FIRST LEGO League Participation: Perceptions of Minority Student Participants and their FLL Coaches

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FIRST® LEGO® League Participation: Perceptions of Minority Student Participants and their FLL® Coaches

Introduction

Many studies have shown, at least anecdotally, that robotics activities and competitions such as FIRST® LEGO® League (FLL®) can successfully promote K-12 student engagement in, and mastery of, engineering skills and habits of mind. [1,2,3,4,5,6,7,8,9] Many of these activities occur through extra-curricular clubs and therefore attract those with an existing interest and means to participate outside of the regular school day. It requires a pro-active effort by teachers, schools, and other supporters to attract K-12 minority students to engineering,[10] and this paper will address one such effort that uses FLL both in schools and local youth organizations to impact minority youth and increase their interest in engineering. We also provide student- and coach-level data on ways participation impacted participants in our initiative.

FIRST® LEGO® League (FLL®)

FLL is an international robotics and research competition operated by For Inspiration and Recognition of Science and Technology (FIRST), a non-profit organization that serves K-12 students. The mission of FLL is to engage students ages 9-14 (ages 9-16 internationally) in an annual, theme-based robotics and research challenge. Each year the organization releases a new themed challenge for teams of up to ten students, which requires students to research, design, and present results of their work to the community and panels of judges. In 2011, FLL programs served nearly 205,000 students in over 60 countries and provinces world-wide[11]. The format of the program challenges students to complete a research project, with possible prototyping; compete in an autonomous LEGO® robot game that focuses on demonstrating the robot's design and function; and demonstrate the teamwork of their group and their understanding of the character (core) values of the FLL program. All activities must be completed in a constrained timeframe.

Teams are required to participate in all four aspects of the challenge, which include research project, robot design, robot performance, and core values (team dynamics) to be considered for any recognition during the tournament events. The program is not about just building a robot, it is directed toward raising socially conscientious, engineering-minded youth that value each other's differences and realize that one's strength is found when partnered with others to achieve a common goal. For the research project, students are challenged to investigate the theme for that year and identify a particular aspect for further work. For the 2012 year, the theme was *Senior Solutions*, which required teams to interview a local senior citizen, identify a struggle in the senior's everyday life, and then create a solution that could impact that individual. Previous years' themes were *Climate Concerns*, *Smart Transportation*, and *Biomechanical Advancement*. In addition to the research project, teams must design, assemble, and program an autonomous LEGO robot that can complete a variety of tasks in a 2.5 minute round. Teams also present their design to judges, communicating their decision process and spotlighting any unique capabilities of their design, regardless of whether they work. The final evaluation centers on the function of the team. During judging, teams are asked to share how they worked together to complete all aspects of the competition and to validate that students completed work with adult mentors providing only guidance. Competition awards are given in areas such as programming, mechanical design, and innovation and strategy (subcategories of the Robot Design category) and other areas in the remaining two components of the challenge. In addition, the best overall team receives the Champion's Award.

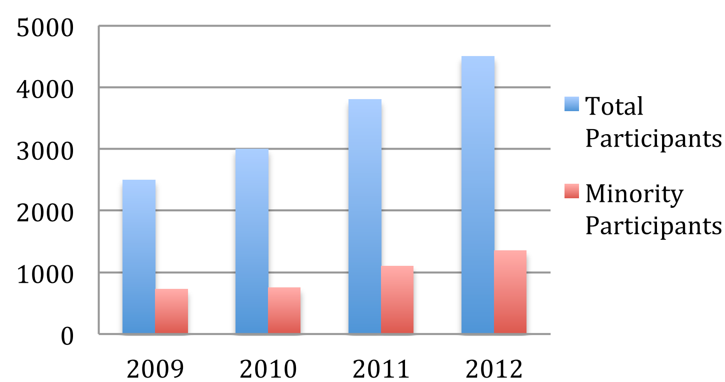
The FLL schedule constrains the time in which teams can operate by releasing information at particular times of the year and restricting the completion date of state tournaments to allow for notification of participation in the international championships, known as the World Festival. Teams can register and receive the robot building kit as early as May the year of competition, and many use the time between registration and game release to conduct training for their students. In early August, registered teams receive the field elements and build instructions, but they are only able to make conjectures on how the items are scored. In early September, once the required materials begin to ship, the game challenge and research topic are released, and then teams begin preparing for the competition season. All regions offer a variety of tournament sequences. Small regions may have only a single championship event, while others may begin with qualifying tournaments. In Georgia, a three-tiered tournament system is used, which starts in December with qualifying events and concludes with the State Championship in late January. During this time teams compete in only one qualifying tournament with the top 30% overall advancing to the Super-Regional level, with 25% of these teams advancing to the State Championship.

