FTC Robotics Club: Does it Really Prepare Students For Beyond College? (Evaluation)

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First Round Evaluation of First Tech Challenge (FTC) Robotics Club: Does it Really Prepare Students for beyond College?

Abstract

It is becoming increasingly difficult to ignore the shift in careers requiring 21st century skills. Schools around the country are striving to prepare students for the competitive and demanding job market after college. As a way to assist students for this shift, there are in-depth discussions about the benefits of project-based learning, methods for teaching all subject-areas, and extra-curricular clubs.

In this paper, a detailed account of the methods and practices used in an extracurricular robotics club at a culturally diverse, low-socioeconomic Title 1 School is provided. As students collaborate within the team and compete against other schools in FIRST Robotics' FIRST TECH Challenge ® (FTC), they gain experience in problem solving, programming, fundraising, documentation, and community outreach. The aim of this paper is to evaluate the premise that Science, Technology, Engineering, and Mathematics (STEM) through robotics has an effect on minority students' confidence to pursue STEM related careers after college education. We also attempted to evaluate if the participants' attitude about learning new things changed as the students grow to become life-long learners.

Our findings suggest that FTC Club benefited this underrepresented group in building confidence in robotics, teamwork skills, and increasing their enjoyment of learning and motivation to pursue STEM careers.

Introduction

To keep leading in the world market, the United States needs more STEM professionals in the labor pool as a nation. According to the 2012 Program for International Student Assessment

(PISA) results, the US placed 26th in math and 21st in science worldwide. While the US needs around one million STEM graduates, it can only meet three hundred thousand of the demand[1]. Increasing STEM interest to fulfill those jobs is one of the fundamental goals of the K-12 stakeholders and researchers. Additionally, STEM interest is almost three times higher for boys than girls[1]. Female students' ratio in STEM fields is around 20% all around the world[1]. A study found that female students think that STEM is not appropriate for their careers because they cannot connect the real world and their assignments during school years, and prefer social studies[1]. Girls, although not limited in their ability to be successful programmers and to excel in engineering design, need positive mentor or instructor support to overcome ingrained stereotypes[1]. The need to find ways to promote successful women in STEM as role models is more pressing than ever. Other components that influences kids are ethnicity and socioeconomic levels. Minority students are behind their peers in science, technology, engineering and math[2]. Student motivation and positive insights and encouragement by parents, in addition to having role models and instructors, were shown to increase interest in STEM as a career choice in the future[2].

Schools have the purpose of developing skills that assist students first in college, and then in the competitive job market. The increase in STEM jobs, requires schools to update their curriculum to fulfill those needs. The implementation of robotics programs in classrooms to excite students in STEM careers is not novel. According to the constructivist learning theory suggested by Papert in the 1970s, knowledge and learning are considered to rely on the context with which they take place; enriching activities dealing with students' interests and prior experience, as well learning-by-doing, involves the creation of meaningful artifacts[3]. Several studies have reported that students advance in their interest and knowledge of problem solving in STEM fields especially after being involved in robotics[4]. Therefore, based on the education theory and the corresponding literature, it is no surprise that robotics is shown to be the most impactful program to positively shape students attitudes towards STEM careers[5]. Generally, robotics is integrated into curriculum to teach students engineering concepts as an extracurricular activity[6]. To increase focus on the skills learned, create enthusiasm, and show a real world example outside of the school context, students are encouraged to participate in robotics competitions[7, 8].

Implementing a successful, competitive robotics club into curriculum requires effort to train teachers, find good mentors, and raise funds for the equipment needed. Success has been reported by following a pedagogical approach emphasizing the social and cultural richness of diverse students[8]. Students who were paired with and mentored by college students with familiar cultural backgrounds, showed improvement in STEM concepts when compared to their peers, who were members of other clubs instead[8]. Schools can run successful programs if district and university partnerships are established to train teachers on the best approach and receive mentor support from people whom share familiar backgrounds[8]. Unfortunately, this was not the case for our group, we lacked available mentors that reflect the culture of our student body in addition to the lack of established partnerships with our charter school and nearby universities due to high turnover rate of coaches. To the best of our knowledge, this is the first time that data has been collected on a FTC team comprised of 83% girls, 80% of students on refugee status, and 100% of students on national free and reduced lunch program.

