8%) reported they have multiracial students on their teams and 34 (27%) reported they have none.
- Only 4 Team Leaders (1.5%) reported they have no boys on their teams.
- 39 Team Leaders (16.5%) reported they have no girls on their teams.

[vi] Percentages should be interpreted with caution. Some Team Leaders may have skipped the item rather than choosing the response that indicated they had no students of a certain racial group on their teams.

As illustrated in Table 36, large percentages of Team Leaders (76%), regardless of type of team coached, agreed or strongly agreed that girls have shown an interest in being on their teams. However, only 45% agreed or strongly agreed that students of races underrepresented in STEM have shown an interest in being on their teams. Further, just over 40% of Team Leaders reported it was easy for them to recruit diverse students to be on their teams, but public school and club Team Leaders reported more difficulty than did their private school counterparts. Across team types, 58% of Team Leaders agreed or strongly agreed that VRC does a good job reaching out to female students, and 43% agreed or strongly agreed VRC does a good job reaching out to racial minority students.

Table 36. Team Leader Responses to VRC Diversity Items

		Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure[vii]	Mean	N
Girls have shown and interest in being on my VRC Team.	Public School	25.7%	49.1%	12.3%	3.5%	9.4%	3.07	171
	Private School	26.8%	46.3%	4.9%	4.9%	17.1%	3.15	41
	Club Team	21.4%	57.1%	---	---	21.4%	3.27	14
Races typically underrepresented in STEM who are minorities in my community have shown an interest in being on my team.	Public School	13.1%	35.1%	22.0%	4.2%	25.6%	2.77	168
	Private School	4.9%	31.7%	7.3%	4.9%	51.2%	2.75	41
	Club Team	14.3%	28.6%	28.6%	7.1%	21.4%	2.64	14
It has been easy to recruit students for my VRC team who are underrepresented in STEM.	Public School	15.9%	26.5%	25.9%	7.1%	24.7%	2.68	170
	Private School	7.3%	26.8%	12.2%	2.4%	51.2%	2.80	41
	Club Team	21.4%	28.6%	28.6%	7.1%	14.3%	2.75	14
VRC does a good job reaching out to racial minority students	Public School	13.7%	31.0%	14.3%	1.8%	39.3%	2.93	168
	Private School	9.8%	19.5%	2.4%	7.3%	61.0%	2.81	41
	Club Team	7.1%	42.9%	21.4%	---	28.6%	2.80	14
VRC does a good job reaching out to female students	Public School	14.9%	42.9%	14.3%	2.4%	25.6%	2.94	168
	Private School	12.2%	34.1%	2.4%	7.3%	43.9%	2.91	41
	Club Team	---	64.3%	21.4%	---	14.3%	2.75	14

Team Leaders provided a number of responses regarding what makes VRC participation appealing to students typically underrepresented in STEM. Several reported that student like building things and like robots, and those are what sparks interest. As one Team Leader commented, "*Everyone likes robots; that gets them in the door. But the teamwork and problem solving keeps them coming back*."

Other Team Leaders commented that the biggest draw in getting minorities to participate was the promise of getting to travel. Three Team Leaders who work with minority students reported this. One Team Leader wrote, "*The trips were the biggest draw for my underrepresented students observing my team getting to travel*." A Team Leader from a public charter school with high minority enrollment on her team, said this in her interview, indicating the draw of the trips as well as how participation impacts her students:

[vii] Includes "does not apply"

This particular group comes from an at-risk population. They have grown emotionally as a team, and academics have improved because they are committed to the club and the trips. Most have never been out of the area. I brought 9 students [to Worlds] and 7 have never flown or been out of the state. It's been neat to see them talk to the community and get sponsorships.

Another Team Leader, during a focus group interview, described the strategy he has used in his school to increase the number of girls on his team. He explained,

We're recruiting girls. We've made a big effort. We're having a STEM fair at the end of this month, and we have a couple speakers coming to specifically speak about engineering for girls. …I've got a team that's only 11 kids, but 3 of them are girls…When we get a girl, we make a big deal about it…We invite them in, and it's not a quota thing. It's, "We want you to understand, this is not the boys playing with the toys. It's…engineering, [and we want them to have] the mindset that they can do this.

Other comments about the way VRC appeals to underrepresented students were:

- *Our girls feel just as equal as the boys on our teams. They can do the technical aspects and really feed into it.*
- *The uniqueness of the program and the challenge that it presents makes VRC participation appealing to students typically underrepresented in STEM. The increasing amount of jobs in theses fields can be incorporated also.*
- *The inventors guide is a huge help in getting students excited. Making robot building appear easy is a huge hurdle for underrepresented students. Most often we've found that it's the perception that they aren't smart enough to build a robot that deters them.*
- *VRC challenges students at an academic and skills based level regardless of sex or race. The majority of students who attend our school are immigrants and find it easy to get involved in our program due to the universal nature of robotics.*
- *Having tournaments in minority regions.*
- *They are in an equal playing field when given a challenge and the resources to accomplish it.*
- *It is a hands-on method of learning in which students are able to take ownership of their problems and solutions. In class a student completes a lab or solves a problem that is teacher designed. VRC participation allows a student to tell someone, "This is my robot, that I designed." This is rare for the students.*

When asked to provide suggestions about how to better recruit underrepresented students to VEX Robotics Competition, Team Leaders made several suggestions. In terms of recruiting girls into VRC, Team Leaders suggested:

- *With two female coaches, recruiting females is not a problem.*
- *THEY must see or know other students participating that are like them!! They only way I get girls involved is that they see other girls involved. Same is true for minorities.*
- *Send veteran female/minority students that are now engineers explaining the value that VRC had in their career and educational path.*
- *Continue to get high profile women and minorities from engineering backgrounds as role models.*
- *[Create a] female competition category.*

The most frequent suggestion for recruiting more underrepresented students was to keep the competition affordable. Some of these comments were:

- *Have to keep the game simple and cheap.*
- *The costs of the kits are somewhat prohibitive.*
- *Making it accessible! VRC is much cheaper than the FIRST programs, and easier for lower-income school districts and families to participate.*
- *[Provide] more grants and alliances with business to help with coaching/mentoring and funding the program.*
- *[Provide] Grants focused on underrepresented populations.*
- *The largest barrier is the cost of software and hardware. To purchase new software yearly or every time hardware gets updated is a financial strain and we often cut the amount of teams we can support based upon software availability alone.*
- *Cost, VEX parts is getting much more expensive than in the past years. Keep VEX affordable! VEX is directly competing with FIRST for student participants. VEX needs to offer scholarships and post high school education opportunities that surpasses FIRST. You need to tier schools on the parts price.*
- *Partner with companies to provide grants to teams who have little or no funding available to them.*

- *Make the costs related to VEX more reasonable or try to find sponsors for under-represented teams. My experience indicates that you need at least $3000-4000 to put together a "competitive" team or two.*

- *Allow for grants to help defray the costs. Also identify potential funding sources. Cost is almost always the biggest hurdle. We have mentored many inner city teams and the costs of the equipment/entry/ and competitions are often the biggest stumbling block.*

- *In our case (homeschoolers), the cost of the VEX products are cost prohibitive. If small teams, that don't have schools backing them, could get grants, you would see A LOT more teams from the homeschool population (which is rapidly growing in the USA).*

- *VEX could continually make competition more financially accessible to students and schools that aren't able to contribute. (IE VEX could help schools and students connect with local Business for sponsorship and other future employment possibilities).*

- *Increase funding of robotics systems. The price for these is getting to high for lower economic students and programs.*

- *One barrier is that low socio-economic schools (typically with those minority groups) and areas continue to be underrepresented due to the increasing costs of VEX. In this economic climate it is unsustainable especially given exchange rates across the globe making it more costly in some countries than others.*

In focus group interviews, offering scholarships was a frequent suggestion for how to improve VRC and involve more underrepresented students.