History of Minority Participation

The FLL program in Georgia, managed by Georgia Institute of Technology's Center for Education Integrating Science, Mathematics, and Computing (CEISMC) & Electrical and Computer Engineering began competition in 2002 with only 100 participants and has grown to over 3500 students participating in 2012. During this ten-year period, the number of minority participants has increased at a rate greater than that of other states' programs. Minority participation is recorded as African-American and Hispanic participants only, as other groups seen as minority in the national studies are locally perceived as attracted to engineering and robotics.

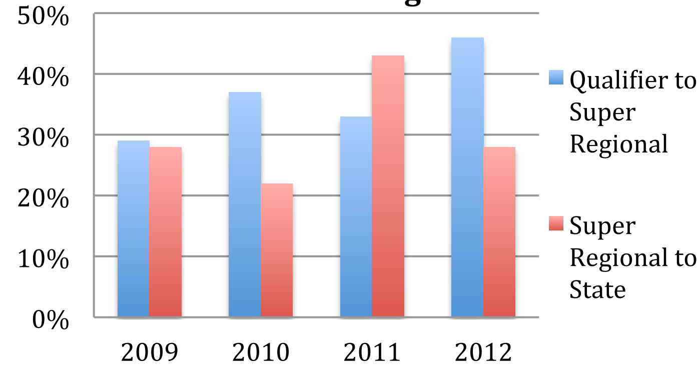
Each team's coach enters team demographic information, and the number of entries equals about 70% of the teams in the competition. Thus, not all teams report demographic data. Based on the demographic data available for 2009, FLL minority participation was reported nationally as 11.4%, which was a 3.2% increase from the earlier study conducted in 2003.[12]

Figure 1
Total vs. Minority Participation



During the 2009 season Georgia Tech's CEISMC began an effort to directly impact the opportunity and availability of FLL in underrepresented communities. With this effort in place, Figure 1 shows the minority participation in 2009 was 29%, with total participation at nearly 2500 students. This year, 2012-13 minority participation has reached 30%, which is equal to the percentage of female participation in Georgia, while the total participation has neared 4500 participants. The other impact from this effort is the number of minority students that advance through the FLL tournament system. In 2009, 29% of the minority participants that competed in qualifying competitions advanced to the second round, and of those participants 28% advanced to the third round (State Championship) as illustrated in Figure 2. Prior to this effort, only 16% of minority participants advanced to a second competition, whereas this year 46% have advanced to the second round of competition. The total percentage of minority participants is slowly increasing; however the percentage of minority participants that are advancing is increasing at a greater rate. The figures show that even with the overall growth of the program, the strength of the minority initiative is producing positive impact on the FLL system. In this paper we describe our initiative and its results on participants. We also provide our model for others who wish to implement similar programs.

Figure 2
Percentage of Minority participants advancing



Actions to Increase Minority Participation

Prior to the 2009 FLL tournament season, CEISMC received a grant to provide opportunities and resources to minority programs interested in FLL participation. Through this grant and an association with local school districts and the local chapter of the *100 Black Men* organization, the current initiative began. During our first year, groups were identified as targeted sites for participation, and invitations were sent to the sites with details of the program and the requirement for participation. Invited sites included local minority public schools and youth organizations, many of which have some affiliation with *100 Black Men*. With additional assistance from a few school districts, we were able to support 14 programs. The goal for the project is to promote active participation in FLL, as well as sustainability, at the selected sites. As of 2012, every site that has been funded since 2009 maintains at least one active team. There are a few sites that have decided to make FLL an institutional effort, and these sites field between 6 and 12 active teams.