The need to train teachers on how to encourage students, especially girls and minorities in computer science and engineering education has been noted[9]. In addition, financial support was proven to play a large role at student success related with participation in robotic teams[10]. FIRST robotics is one of the most expensive competitions. Therefore, there is a need for students to develop computer skills for writing fundraising presentations, trip and team budgets, and business plans as they search for sponsors to fund their team's needs. Many Title I students are unable to accomplish these tasks without mentors that can provide the support and answer technical questions as they arise.

The objective of this study is to find how robotics and the participation in robotics competitions influence the development of successful collaboration and future education goals. We obtained Institutional Review Board approval (project 803724-1) to collect participant data and present the results found in this study. In addition to researched recruitment practices and additional support, this paper shows how minorities in STEM can improve their confidence in using technology and increase their desire to continue to learn new things and be equipped with 21st century skills despite of all challenges. We will continue to refine the methodology and collect additional data to address our research questions.

Data Sample

This kindergarten through 12th grade charter school serves a very at-risk student population with 100% of students receiving free and reduced lunches. Students' proficiency scores in mathematics average just above 48% in grades 3-12 according to the Arizona Department of Education (ADE). The Sonoran Science Academy especially emphasizes STEM education that is primarily designed to meet the needs of the students and parents of metropolitan Phoenix, Arizona. The community surrounding the school can be characterized as lower middle class, although many residents are below the poverty line. The school is highly diverse and the FTC team reflects that diversity. As shown in *Table 1* below, the demographics of the team consists of seven students from African countries primarily Somalia, five students Caucasian; mostly from Eastern Europe, one Hispanic/Latino, and two students from Asian countries.

Table 1: Ethnic Diversity of FTC Club Students

Ethnicity	**Number**	**Percent**
Caucasian	5	33
African American	7	47
Hispanic/Latino	1	7
Asian	2	13
Total	15	100

One obstacle for charter schools like Sonoran Science Academy is competing with other clubs for the participants in the club. The high school does not have a large student population, 86 students in total, therefore students may be participating in three or four different extra-curricular activities after or before school and on weekends. All students participating in FTC robotics are fulfilling their membership requirements of maintaining an average of 70% or better in their classes and ensuring a positive score in the school-wide behavior management system. The majority of these students are also meeting requirements for one to two other clubs and their commitments to their family. A second obstacle is that about one third of the students participating live over twenty miles from the school. Because of this distance, regular attendance for the required two hours, twice a week has been adapted to fit within the students' schedule and the families' transportation availability. This has created the need for a large team of

students. Other robotics teams may have only two programmers, whereas on this team, there are two main programmers, but every member is learning programming at some level to fill in when needed. Other accommodations have been made to ensure the required work is completed. Such as, the team camera started as only something the team photographer used, however eventually the students responsible for the engineering notebook and for maintaining social media learned how to use the camera as well to document the meetings. Furthermore, pictures, the notebook, and team forms were all uploaded onto a Google Drive folder and shared with all members, mentors, and coaches so that the team could access any files from home if they were unable to make any of the meetings. Due to the reasons mentioned above, the team slowly accumulated more members than the recommended fifteen students per team, but there was rarely more than ten students per meeting.

One of the biggest challenges for many robotics teams is recruiting girls. However, this year the school's athletic team had most of the high school boys participating four days a week. This made it impossible for many of the boys to join robotics even if they wanted to. Therefore there were many girls that were looking for a club to participate in. Sonoran Science Academy has one of the largest teams, but also one of the only teams with girls as the majority. There are 12 female and 3 male students in the club who participated in the survey.

Method

To increase STEM interest for high school students, Sonoran Science Academy implemented FIRST Tech Challenge (FTC) ® Robotics Competition in grades 9 through 12. Through their involvement in FTC, the students are expected to gain experience and build confidence. This research compares students' pre and post survey results to be able to answer the following research questions:

- **RQ1:** Does FTC robotics club help minority students build confidence in team collaboration?
- **RQ2:** Does Robotics club motivate minority students to pursue a career in STEM?
- **RQ3:** Does FTC participation positively correlate with motivation to learn new things, and therefore become a lifelong learner?