Other suggestions included using high profile minority role models, including minorities in VEX advertising, and showcasing "*students who are excelling in VRC so others can see 'if they can do it, so can I.'*" Several other Team Leaders suggested marketing VEX as something "cool" rather than something "nerdy." As on Team Leader stated,

> *I think that the major thing keeping these kids away from doing VEX is that robotics are seen as "nerdy". If VEX could portray itself as being more "fun" and "cool", there would be more participation. The age of the participants make it so that having fun and being cool is more important than learning.*

WHAT STUDENTS AND TEAM LEADERS LIKE BEST ABOUT VEX ROBOTICS COMPETITION

On their respective surveys, students were asked what they liked best about VRC, and Team Leaders were asked what were the greatest benefits of participating in VRC. Of the 200 students who wrote a response on the survey, the majority (77%) said that working with robots or designing robots was what they liked best. Four students in this category who were also on

other robotics teams (e.g., FIRST FRC) distinguished what set VEX apart from the others. As one student explained,

> *I enjoy programming the robot, but that is a common trait to all robotics competitions. I like VRC in particular because the robot is fairly simple to construct, but it is "real" enough to need to apply engineering principles. (i.e. With LEGOs, you don't really need to plan - taking apart doesn't take very long. However, with VEX taking something apart can take hours - it requires planning ahead/design process.)*

Another student, comparing VRC to FRC, stated,

> *As I am part of a FIRST FRC Team, I think VEX is cool because I can think for myself, which is how I work best. We built a solid robot this year and I was sorry to have to take it apart. I also bussed around town on my bike writing code for about ten vex teams in the region.*

A third student said about VRC, *"[There's] more robotics and programming than other competitions. I like the multiple times you get to compete with your robot and I like building with the VEX and the skill level you have to achieve*." Finally, a fourth student explained, "*It gives me a chance to build an actual robot, with as little pre-made parts (sensors, motors, controller) as possible, unlike NXT*."

In a focus group interview, a male middle school Team Leader also compared robotics competitions, explaining the benefit of VEX over LEGO. He stated,

> *Because of VEX, females have increased participation to 40%. Next year it will increase to 60%. It is all because of VEX. LEGO was too rigid for girls. [Girls] like [VEX] because they can control, program, and drive their robot.*

Team Leaders also commented on the benefits of VRC over other robotics competitions. As one Team Leader explained, "*A huge benefit is that we can have more teams, with fewer students. This gives students more hands on experience than they would normally get in FRC*." It was noted, however, that two Team Leaders said they use VRC as a way to prepare their students to compete in FRC.

The second most popular student response about what they liked best about VRC was **competing with other teams**. Just over 30% of student respondents listed this on their surveys. Students described the competition aspect as "fun," "exciting," "interesting," "high energy," "a rush," "challenging," and "a thrill." One student said what he liked best was the "*competitive spirit combined with science, technology, an engineering*." Another student wrote,

> *[I like] the thrill of the competition and the success of all robots that compete! I find it enriching to be beaten by other teams and improve on our design. In the end though, being on top is one of the best feelings in the world*.

Another student explained the benefit of competition this way, *"[I like] the idea that you not only compete with the robot you designed but the opportunity to learn, collaborate and ultimately become friends with your alliances and competitors*."

Team Leaders also described the benefits of competition for students, noting as the students did that there is a spirit of collaboration and encouragement across teams. As one Team Leader explained,

> *The students learn how to be competitive, yet encouraging to other teams/other students. The teams are forced to work through a design and make improvements throughout the year. They are invested in their solution to the competition challenge and want to see it succeed. Additionally, the students learn something new and are given many opportunities at competitions to collaborate with other teams and help those teams improve*.

Another Team Leader, responding to what he liked best about VRC, wrote, "*Seeing the cooperation between the teams in a competition, and how it affects my students*."

Working with teammates was the third most popular student response regarding what they like best about VRC, and 28% of students wrote this on their surveys. Several students wrote that meeting other teams was what they liked best, whereas others wrote "*working as a team*," "*cooperating with other teams*," "*solving problems as a team*" and "*teamwork*" when explaining the team aspects they like best. A large number of Team Leaders (66% who responded to the open-ended survey item on VRC benefits for students) listed the team or teamwork in their answers. Most often, responses were about teamwork within a team, but a number of Team Leaders, like students, wrote about teamwork across teams at competition. One Team Leader explained,

> *Team building and problem solving in a practical setting encouraging growth on a personal as well as academic level. The competition over here is fierce but friendly. We all help other teams out at scrimmages and socially. A wonderful setting to show how growth can come from unexpected quarters.*

Fourteen percent (14%) of students who wrote survey responses about what they liked best about VRC said **generating ideas**. For example, one student wrote, "*The process of thinking up a new idea, building it, testing it, and perfecting it is exhilarating.*" Similarly, another student wrote, "*The best part of the Vex Robotic Competition would most likely be the ability to follow through with your ideas, going through the whole process of brainstorming, sharing ideas, designing, building, and troubleshooting*." A Team Leader also explained this process for students as he described his perception of the greatest benefit of VRC for students:

Students are exposed to fields such as engineeingr and computer science using practical methods. They are given a problem and have the opportunity to solve it and test their idea against others. The ability to brainstorm and test ideas and then compare them to others is an invaluable experience. With my team it all about what the students are able to do NOT me the teacher. I let them formulate the ideas and test them.

In interviews, Team Leaders also mentioned the satisfaction they felt as coaches and mentors when students generated ideas and worked through the process of problem solving. As one homeschool Team Leader explained when asked what she liked best about coaching, *"…to see them coming up with ideas all on their own, and how to solve problems. Their ideas amaze me…you know, I wouldn't have though of [that idea].*" Another homeschool mentor added to this in the focus group, saying, "*Yeah, I think it's the same thing…seeing them come up with the ideas and try to figure out the physics or whatever's required and then assisting them through the hard parts*."