Funded teams in our initiative receive competition materials (which include an FLL Robot Kit and a field challenge set) and approximately $1000 to pay fees for national registration and all local competitions. To receive funding, teachers/coaches and their student teams are required to attend a one-day training workshop to acquire knowledge on the LEGO materials, the research project, and the judged presentation expectations. This workshop is divided into four one-hour sessions and a time for the teams to begin brainstorming and designing their robot and strategy.

The State Operational Partner prepares local high school or college students that have experience with the FLL program and the materials to teach the sessions. The four sessions cover basic building principles with the LEGO robot kit; programming including the use of sensors, mission strategy; and scoring. The final session addresses the judging system and research project. Throughout the workshop, the importance of all aspects of the program is emphasized to the teams, as well-rounded teams that completed all areas of the competition are advanced to the next level. The other contributing factor in making this type of an initiative a success is the assignment of teams to tournament locations using a system that ranks the teams. All teams in the initiative compete at the same qualifying event; any additional teams needed to fill the event must have a similar rank as those at the event. A complete power ranking system[13] is used to determine the potential of a team and to help level the competition so the students participating see many similar faces and levels of competitive designs.

Data Collection and Results

In this study, our goal was to collect pre- and post-surveys from all students on 13 teams in the region as well as their coaches. We developed two brief surveys for students and one survey for coaches. The student pre-survey was completed at the beginning of the competition season, and the student post-survey was completed at the qualifying competition. On the pre-survey, we asked students to complete three Likert scale items. Two focused on how much students liked math and science, and the third focused on student interest in becoming a scientist or engineer. A 4-point scale was used for these items (e.g., 1=I really don't like science; 2=I don't like science; 3=I like science a little; 4=I like science a lot). The pre-survey also included demographic items (gender, age, grade, race) as well as three open-ended questions. One question was about the reasons the student joined FLL, the second was about what students thought would be best about being on the FLL team, and the third focused on what students wanted to be when they grow up.

On the post-survey, students answered the same three Likert items from the pre-test. Students were also asked about the kinds of activities they participated in on their FLL team. The post-survey included five open-ended questions. Students were asked what they had learned from being in FLL, what ways (if any) they had changed because of FLL, what they liked most about FLL, and what they would change about FLL. Students also answered a question, which was identical to the pre-survey question, about what they wanted to be when they grew up. Coaches completed a survey at the end of the competition year. The survey included five open-ended questions related to coaches' perceptions of students' participation in FLL as well as demographic items including gender, ethnicity, and number of years as an FLL coach.

The student population included 84 students from 13 teams. The minority participation on these teams is 90% African-American and 10% Hispanic. Approximately 90% of participating students are from low-income households. Due to challenges obtaining parental consent and student assent to participate in this study, useable data were collected from 21 students (25% of the population) representing 5 teams or schools. Participants were in grades 3-8, but the majority of participants (61.9%) were in seventh or eighth grade. There was one third grade participant and two participants each from grades 4, 5, and 6. The average age of study participants was 11.38, and the median age was 12. Most participants were boys (61.9%). All participating girls but one was in either seventh or eighth grade. Sixteen students (76.2%) were African-American, one was Caucasian, two were multi-racial, and two listed their race as "other" (one listed himself as African, and the other listed himself as Portuguese). Six students (28.6%) said they had been on a previous FLL team, but the remaining students were in their first year of participation. When asked on the post-survey about the FLL activities they had participated in during the competition season in, 20 students (95.2%) said research, 19 (90.5%) building robots, 17 (81.9%) said programming, and 11 (52.3%) said making formal presentations.