Data collected for this study include researcher notes from the meetings throughout the semester, artifacts produced during the sessions and responses to two sets of anonymized questionnaires. During the second meeting, students were asked to volunteer for the study. Home visits were conducted on weekends and over school breaks to acquire parent permission. The pre-survey was completed within the first month of the club and the post-survey was completed five months later. The survey questions were developed with the study's purpose as the prime focus and asked the participants the following questions:

1. *Gender*
2. *Ethnicity*
3. *Why did you choose to participate in robotics?*
4. *How long have you been part of this club?*
5. *What are you most excited about learning?*
6. *What is your future dream career? Please explain why you chose that career.*

Question 7 through 9 are level of confidence questions scored as: 1=" Not Confident at all", 2=" Little Confident, 3=" Somewhat Confident", 4=" Very Confident"

7. *I am going to college or university after school*
8. *How confident do you feel working within a team (Collaborative group)*
9. *How confident do you feel about your computer programming skills?*

Question 10 was answered with Likert scale categories: 5= "Strongly Agree", 4= "Agree", 3= "Neither Agree Nor Disagree", 2= "Disagree", and 1= "Strongly Disagree".

10. *How would you rate the following statements?*
    - *a. I enjoy learning new concepts and ideas*
    - *b. Making a plan before I start to solve a problem is important*
    - *c. Trying new methods to solve a problem when one does not work is important*
    - *d. Carefully analyzing a problem before I begin to develop a solution is important.*

e. Listening to others when trying to decide how to approach a task or problem is important.

f. I think understanding basic technology and engineering concepts behind building a robot is important.

Short answer:

11. What do you hope to accomplish by the end of the club?

Fifteen students completed the pre-test and twelve students completed the post-test, were aged between 14 and 18. All participants and their parents consented to the use of their data for this study. Upon completion of the online surveys, data management and analysis was performed using SPSS 23.0 for Mac. To control for bias, analysis was carried out by a person without access to the participants.

Because this is the first year that Java programming has been applied in FTC ® we also gave a survey to students that assessed their initial Java programming knowledge. This survey was a paper assessment of 12 multiple choice questions intended to determine growth in the programming aspect of robotics. Although we intended the students to begin Java earlier in this competitive season, the obstacle of finding a programming mentor delayed this intention. Therefore we were not able to adequately assess the student growth in this area. If teams were not at the level for Java programming, *MIT App Inventor* was also available. *MIT App Inventor* was assessed as a great starting point for beginner computer science classes to motivate and encourage students in K-12 classrooms[3]. Code based programming can be challenging and frustrating for beginners and the learning curve is steep, which may cause them to lose interest in programming. App Inventor is not gender biased and equally attractive to both boys and girls[3]. Sonoran Science Academy has found the App Inventor programming software to be a useful starting point. FTC's Android platform training resources have been a critical support for the programmers on the team. However, this block-based language limits the flexibility and creativity of the script for the robot's programming. It provides a powerful foundation, but to accomplish the greatest variety of tasks, programmers will eventually hope transition to Java.

Results and Discussion

After data collection, three authors analyzed the data separately and collaborated to reach the following discussion points, and indicative responses with 90% agreement after omitting anomalies. Question 4 (*How long have you been part of this club?*) on the survey indicated that 14 out the 15 students in the pre-survey had only experienced FTC robotics for a month or less. This can indicate that any positive growth during the months between the pre and post-survey were influenced by their participation in the club since the majority of students started with limited experience. This result has provided perspective when analyzing the survey data.

RQ 1: Does FTC robotics club help minority students build confidence in team collaboration?

Survey Question 8 (*How confident do you feel working within a team (Collaborative group))* was measuring participants' confidence in teamwork using range 4="Very Confident" to 1="Not Confident At All". According to Table 2 below, student's confidence mean increased in terms of working in a team from 3.87(SD .352) to 4.00(SD .0). Two students out of fifteen reported *somewhat confident* in the pre survey, all of the students in the post survey reported *very confident*.

Table 2. Mean, standard deviation, maximum and minimum values for Likert Question 8

Items	**Mean Pre**	**Mean Post**	**SD Pre**	**SD Post**	**Max Pre**	**Max Post**	**Min Pre**	**Min Post**
Question 8	**3.87**	**4.00**	**.352**	**.000**	**4**	**4**	**3**	**4**

Also below, Figure 1 shows a breakdown of Question 8 data by gender. There is an increase in female confidence over the five month participation in the club (from 3.87 to 4). Male participants remained consistently *very confident* in working with others.