Other student responses about what they liked best about VRC included that it is fun (13%), that it is challenging (8%), and that they like the learning that occurs (7%). Comments in these areas included:

- *[It's] really cool that you get to build these robots from a wide range of parts and have a lot of fun along the way. It involves a lot of physical and mental work to see how your going to play the game and you also get to learn a lot of cool new things.*

- *[VRC] is a fun way to use creativity while working in a team to reach a goal.*

- *[What I like is] that I have the opportunity to see what other ideas teams have come up with to overcome the challenge of the game and somehow incorporate those ideas into our team's robot to make it better.*

- *The VEX robotics competition is a great challenge that brings together multiple disciplines of science, and helps you develop your teamwork skills.*

- *I like that we have to solve the challenge on Round Up the most efficient way we can.*

- *I like the chance to learn engineering concepts hands-on, and then to compete with others.*

- *It gives me a chance to compete with, learn from, and make friendships with people with similar interests.*

The VRC student benefit of **learning** was also listed by 46% of the Team Leaders who responded to the open-ended survey prompt. As one Team Leader noted,

> *They learn basic design and build skills. Most of our roboteers have never touched a wrench or screwdriver before. The first year is a transformation into a builder, the second year is into a designer. Second and third years we start to get good programmers.*

Like this Team Leader, others also frequently listed the types of learning that occurred with students, as opposed to most students, who frequently listed *learning* as an outcome with few descriptors of the types of learning in which they engaged. Team Leaders listed learning about teamwork, leadership, problem solving, programming, engineering design, career possibilities, technology, and social skills. An interviewed female middle school coach simply stated, "*The kids are fired up, and it's getting them excited about learning*."

STUDENT AND TEAM LEADER SUGGESTIONS FOR IMPROVING VEX ROBOTICS COMPETITION

When students were asked what they would change about VRC, several themes emerged. The most frequently occurring response was *nothing*, with 13% of students writing that they wouldn't change anything about VEX Robotics Competition. Changes related to hardware, software, or programming were suggested by 13% of students who completed the survey item on changes to VRC. Students suggested having better motor parts and electrical components, allowing more motor power on robots, and improving VEXnet. Students also requested VEX fix software bugs and make programming easier.

The third most frequent answer related to competition rules, with 8% of respondents making suggestions about how make improvements related to rules. One comment focused on making rules clear and not changing them during the competition season. Comments included "*Better rules (clearer)*," "*The rules would be more clear, especially…concerning what parts you can have on your robot*," and "I *would make the rules clearer to help new teams*." Two students also suggested making rules about robots less strict to increase creativity. As one student explained,

> *I would probably change the fact that the rules to the competition, I find, are too strict. If the rules pertaining to what parts can be used on the robot were to be less strict, I believe that people could come up with more creative ideas as they wouldn't be limited to VEX products*.

Other student suggestions regarding rules included changing the field size, allowing bigger robots, and increasing the number of awards/trophies. Related to rules, five students also suggested making changes to the alliance selection process. Student comments about alliance selection were:

- *Improve alliance selection at smaller events.*

- *Make it so that you can't get as far just by luckily getting paired with good teams, or lose because of a bad one.*

- *Pairings. Many good teams got stuck with us, which inflated our score. Our "offensive" robot didn't score all day, and we were 8th of 50 at the end of the day. We didn't deserve that.*

- *If I could change one thing about the VEX Robotics Competition, I would change how the partner choosing system works so that carried teams who did not truly earn a top rank could not negatively impact the results of another team, that performed well, but did not get the highest point score.*

- *I would change the alliance selection process from (first seed to eighth and then first to eighth again) to (first seed to eighth and then eighth to first) in order to foster competition.*

Related to rules was the refereeing that occurs at competitions, and 5 students suggested improvements in this area. Two students said refereeing is inconsistent at competitions, and a third requested that referees know game rules and maintain attention. One student expressed, "*I think there is too much variation in the refereeing, and it can make a difference between winning and losing*." Another wrote, "*If I could change one thing about VEX I would just try to make sure to have referees that are very knowledgeable of the game and attentive*." A third student explained,

> *I'm sure you have heard enough about how inconsistent the refereeing is. One ref is calling a pin if you brush by a robot and another doesn't call anything even if a robot is repeatedly pinned, (based on the rule description) during a match and throughout entire competitions. There needs to be more thought put into how referees are chosen and trained to respond to infractions. It can make the difference between winning and losing an entire competition.*

Approximately 6% of student survey respondents listed **price** as an area where VRC could be improved. These students asked for cheaper parts. One student explained her perception of the way cost impacts the competition, writing,

> *I think I'd change the pricings a bit, I bet they're needed. But for smaller groups, they really don't have as much of a chance to win. It all seems to depend on 'Who has the most money to throw into robotics'?*

Another student explained how reducing the cost would allow for more participation in VRC, stating,

> *If I could change the VEX Robotics Competition, I would make the parts cheaper as many teams can't afford them. If the parts were cheaper, more people would be encouraged to participate and VEX would become more widespread. Many schools and teams do not have enough money to sponsor and a team but by making these parts cheaper or giving grants to them, it would be easier for them to participate.*

Four students also indicated their dissatisfaction with parents or coaches being overly involved in VRC. As one student stated, "*The robots need to be built by the kids NOT the parents. The judges need to figure this out*." Other students asked that parents not be allowed into the pit and that parents and coaches should not be allowed to build, program, or run robots. In interviews, a few Team Leaders also noted their dissatisfaction with some teams having too much adult involvement. As one middle school coach stated in an interview,

> *When kids are participating, parents are writing down strategies, [but] kids need to coach each other. Adults just need to be the facilitator. Some of the coaches are too "into" it…football parents do not throw a football during a game for their kid. Too much help [from parents] takes away from the integrity of the [competition].*

In analyzing Team Leader surveys, there were two main categories of responses for ways VRC could be improved for students. Overwhelmingly, Team Leaders suggested keeping costs down and/or making specific changes to equipment or the competition game. As was the case with ways to increase numbers of underrepresented students, when asked how VRC could be improved, 32% of Team Leaders who completed the survey said it was important to keep costs down. This concern was echoed in most of the interviews and focus groups with Team Leaders as well. One Team Leader from a public charter school with limited funds for robotics stated her frustration with changes to the equipment. She stated, "*When VEX changes the product and we have to purchase new equipment, [it's hard]. Slow down the changes so schools can purchase equipment…or come up with grants*."

It should be noted that cost was not just a concern of public school teams. One private school Team Leader explained,

> *Keeping the costs down is critical. I work at an affluent private school, but running 5 teams (I actually have 13 total-some are not VEX) is not simple. I cannot go out into the community to ask for funds, so I find that I have be incredibly creative in mining internal resources. More opportunities to showcase our teams are always appreciated. Also, I would suggest that you build in some sort of "reward" system for mentoring new teams. Maybe just a break on membership fees. Once you get a team hooked, they only seem to want more.*

Another Team Leader from a public school, in a focus group interview stated:

It's been really tough financially. The kids have tried their utmost best to raise the money on their own. They have this thing, they're trying to sell warm beverages in the morning just to raise some money, but we can't possibly raise enough money to support the program, and that's a big thing for us. I don't know if VEX…if there's any way that they could help in that, but for first time teams, it's really difficult. Really *difficult.*

One frequently occurring response was that VRC has been much more affordable in recent years, but the costs are getting prohibitive, not just for paying to attend Worlds, but for buying equipment as well. This is made more difficult by the fact that a number of public school coaches reported that they receive no funding from their schools. Team Leaders commented:

- *Find a way to make the challenges use items (balls / rings / other) that are more commonly available at a local discount store. Special ordering costs too much for small schools to absorb.*

- *Keep the costs down as before; it makes it more attractive to join. (This is in contrast to FVC which priced us out when they did not continue with the VEX parts).*

- *Some of the parts are just too expensive to purchase for our teams, so maybe donations by companies to help offset the costs to the teams.*