Six FLL coaches completed surveys, representing 60% of the total number of coaches (n=10). All coaches were male, and five were African-American. The remaining coach was Asian. Four coaches were in their first year with FLL. The other two coaches had 5 and 10 years' coaching experience each. Three coaches were from elementary schools, two were from middle schools, and one was from a K-8 public charter school that has a STEAM (science, technology, engineering, arts, math) emphasis.

Reasons Students Joined FLL

Twenty of the 21 student participants responded to the open-ended question about why they joined FLL. The two youngest students (both 8 years old) said they joined because they thought it would be fun. Five students (23.8%)—3 males and 2 females—provided an answer related to their interest in robotics. An eighth grade female student wrote, "I considered it because I love robots and I was interested in the engineering and mechanics of robots." Four students—3 boys and 1 girl—also wrote responses related to their interest in building. A male seventh grade student joined "Because I love building things and love the idea of being creative and innovative to solve a problem." Two fifth grade and one sixth grade student said they joined FLL because they liked LEGO bricks. This group included one girl, who explained, "I like playing with LEGO so being in a club for it and being in a group is even better." Three other responses related to teachers, with one eighth grade girl explaining that "My teacher inspired me to [join] through science." One student said he joined to have something to put on his transcript, and a second wrote, "I always planned on being in the technology field, so I thought this was a good way to start."

Pre/Post Differences

We used paired sample t-tests to examine pre/post differences in students' interest in science, math, and future science or engineering careers. Because our sample size was small (n=22), large pre-post differences were necessary to find statistical significance, so we have also reported standardized effect sizes, using Cohen's *d* as a measure of effect. With Cohen's *d*, standardized effect sizes are described in standard deviation units, which explain the magnitude of difference between scores. An effect of .2 is considered small, .5 is considered moderate, and .8 is considered large.[14]

Although there were no statistically significant differences between pre- and post-measures of students' math interest, science interest, or desire to go into a science or engineering field, there were small, positive changes in each area, as illustrated in Table 1. The largest effect size was for math interest. As indicated in Table 1, students' interest in math, science, and science/

engineering careers was fairly high on both pre- and post-surveys. A mean of 3.5 on the science interest question, for example, indicates a response between "I really like it a lot" and "I like it."

Table 1. Comparisons of Students' Interest in Math, Science, and STEM Careers

	Mean	N	SD	diff	t	df	Sig	SES†
Science Interest								
Pre Science Interest	3.81	21	.402	0.05	0.568	20	.576	0.13
Post Science Interest	3.86		.359					
Math Interest								
Pre Math Interest	3.52	21	.602	0.10	1.00	20	.329	0.22
Post Math Interest	3.62		.669					
Interest in Sci./ Eng. Career								
Pre Career Interest	3.24	21	1.091	0.190	0.847	20	.407	0.18
Post Career Interest	3.43		.870					

† Standardized effect size (Cohen's *d*)

To analyze the results further, we re-ran our analyses separately for boys and girls, which revealed that for girls there was a greater effect in science interest and interest in a science or engineering career, and for boys there was a greater effect in math interest. In fact, for boys, there was no difference between pre- and post-survey responses for science interest or science/engineering career interest. There was, however, a 0.154 mean difference (on a 1 to 4 scale) in math interest, and the effect size was 0.41. For girls, the result was reversed. Though there was no pre-post math interest difference for girls, there was a 0.125-point difference in science interest (Cohen's $d = 0.35$) and a 0.5-point difference ($d = 0.33$) in science/ engineering career interest (see Table 2).

Table 2. Pre-Post Differences in Math, Science, and Career Interest, by Gender

		Mean	N	SD	diff	t	df	Sig	SES
Boys									
Science Interest	Pre	3.77	13	.439	0	.000	12	1.00	0
	Post	3.77		.439					
Math Interest	Pre	3.46	13	.660	0.16	1.47	12	.165	0.41
	Post	3.62		.650					
Science/Engineering Career Interest	Pre	3.38	13	.961	0	.000	12	1.00	0
	Post	3.38		.961					
Girls									
Science Interest	Pre	3.88	8	.354	0.12	1.00	7	.351	0.35
	Post	4.00		.000					
Math Interest	Pre	3.63	8	.518	0	.000	7	1.00	0
	Post	3.63		.744					
Science/Engineering Career Interest	Pre	3.00	8	1.31	0.50	.935	7	.381	0.33
	Post	3.50		.756					