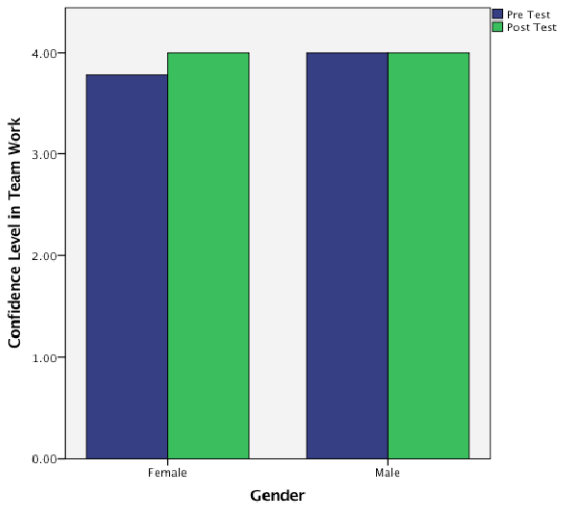

Figure 1. Gender vs. Confidence Level in Team Work

The results are not shocking due to the nature of the voluntary clubs; they generally tend to show similar behaviors. As mentioned, students were picked by student interest in robotics, science and technology, success in math and science classes, or teacher reference, student application and volunteer requests, which are the signals of high confidence and motivation in advance.

The last short response Question 11 (*What do you hope to accomplish by the end of the club?*), most of the participants replied a desire to learn more about the engineering, design, and programming associated with robotics in the pre-test and the post-test. There was a subtle shift in answers to show that there was a bigger appreciation of skills needed for communication and teamwork towards the end. In the pre-test there was comments about "*winning*" from two of the 15 participants, eight students mentioned *"learn how to code"* and *"program robots*" and five of the 15 gave nondescript responses like "*nothing", "my goals"* and "*narwhals".* In the post test responses, one participant talked about "*winning*", three students mentioned "*programming*" but five students talked about cooperation, building communication skills and social skills. Student responses included *"be a person that helps out", "how to cooperate with others …", "I hope to accomplish being a better social person".*

RQ 2: Does Robotics club motivate minority students to pursue a career in STEM?

Short answer responses to question 6 (*What is your future dream career? Please explain why you chose that career*) on the survey showed growth in reference to Research Question 2. In the pre-survey, only two of the students noted an uncertainty in their career after college. Also the majority of students listed a STEM career as their plan for the future. The responses included "*engineer*" from four students, "*pharmacist"* from three students, *"interior designer"* and *"criminal defense lawyer"*. In the post-survey, while the number of students unsure about their career doubled from two to four, the majority still preferred STEM careers, specifically in engineering and medical fields. Furthermore, 20% of the responses in the pre-survey contained future careers like "*modeling*" or "*basketball player*", which were considered Non-STEM. But in the post-survey, the non-STEM careers decreased to 0% and fields that did require higher education like "*project manager*", "*bank management*" appeared. The results from the confidence statement 7 (*I am going to college or a university after high school*) also demonstrated an increase in the expectation of attending a college or university after high school from 3.87(SD 0.352) to 3.92(SD .289). Last but not least, the increasing tendency in STEM jobs and teamwork was notable to mention. Pre and Post survey results explained that there wasn't a statistically significant change after students' involvement in FTC club. However, we saw an increasing trend in the Likert scale post survey results and a higher level of maturity in the open ended questions.

RQ 3: Does FTC participation positively correlate with motivation to learn new things?

Short response questions 3, 5 and 11 in the participant surveys applied to Research Question 3. We asked students "Why did you choose to participate in robotics?" seven of the twelve students took the survey expressed "*wanted to try something new*", "*the desire to learn new things*" or "*introduce myself to new things*" in the post-survey as compared to three students in the pre-survey. Another comparison is the transition from a majority of students just wanting to "*build*" in the pre-survey to an increase in wanting to "*program*" in the post-survey. There was also a greater maturity and elaboration in the post-survey responses for example: *"... So that I can expand my skills, knowledge, and experience on robots*". One student responded "*because i want*

to major in engineering and robotics may be the first step towards it". Another mentioned "*I chose to participate in robotics because I am very interested in it and I love learning new things*".