- *The cost is our biggest and most difficult challenge. Especially since the VRC parts are consumables most of the time because we have to cut them or bend them… we pay $100 to register a team, $25 for each additional team, and the shipping cost to mail the welcome package or license plates cost more than the registration fee itself. Very disappointed in that also. Our students and parents work very hard fundraising every single Saturday for 5 months in order to cover the cost of this program for one semester.*

- *The registration fee is so high ($750) for the world competition. With the purchasing of the robotic material from the beginning, the air ticket & hotel arrangement to the world competition, as a team, we struggle with the fund raising program because we are not from any school program. We did not get any sponsor from the public school funding. I wonder if VRC can give some discount to some of the group like us in the future to encourage more participation because of the high cost.*

- *Keep the costs down for regular season and post-season play to encourage participation. VRC had been the lower cost alternative when compared with FTC, but lately that doesn't seem to be as true.*

- *Keep the costs down in order to maintain growth and attract new members/ schools. Presently it is becoming too expensive.*

- *The expense of the materials is a huge drawback and with budget cuts looming, my program may be one of the first to go.*

The second suggestion Team Leaders and students made for improving VRC related to specific changes that could be made to equipment, software, or the competition. For example, six Team Leaders reported their concern that there were issues related to rules enforcement during competition. Comments included the need for there to be unbiased judges and making sure rules don't have loopholes. As one Team Leader explained, "*There needs to be an un-bias judge at the contest. Some rules are fairly open ended and were allowed in early rounds but not later rounds.*" Another commented, "*How about sticking to your rules and enforcing them? Maybe eliminating the loopholes to rules that provide points for someone that does little during autonomous periods.*" These comments were similar to those provided by students.

As was the case with students, some Team Leaders suggested making equipment more durable, ensuring software is robust, not beta-testing software during competitions, and increasing types of parts used in competition. Comments in this area included:

- *Make sure that all the electrical components work correctly. We have had a lot of electrical failures that required sending parts back. (However, VEX has been outstanding at replacing or repairing parts.)*

- *I'd like to see a wider variety of sensor parts, like an IR sensor, a line follower that does not need to be 1/8" off the floor, a more sensitive visible light sensor, etc.*

- *More guides for students to learn about the parts and concepts. Seems there are very few of these and you have to hunt the Internet to find information.*

- *Better technical background for the equipment. The guidebooks are too hard for the students to understand. I have difficulty with some of the topics, especially the ones that I am less familiar with such as the software, programming and physical set up of the controllers. Thank goodness my students understand the programming side since I find the documentation very difficult. There definitely needs to be a lot more model details provided to give the students something to learn from. We struggle with just the physical building side of the robot. I am a thermal engineer and don't have much knowledge in machine design and I find very little help from Vex as far as building ideas. Such as the best way to connect parts so they do not fall apart (especially keeping the drive shafts in the motor)*

- *The autonomous portion needs to be at least 30 seconds. 20 seconds is not long enough for the students to accomplish much. They don't have much incentive to use sensors for guidance and create intelligent programs when there is not enough time. As an electrical engineer I am frustrated with the inability to modify or improve anything electrical. Such*

*as: * use positive latching connectors * make custom extension cables * make your own battery extension cables * make a battery switch * make a direct battery charging port*

- *Add more sensors and other products. Allow playing field objects, especially major pieces like this year's Roundup Ladder to be purchased a la carte. Having an accurate ladder to prototype with would have been very important, but not important enough to purchase an entire playing fields worth of game pieces. I liked the addition of polycarbonate to the allowable materials this year. This gave students some additional fabrication opportunities.*

- *Better quality components. More powerful and reliable motors, rugged gears, summer camp classes in programming.*

- *The equipment used could be a bit sturdier, chains, gears, single length bars. Also have run into difficulties with cortex hardware and low amp fuses shorting out when High load form heavy torque motors are used.*

Team Leaders also suggested using different programming software or programming aids. Suggestions included "*Having a RobotC programming text*," "*Improve field software*," "*More robust Cortex software*," and "*more user friendly teaching aids for the programming part*." Other Team Leaders commented:

- *Programming seems to be too convoluted. We've been using the MicroChip based system with the MPLAB IDE. Maybe RobotC is better?? This is an area where I don't have much support so I'm not too sure of what to do.*

- *Programming needs to be easier for those that do not understand or want to understand programming.*

- *The software isn't always robust…so if you are trying to teach about certain programming structures and they don't work, it can be bad.*

These suggestions were echoed in Team Leader focus groups. One Team Leader stated:

> *For every competition, have a website for what software requirements are required or suggested so students can compare their software before they get [to the competition]. VEX does a great job of having [on onsite] helper do that, but it would be nice to be able to do that ahead of time, on our own. With [the current competition's] website, I didn't see anything of what I needed or what software I needed, what version I needed for any of our controllers, and so we kind of came here blind, not knowing if things were actually going to work.*

Two Team Leaders commented on the importance of training for better-run competitions. One Team Leader wrote, "*Provide Tournament organization training so that local competitions run smoothly,*" and a second commented:

> *I believe the competition aspects can be improved to be more consistent from area to area such as how the competitions are run, how they are refereed and how students are treated at them. I know you are dependent on your volunteers but there should always be an official VEX person there to make sure the local coordinators are up on all of the rules and do not make egregious decisions when referring…There should always be a voice of reason making sure a healthy balance is maintained, so having official VEX Competition Supervisors overseeing competitions would be one solution to this problem. I doubt you will lose participants or volunteers if you began overseeing competitions in this manner. VEX is too well established and "loved" by its participants for anyone to actually object to it. I think they would welcome the support.*

In interviews and focus groups with Team Leaders, several suggested that VRC not become so big that it loses its personal touch. Based on the Team Leader input, what is so desirable about VRC is that it has been responsive to its stakeholders. One focus group exchange among Team Leaders illustrates this:

> Team Leader 1: *Make sure [VRC] stays responsive. You know, in the first couple of years, you got really quick responses from VEX. And not it's getting slower and more, "Aw, it's too big."*
>
> Team Leader 2: *Yeah. I think it's because it's growing*.
>
> Team Leader 3: *If they don't stay personal, somebody is going to come along and take the low end again*.

In interviews and focus groups with students and Team Leaders, several participants echoed the desire to keep VRC "special." As one Team Leader said in a focus group:

> *VEX [does] an awesome job. It's only what, three years old, basically. And they've done an awesome job…it's a startup organization, and it's getting going. I think they should feel confident that we believe in the program, too, that we're supporting it from the bottom end, and that what they're doing is on the right path, overall.*

It was clear many participants were drawn to VRC because of its "close-knit" feel and the student-centered aspects of the competition (e.g., students, not coaches/mentors, to the building and competing). It was evident, particularly in talking with students and Team Leaders at competitions, that there is a growing concern that VEX is becoming too big too fast and has the potential to lose its unique intimate feel and become like the other robotics competitions.

RECOMMENDATIONS

Recommendations made here focus on the next steps of the evaluation process rather than on recommendations for improvement to VEX Robotics Competition. As a first external evaluation, this report provides useful information about areas in which students and Team Leaders perceive VRC to have the greatest student impact. Results, and thus conclusions, are limited because a small percentage of students and Team Leaders participated in this study. Because there is no existing database to provide (a) number of students participating in VRC, (b) demographic data on students, (c) number of Team Leaders, (d) demographic data on Team Leaders, and (e) data on teams (team type, number of participants, years competing, etc.), it is difficult to determine how representative student and Team Leader samples are for this study.

Recommendation 1: Create a team database that all Team Leaders are required to use, on a yearly basis, to input team, student, and Team Leader data. This database should include email addresses of all students, Team Leaders, and mentors so they can be directly contacted to complete surveys and provide information on their participation.

One concern noted by participants in this evaluation is the rate at which the competition is growing and the possible negative consequences of that growth. Some respondents indicated that the aspects of VRC that set it apart from its competitors (e.g., intimacy of the competition, responsiveness of staff, low cost, simple parts) are changing in ways that are negatively perceived by participants.

Recommendation 2: In a future evaluation, determine what the vision of VRC is for its stakeholders, including RECF, VEX, and VRC teams. Conduct a needs-assessment to determine what must be done to move the common vision forward.

This evaluation was limited in that a small number of Team Leaders and students provided data, and responses were limited to English-speaking teams in North America. There is a need to evaluate the experiences of teams in other countries, and there is a need to hear from other groups such as VRC alumni, students on college/university VRC teams, and parents of VRC students.

Recommendation 3: Use the database described in Recommendation 1 to create a complete list of teams, Team Leaders, and student participants. Extend the evaluation so that there is broad representation across regions and countries where VEX teams exist. Fund a more in-depth evaluation of a representative sample of all VRC participants. Ensure funds exist for creating surveys in languages other than English, and ensure translators attend World Championships so students and Team Leaders from non-English speaking teams can participate in interviews. Work with Team Leaders to create a database with alumni contact information, and survey those alumni to determine ways VRC participation has impacted them post-participation.

Appendix 1. VEX Robotics Competition Student Survey

VEX Robotics Competition Student Survey

1.

Thank you for taking the time to provide us information about your experiences in VEX Robotics Competition! If you complete and submit this survey and provide contact information, your name will be entered into a random drawing, and YOU HAVE THE OPPORTUNITY TO WIN a $100 VEX Robotics credit, generously provided by VEX Robotics. This survey will take about 10 minutes to complete.

In this section, please let us know in what ways, if any, participating in the VEX Robotics Competition (VRC) has increased your confidence.

1. Participating in the VEX Robotics Competition has increased my confidence that I can

	Strongly Agree	Agree	Disagree	Strongly Disagree	Not sure
do well in school	◯	◯	◯	◯	◯
do well in my science classes	◯	◯	◯	◯	◯
solve hard problems	◯	◯	◯	◯	◯
be a good leader	◯	◯	◯	◯	◯
ask questions when I need help	◯	◯	◯	◯	◯
present my ideas to others	◯	◯	◯	◯	◯
work well with a team	◯	◯	◯	◯	◯

2.

In this section, tell us in which areas, if any, participating in VRC has helped you.

VEX Robotics Competition Student Survey

1. In which of these areas has participating in the VEX Robotics Competition helped you?

	Helped me a lot	Helped me	Helped me a little	Hasn't helped me at all	Not sure
coming up with ideas and sharing them with your team	◯	◯	◯	◯	◯
seeing failure as an opportunity to learn	◯	◯	◯	◯	◯
solving difficult problems in new or creative ways by yourself	◯	◯	◯	◯	◯
solving difficult problems in new or creative ways with your team	◯	◯	◯	◯	◯
valuing each team member's contribution	◯	◯	◯	◯	◯
communicating your ideas	◯	◯	◯	◯	◯
accepting and using feedback and criticism	◯	◯	◯	◯	◯
setting goals for yourself	◯	◯	◯	◯	◯
setting goals with your team	◯	◯	◯	◯	◯
using time effectively	◯	◯	◯	◯	◯
being a good team member	◯	◯	◯	◯	◯
treating team members respectfully	◯	◯	◯	◯	◯
being honest and fair in competitive situations	◯	◯	◯	◯	◯
taking responsibility for doing your part on the team	◯	◯	◯	◯	◯

3.

In this section, tell us in what ways, if any, participating in VRC has made you interested in science, technology, engineering, and/or math.

VEX Robotics Competition Student Survey

1. Participating in the VEX Robotics Competition has made me

	Strongly Agree	Agree	Disagree	Strongly Disagree	Not sure
interested in taking additional math or science classes in high school	◯	◯	◯	◯	◯
more interested in taking math or science classes in college	◯	◯	◯	◯	◯
more interested in taking engineering classes in college	◯	◯	◯	◯	◯
more interested in having a job in a science, technology, engineering, computer, or math field	◯	◯	◯	◯	◯
want to go to school more or have better attendance	◯	◯	◯	◯	◯
want to join more clubs or teams at school	◯	◯	◯	◯	◯
more interested in school or education	◯	◯	◯	◯	◯
understand how math, science, engineering, or technology are used to solve real-world problems	◯	◯	◯	◯	◯
want to learn more about robotics	◯	◯	◯	◯	◯
want to learn more about computer programming	◯	◯	◯	◯	◯
want to learn more about engineering design	◯	◯	◯	◯	◯
want to coach VEX teams in the future	◯	◯	◯	◯	◯

JUST ONE MORE SECTION!

4. Information about you

In this last section, please provide information about yourself. Don't forget to put in your email to be entered for the random drawing. You could win a $100 VEX credit!

1. How old are you?

- ◯ 10 or younger
- ◯ 11
- ◯ 12
- ◯ 13
- ◯ 14
- ◯ 15
- ◯ 16
- ◯ 17
- ◯ 18
- ◯ over 18

2. Are you male or female?

- ◯ Male
- ◯ Female

VEX Robotics Competition Student Survey

3. How long have you participated in the VEX Robotics Competition?

- ◯ This is my first year
- ◯ 1 year
- ◯ 2 years
- ◯ 3 years
- ◯ 4 years
- ◯ 5 years
- ◯ more than 5 years

4. What kind of team are you on?

- ◯ Public School Team
- ◯ Private School Team
- ◯ Homeschool Team
- ◯ Club Team (like 4-H)
- ◯ Other (please specify)

5. How would you describe your ethnic background?

- ◯ African-American/Black
- ◯ Asian/Pacific Islander
- ◯ Hispanic/Latino
- ◯ Native American/Alaskan/First Nations
- ◯ White/Caucasian
- ◯ Multi-racial
- ◯ Some other race (please specify)

6. Is English the main language spoken between you and your parents?

- ◯ Yes
- ◯ No

7. What is the highest level of education your parents or guardians completed?

	Less than high school	Graduated high school	Some college	Graduated college	Graduate degree (masters, PhD, MD, JD, MBA, etc.)	Not sure
parent/guardian 1 [mother or father]	◯	◯	◯	◯	◯	◯
parent/guardian 2 [mother or father]	◯	◯	◯	◯	◯	◯

VEX Robotics Competition Student Survey

8. If you are planning to go to college or university, what's the highest degree you hope to complete?

- ◯ I don't know
- ◯ Associates Degree
- ◯ Bachelors Degree
- ◯ Masters Degree
- ◯ Higher than Masters degree (MD, PhD, JD, etc.)
- ◯ I'm not planning to go

What do you want to study or major in? (you may list more than 1 field)

9. On average, what kinds of grades do you get in math, science, and overall (all your classes)?

	Mostly A's	A's and B's	Mostly B's	B's and C's	Mostly C's	C's and D's	Mostly D's or below
Math	◯	◯	◯	◯	◯	◯	◯
Science	◯	◯	◯	◯	◯	◯	◯
All Classes/ Average	◯	◯	◯	◯	◯	◯	◯

*** 10. What grade are you in?**

- ◯ 6th
- ◯ 7th
- ◯ 8th
- ◯ 9th
- ◯ 10th
- ◯ 11th
- ◯ 12th
- ◯ Other (please specify)

5.