Later, in Question 5 (*What are you most excited about learning?),* the pre-survey responses were vague. One third of the student's answers had no focus while the rest of the students indicated an intention to "*build robots*" or use robotics to fulfill requirements for another club. One student mentioned his/her excitement about social skills and *"building relationships"*. Despite this start, the comments in the post-survey yielded much different results. Half the students noted a desire to [increase] their *"ability in programming"*, some still kept their motivation to "*build*", but surprisingly the remaining members commented social aspects like helping others or the club with following responses "*supplying the teams with things they need*", "*fundraising*", "*I am most excited about learning how to interact with people*".

In response to Likert question 10a, students showed increase in their enjoyment of learning new concepts and ideas, the mean increased from 4.73(SD 0.594) to 4.92(SD 0.289). These responses make us believe that students' participation in the robotics club were positively correlated with increase in motivation to learn new things.

A final, informal assessment was given after the regional competitions, which was the conclusion of the club. Each student was asked, individually, to write a word or phrase to describe their experience as a member of FTC Robotics. Each student was left alone to write and were instructed to keep the question and his or her own responses private until all members present had completed the task. 14 of the 15 team members were able to provide a response. The student responses to this question are listed in the Table 3 according to themes emerged.

Table 3: Authentic Responses: *What is one word or phrase to describe your experience in FTC Robotics*?

Theme: Family/Team	**Theme: Inspirational**	**Theme: Practical**
"Family" *"My second family"* *"Team/Family P.S. Let's do better next year!!!"* *"Teamwork!!!"*	*"Amazing, Life changing"* *"Full of excitement"* *"Unexpected outcomes"* *"Accomplished, Experienced, Amazing"* *"Different, #1 (number one)"* *"Experience with partnership"* *"Inspire"*	*"An engineering aspect in which you build a robot to compete."*

According to the authentic responses listed in the first column, it is noticed that students emphasized the value of being involved and becoming a member of FTC club. The second dominant theme of student responses showed that they found this experience inspirational. Although the last comment did not fall into either category, it showed an affirmation of practical engineering aspect of the club. Many of the students wrote words or phrases that imply a desire to do more next year or acknowledge the importance of teamwork. Some responses demonstrated the student's pride for his or her achievements during the season. Because the students felt accepted and engaged in the club which is based on accomplishing new challenges, meeting new people, and traveling to new places, their responses can be used as tool to indirectly measure motivation to learn new things.

Future Work

In the future, we aim to expand the analysis by adding content knowledge tools, and include academic achievement in Science, Math and Computer classes. We also like to explicitly analyze and discuss the results according to the grade level of students (9th through 12th grade) over a longer period of involvement in the club. Lastly, reliable quantitative Likert scales for each research question will be developed by using literature to eliminate all the limitations we faced during data analysis, which will help us reconcile data in later work.

Conclusion

The small sample size (15 for pretest, 12 for posttest), and progressive nature of this research, generalization of our results was difficult. Our preliminary findings show that, FTC Robotics Club positively impacted minority students' attitudes toward STEM careers, and increased confidence in teamwork and collaboration skills. The questionnaires also provided data that FTC creates an environment where students enjoyed learning new things. We hope to see that seed turn them into lifelong learners, one of the most important aspects of STEM careers.

We observed that female students total confidence levels increased and reached the male students confidence scores as a result of involvement in the robotics team, gaining knowledge in coding and teamwork. Authors believe that involvement of girls in competitive collaborative teams like robotics will help motivate more women going into STEM pipeline.

Generally, participants of robotics clubs are self-motivated students. They already have an interest in hands-on activities and have positive attitude towards robotics and engineering. This caused increased confidence and motivation scores in advance, and created the problem commonly referred as "ceiling effect[11]" for our research. The mean results of pre and post-surveys both were ranged between 3 and 4 for confidence and produced not statistically significant results. However, it is important to maintain this high motivation through similar programs, especially for girls and minorities. From this perspective, it is important to continue to work with this group of students to further evaluate the positive effect of their involvement with educational robotics. All in all, this work in progress recommends that, using informal robotics clubs in closing sex and minority gap can be an encouraging area for further STEM research.

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