1. Which of these high school courses have you taken or do you plan to take?

- ☐ Algebra 1
- ☐ Algebra 2
- ☐ Advanced Algebra
- ☐ Geometry
- ☐ Trigonometry
- ☐ Pre-Calculus
- ☐ Statistics
- ☐ Biology
- ☐ Chemistry
- ☐ Physics
- ☐ Engineering
- ☐ Computer Science

VEX Robotics Competition Student Survey

2. How many VEX Robotics Competitions have you competed in?

- ◯ none yet
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10 or more

3. What do you like best about the VEX Robotics Competition?

4. What would you change about the VEX Robotics Competition, if you could?

5. How has the VEX Robotics Competition positively impacted you, if at all?

6. If you'd like a chance to win a $100 VEX credit, fill in the section below. You MUST include your name, email (or phone number if you don't have an email address), and team number to be entered for the drawing.

YOU CAN ONLY BE ENTERED INTO THE DRAWING ONCE, SO PLEASE DO NOT COMPLETE THIS SURVEY A SECOND TIME!

Name

email address (or phone #)

Team number

THANK YOU FOR COMPLETING THIS SURVEY! The winner of the VEX Credit will be notified by June 1, 2011.

Appendix 2. VEX Robotics Competition Survey for VRC Team Leaders

VEX Robotics Competition Survey For VRC Team Leaders

Thank you for taking the time to complete the VRC Team Leader Survey! Your answers will help us learn more about ways VEX Robotics Competition is impacting students on your team. You should be able to complete this survey in about 15 minutes. Please include your contact information at the end of this survey so we can enter you in a drawing for the chance to win a $100 VEX credit.

1. Would you define yourself as a coach or mentor or parent/adult non-technical mentor? We've provided our current *working* definitions of these roles.

- ◯ COACH: defined as someone who helps students with design, building, and planning related to competition.
- ◯ MENTOR: defined as someone sharing their specific expertise in engineering, robotics, computer programming, and/or technological areas who serves as an expert adviser to teams.
- ◯ PARENT OR OTHER ADULT, NON-TECHNICAL MENTOR: defined as someone who helps coordinate travel, chaperons students, does event planning, or other similar activities.
- ◯ A combination of two or more of these roles

2. How much time do you spend, on average, in the roles above?

	None of my time	Up to 25% of my time	26-50% of my time	51-75% of my time	More than 75% of my time
Coach	◯	◯	◯	◯	◯
Mentor	◯	◯	◯	◯	◯
Parent/Adult Non-Technical Mentor	◯	◯	◯	◯	◯

3. If you have suggestions about how best to define "coach" and "mentor" please provide them here.

VEX Robotics Competition Survey For VRC Team Leaders

4. What type of team do you work with?

- ◯ Team affiliated with a traditional public school.
- ◯ Team affiliated with a public charter school.
- ◯ Team affiliated with a public school focusing in a STEM area.
- ◯ Team affiliated with a private school.
- ◯ Team affiliated with a homeschool group.
- ◯ Club team (e.g., 4-H club, Boys/Girls Club, etc.).
- ◯ Other.

(please specify)

Part 1

In this section, please rate how often you observe each behavior.

1. Students who participate in VRC demonstrate interest in...

	I observe this very often	I observe this sometimes	I observe this rarely	I never observe this	Not sure
taking additional math or science classes in high school	◯	◯	◯	◯	◯
taking math or science classes in college	◯	◯	◯	◯	◯
taking engineering classes in college	◯	◯	◯	◯	◯
having a job in a science, technology, engineering, or math (STEM) field	◯	◯	◯	◯	◯
majoring in a STEM field in college	◯	◯	◯	◯	◯
wanting to learn more about robotics	◯	◯	◯	◯	◯
wanting to learn more about engineering design	◯	◯	◯	◯	◯
wanting to learn more about computer programming	◯	◯	◯	◯	◯
going to school more or having better attendance	◯	◯	◯	◯	◯
joining more clubs or teams at school	◯	◯	◯	◯	◯
school or education in general	◯	◯	◯	◯	◯

VEX Robotics Competition Survey For VRC Team Leaders

2. How does participation in VEX Robotics Competition DIRECTLY INFLUENCE students' interest in these areas? What have you observed?

Changes in Teamwork, Sportsmanship, and 21st Century Skills

VEX Robotics Competition Survey For VRC Team Leaders

1. In which of these areas, if any, have you observed STUDENT GROWTH as a direct outcome of students' participation in VRC?

	VRC students demonstrate a lot of growth in this area.	VRC students demonstrate some growth in this area	VRC students don't demonstrate much growth in this area	Not sure
coming up with ideas and sharing them with teammates	◯	◯	◯	◯
seeing failure as an opportunity to learn	◯	◯	◯	◯
solving difficult problems on one's own	◯	◯	◯	◯
solving difficult problems with teammates	◯	◯	◯	◯
valuing each team member's contribution	◯	◯	◯	◯
communicating ideas	◯	◯	◯	◯
accepting and using feedback and criticism	◯	◯	◯	◯
setting individual goals	◯	◯	◯	◯
setting team goals	◯	◯	◯	◯
using time effectively	◯	◯	◯	◯
being a good teammate	◯	◯	◯	◯
treating teammates respectfully	◯	◯	◯	◯
treating opponents respectfully	◯	◯	◯	◯
being honest and fair in competitive situations	◯	◯	◯	◯
taking individual responsibility for doing one's part on the team	◯	◯	◯	◯
understanding how math, science, engineering, or technology are used to solve real-world problems	◯	◯	◯	◯
coming up with creative solutions to difficult problems	◯	◯	◯	◯
seeing possibilities and opportunities in design challenges	◯	◯	◯	◯
understanding that every technology can be improved	◯	◯	◯	◯
communicating to explain and justify design solutions	◯	◯	◯	◯
engaging in systems thinking (understanding that systems have unexpected effects that cannot be predicted from the behavior of individual subsystems).	◯	◯	◯	◯

Changes in Student Confidence

VEX Robotics Competition Survey For VRC Team Leaders

1. In which of these areas, if any, have you observed changes in students' CONFIDENCE IN THEIR ABILITIES as a direct outcome of participation in VRC?

	VRC students' confidence becomes much higher	VRC students' confidence becomes somewhat higher	VRC students' confidence becomes a little higher	There's really no change	Not sure
doing well in school	◯	◯	◯	◯	◯
doing well in science classes	◯	◯	◯	◯	◯
doing well in math classes	◯	◯	◯	◯	◯
solving hard problems	◯	◯	◯	◯	◯
being a good leader	◯	◯	◯	◯	◯
asking questions when they need help	◯	◯	◯	◯	◯
presenting/communicating ideas to others	◯	◯	◯	◯	◯
working effectively with a team	◯	◯	◯	◯	◯

2. How does participation in VEX Robotics Competition DIRECTLY INFLUENCE students' confidence in these areas? What have you observed?

VRC and Diversity Issues

In this section, please tell us ways, if any, VEX Robotics Competition works with diverse populations.

1. Please tell us how diverse your VRC team is by providing a number of participants on your team from each racial category.

	African-American/Black	Asian/Pacific Islander	Hispanic/Latino	Native American/Alaskan/First Nations	White	Multi-racial/other
Number of students						

2. How many males and females do you have on your team(s)?

	Male	Female
Number of participants		

VEX Robotics Competition Survey For VRC Team Leaders

3. Please rate your level of agreement with each statement.

	Strongly Agree	Agree	Disagree	Strongly Disagree	Not sure/doesn't apply
Girls have shown a interest in being on my VRC team.	◯	◯	◯	◯	◯
Races typically underrepresented in STEM and WHO ARE MINORITIES IN MY COMMUNITY have shown interest in being on my VRC team.	◯	◯	◯	◯	◯
It has been easy to recruit students for my VRC team who are typically underrepresented in STEM.	◯	◯	◯	◯	◯
VRC does a good job reaching out to racial minority students.	◯	◯	◯	◯	◯
VRC does a good job reaching out to female students.	◯	◯	◯	◯	◯

4. In your experience, what, if anything, makes VRC participation appealing to students typically underrepresented in STEM?

5. What could be done to increase VRC participation of students typically underrepresented in STEM?

Information about You

Please complete this very important demographic information section.

1. How long have you been coaching VRC teams?

- ◯ This is my first year
- ◯ 1 year
- ◯ 2-3 years
- ◯ 4-5 years
- ◯ More than 5 years

VEX Robotics Competition Survey For VRC Team Leaders

2. What is your gender?

- ◯ Male
- ◯ Female

3. Are you the parent of a current or former VRC participant?

- ◯ Yes
- ◯ No

4. How would you describe your ethnic background?

- ◯ African-American/Black
- ◯ Asian/Pacific Islander
- ◯ Hispanic/Latino
- ◯ Native American/Alaskan/First Nations
- ◯ White/Caucasian
- ◯ Multi-racial
- ◯ Some Other Race

(please specify)

5. What level team do you coach?

- ◯ Middle School
- ◯ High School
- ◯ Both

*** 6. What is your current full-time job? [please choose ONE]**

- ◯ I am a middle school teacher
- ◯ I am a high school teacher
- ◯ I am university faculty
- ◯ I am an engineer
- ◯ I work in a math, science, technology, or computer field
- ◯ I work for a youth organization (such as 4-H, Boys/Girls Club)
- ◯ Other

(please specify)

VEX Robotics Competition Survey For VRC Team Leaders

1. How many years have you been a teacher?

- ◯ This is my first year
- ◯ 1-5
- ◯ 6-10
- ◯ 11-15
- ◯ 16-20
- ◯ More than 20

2. What grades do you teach? Please check all that apply.

- ☐ Elementary
- ☐ 6th
- ☐ 7th
- ☐ 8th
- ☐ 9th
- ☐ 10th
- ☐ 11th
- ☐ 12th
- ☐ Other

(please specify)

VEX Robotics Competition Survey For VRC Team Leaders

3. In what fields are you certified/qualified to teach?

- [ ] Middle school science
- [ ] Middle school math
- [ ] Middle school computer science
- [ ] High school science
- [ ] High school math
- [ ] High school computer science
- [ ] AP math course(s)
- [ ] AP science course(s)
- [ ] AP computer science
- [ ] Other

(please specify)

Comparing VRC Students to Their Non-VCR Peers

In this section, think about the students you work with in VRC and those you work with or teach who are not in VRC. What have you noted about differences between these groups?

VEX Robotics Competition Survey For VRC Team Leaders

1. Please rate your level of agreement with each statement.

	Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure	Doesn't Apply to Me
VRC students are better behaved in school than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students have better attendance than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students are more comfortable using computers than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students are more interested in taking additional or harder math classes than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students are more interested in taking additional or harder science classes than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students are more interested in taking additional or harder computer classes than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students demonstrate more interest in going to college than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students demonstrate more interest in majoring in STEM fields or having a STEM career than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students have higher confidence in their abilities in STEM areas than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students have higher confidence in their general academic abilities than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students demonstrate greater teamwork skill than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students demonstrate higher problem-solving ability than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students demonstrate better leadership qualities than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students demonstrate better communication skill than their non-VRC peers.	◯	◯	◯	◯	◯	◯
VRC students demonstrate more perseverance than their non-VRC peers.	◯	◯	◯	◯	◯	◯

2. If you have observed differences between VRC students and their non-VRC peers, to what do you attribute these differences, specifically as they relate to VRC?

VEX Robotics Competition Survey For VRC Team Leaders

1. What are the greatest benefits of VRC for students?

2. What are the greatest benefits to you as a coach for participating in VRC?

3. How could VRC be improved for students?

4. Please include your contact information below to be entered into the random drawing for a chance to win a $100 VEX Credit.

Name

Email

Phone number

Team Number:

THANK YOU FOR YOUR PARTICIPATION!

Appendix 3. Student and Team Leader Responses to Self-Efficacy Survey Items

Participating in the VEX Robotics Competition has increased my confidence that I can		Strongly Agree	Agree	Disagree	Strongly Disagree	Not sure	Mean	N
do well in school	MS Student	42.9%	45.5%	3.9%	2.6%	5.2%	3.36	77
	MS Team Leader	27.6%	41.4%	5.2%	12.1%	13.8%	2.98	58
	HS Student	32.9%	50.0%	7.6%	1.0%	8.6%	3.26	210
	HS Team Leader	35.3%	41.0%	10.3%	5.8%	7.7%	3.15	156
	MS/HS Leader	42.3%	40.4%	5.8%	1.9%	9.6%	3.36	52
do well in my science classes	MS Student	40.3%	44.2%	9.1%	3.9%	2.6%	3.24	77
	MS Team Leader	27.6%	37.9%	10.3%	10.3%	13.8%	2.96	58
	HS Student	38.0%	42.8%	10.1%	<1%	8.7%	3.29	208
	HS Team Leader	28.2%	41.0%	11.5%	7.7%	11.5%	3.01	156
	MS/HS Leader	56.6%	22.6%	9.4%	3.8%	7.5%	3.43	53
solve hard problems	MS Student	51.3%	36.8%	7.9%	1.3%	2.6%	3.42	74
	MS Team Leader	38.6%	36.8%	15.8%	3.5%	5.3%	3.17	57
	HS Student	51.4%	39.5%	4.3%	<1%	4.3%	3.48	210
	HS Team Leader	40.4%	35.3%	14.7%	2.6%	7.1%	3.22	156
	MS/HS Leader	54.7%	28.3%	9.4%	---	7.5%	3.49	53
be a good leader	MS Student	46.8%	37.7%	7.8%	1.3%	6.5%	3.39	77
	MS Team Leader	34.5%	37.9%	22.4%	3.4%	1.7%	3.05	58
	HS Student	45.9%	39.7%	5.7%	1.0%	7.7%	3.41	209
	HS Team Leader	41.7%	39.7%	13.5%	1.9%	3.2%	3.25	156
	MS/HS Leader	52.8%	35.8%	5.7%	1.9%	3.8%	3.45	53
ask questions when I need help	MS Student	28.6%	53.2%	9.1%	2.6%	6.5%	3.39	77
	MS Team Leader	41.4%	39.7%	15.5%	1.7%	1.7%	3.23	58
	HS Student	40.2%	43.1%	7.7%	1.0%	8.1%	3.33	209
	HS Team Leader	35.9%	46.8%	10.9%	3.8%	2.6%	3.18	156
	MS/HS Leader	45.3%	35.8%	15.1%	---	3.8%	3.31	53
present my ideas to others	MS Student	48.1%	37.7%	9.1%	1.3%	3.9%	3.38	77
	MS Team Leader	34.5%	48.3%	13.8%	1.7%	1.7%	3.18	58
	HS Student	47.4%	44.0%	3.8%	1.9%	2.9%	3.41	209
	HS Team Leader	38.1%	42.6%	14.2%	2.6%	2.6%	3.19	155
	MS/HS Leader	50.9%	28.3%	13.2%	3.8%	3.8%	3.31	53
work well with a team	MS Student	59.7%	37.7%	2.6%	---	---	3.57	77
	MS Team Leader	39.0%	37.3%	18.6%	3.4%	1.7%	3.18	58
	HS Student	55.5%	38.8%	1.0%	1.9%	2.9%	3.52	209
	HS Team Leader	53.5%	31.6%	11.0%	1.3%	2.6%	3.41	155
	MS/HS Leader	47.2%	41.5%	7.5%	---	3.8%	3.41	53

Appendix 4. Disaggregated Student and Team Leader Responses to STEM Interest Survey Items

Participating in the VEX Robotics Competition has made me		Strongly Agree	Agree	Disagree	Strongly Disagree	Not sure	Mean	N
interested in taking additional math or science classes in high school	MS Student	40.0%	41.3%	9.3%	2.7%	6.7%	3.27	75
	MS Team Leader	44.9%	42.3%	3.8%	<1%	8.3%	3.43	156
	HS Student	44.6%	29.9%	14.2%	3.9%	7.4%	3.24	204
	HS Team Leader	44.9%	42.3%	3.8%	<1%	8.3%	3.43	156
	MS/HS Leader	49.1%	30.2%	5.7%	1.9%	13.2%	3.46	53
more interested in taking math or science classes in college	MS Student	38.7%	40.0%	9.3%	2.7%	9.3%	3.26	75
	MS Team Leader	36.4%	34.5%	3.6%	---	25.5%	3.44	55
	HS Student	47.1%	32.4%	11.8%	2.0%	6.9%	3.34	204
	HS Team Leader	45.8%	34.8%	6.5%	<1%	12.3%	3.43	155
	MS/HS Leader	47.2%	39.6%	1.9%	---	11.3%	3.51	53
more interested in taking engineering classes in college	MS Student	51.4%	33.8%	6.8%	1.4%	6.8%	3.45	74
	MS Team Leader	32.7%	25.5%	1.8%	---	40.0%	3.52	55
	HS Student	58.8%	25.0%	11.3%	1.5%	3.4%	3.46	204
	HS Team Leader	44.8%	42.2%	3.2%	<1%	9.1%	3.44	154
	MS/HS Leader	47.1%	37.3%	3.9%	---	11.8%	3.49	51
more interested in having a job in a STEM or computer field	MS Student	58.7%	25.3%	8.0%	4.0%	4.0%	3.44	75
	MS Team Leader	35.2%	31.5%	---	---	33.3%	3.53	54
	HS Student	61.6%	28.1%	6.4%	1.5%	2.5%	3.54	203
	HS Team Leader	40.3%	35.1%	6.5%	1.9%	16.2%	3.36	154
	MS/HS Leader	41.5%	32.1%	7.5%	---	18.9%	3.42	53
want to learn more about computer programming	MS Student	61.3%	30.7%	5.3%	---	2.7%	3.58	75
	MS Team Leader	43.9%	45.6%	7.0%	---	3.5%	3.38	57
	HS Student	56.4%	31.4%	8.3%	1.5	2.5%	3.46	204
	HS Team Leader	36.5%	50.0%	11.5%	<1%	1.3%	3.24	156
	MS/HS Leader	39.6%	52.8%	3.8%	1.9%	1.9%	3.33	53
want to learn more about robotics	MS Student	68.0%	22.7%	6.7%	---	2.7%	3.63	75
	MS Team Leader	67.2%	29.3%	---	---	3.4%	3.70	58
	HS Student	66.5%	26.6%	3.4%	1.5%	2.0%	3.61	203
	HS Team Leader	64.5%	31.0%	2.6%	<1%	1.3%	3.61	155
	MS/HS Leader	73.6%	22.6%	---	1.9%	1.9%	3.71	53
want to learn more about engineering design	MS Student	60.0%	32.0%	6.7%	---	1.3%	3.54	75
	MS Team Leader	57.9%	33.3%	5.3%	---	3.5%	3.55	57
	HS Student	61.3%	28.9%	4.9%	2.0%	2.9%	3.54	204
	HS Team Leader	52.3%	39.4%	4.5%	<1%	3.2%	3.48	155
	MS/HS Leader	60.4%	32.1%	3.8%	1.9%	1.9%	3.54	53

Appendix 5. Disaggregated Student and Team Leader Responses to Academic Engagement Survey Items

Participating in the VEX Robotics Competition has made me		Strongly Agree	Agree	Disagree	Strongly Disagree	Not sure	Mean	N
want to go to school more or have better attendance	MS Student	37.8%	37.8%	9.5%	4.1%	10.8%	3.23	74
	MS Team Leader	28.6%	19.6%	10.7%	5.4%	35.7%	3.11	56
	HS Student	33.2%	29.2%	21.3%	5.9%	10.4%	3.00	202
	HS Team Leader	38.7%	31.6%	11.6%	4.5%	13.5%	3.21	155
	MS/HS Leader	28.3%	32.1%	13.2%	9.4%	17.0%	2.95	53
want to join more clubs or teams at school	MS Student	32.4%	33.8%	20.3%	1.4%	12.2%	3.11	74
	MS Team Leader	21.4%	28.6%	10.7%	7.1%	32.1%	2.95	56
	HS Student	24.0%	33.8%	28.9%	3.9%	9.3%	2.86	204
	HS Team Leader	25.5%	28.1%	20.3%	7.2%	19.0%	2.89	155
	MS/HS Leader	20.8%	35.8%	18.9%	3.8%	20.8%	2.93	53
more interested in school or education	MS Student	32.4%	44.6%	12.2%	2.7%	8.1%	3.16	74
	MS Team Leader	39.3%	35.7%	1.8%	3.6%	19.6%	2.95	56
	HS Student	35.0%	38.4%	18.2%	2.5%	5.9%	3.13	203
	HS Team Leader	47.7%	36.1%	6.5%	1.3%	8.4%	3.42	155
	MS/HS Leader	43.4%	39.6%	7.5%	---	9.4%	3.40	53