Open-ended survey responses provide additional information about changes in students' interests. One 8th grade girl, for example, explained that "all the programming and building [in FLL] helped her reach [her] goal" of becoming a computer engineer. When asked how participation in FLL changed them, if at all, all but three students said FLL had changed them in positive ways. Two students provided responses related to academics. One student wrote that FLL "teaches you to be a better student," and another explained, "I have changed in many ways, but for the most part I have changed in my dedication. Now I am more dedicated and ready to learn."

By far, the most common response about changes due to FLL participation focused on students learning to work with others. Seven (4 boys, 3 girls) of the 18 students (38.8%) who said FLL had changed them provided a response related to teamwork or working in groups. An eighth grade male student, for example, wrote, "I believe that FLL has changed me as a person as a whole my personality has expanded and I'm more eager to work and learn in groups." Twelve students (57.1%) also wrote about teamwork in response to the question about what they had learned by being in FLL. These comments included: "That working as a team can be better sometimes to fix a problem" and "I learned that you need to create a compromise whenever there is a problem among people."

Other typical comments included, "It changed how I worked with others" and "I've learned to work together as a team." Another student wrote, "I have gained patience and tolerance from FLL, which I use in daily life through interaction with people."

Comments about what students learned from FLL also included:

- "Robots can improve people's everyday lives."
- "I learned that cooperation is important because that is the only way to go about the competition. I also learned how to have fun."
- "How to show my inner inspirations of building and engineering."
- "How to work with others on hard tasks and how to have fun with my friends in a different way."

When asked what they liked best about FLL, the most popular responses were programming (19.0%), working with teammates (14.3%), the challenge (14.3%), building (14.3%), and participating in the competition (14.3%). About the challenge-based competition, a female eighth grade student wrote, "I like the theme of the challenges and [that] they want us to make innovative solutions to real life problems." A male eighth grader wrote, "Being in FLL not only allows me to communicate with my peers but lets us learn in the process of doing so." A female eighth grader who was in her third year in FLL stated, "I enjoy the research projects that FLL comes up with[;] they are always interesting and fun to do."

When asked what they would change about the competition, 8 students (38.1%) said they wouldn't change a thing. Comments included, "I wouldn't change a thing because it poses just the right challenge I am looking for" and "The whole program is perfect as it is. I hope many people will join as I plan to do so also." For those students who did suggest changes, 9 comments related to technical aspects of the competition such as how much time teams have on the field or how much time occurs between competitions.

Coaches' Responses

All six coaches who responded to the survey at the end of the competition year had positive comments about FLL and/or the initiative described in this paper. When asked to rank the top three benefits for students competing in FLL, four of the six coaches (67%) listed teamwork as one of the top benefits of the FLL experience. Four coaches also listed exposure to robotics and/or STEM as a benefit.

When asked to describe ways their students changed or grew as a result of being in FLL, two coaches wrote about some aspect of teamwork. One coach explained that his students were able to "assist others and are able to work better in teams in solving problems" and another wrote, "Students began the process not understanding the order required for a lab to function properly, [but within] a short period they learned how to divide the project into smaller parts, delegate duties and still work towards a common goal."

Two other responses related to the empowerment students felt as a result of their participation in FLL. A middle school coach in his first year of coaching explained, "My students became superstars around their neighborhood and school district because we were the first school in [our district] to ever participate in FLL. This gave my students a lot of confidence in [wanting] to learn about robotics." Another coach described the impact on team members at his elementary school. He wrote

> *Since our engagement in FLL I have seen an increase in Science Fair participation. Students are seriously considering pursuing STEM careers in grades as low as 2nd. Minority students that may have doubted their ability to complete challenging task feel empowered to accomplish anything.*

We also asked coaches to describe the particular aspects of FLL that lead to the changes witnessed in students. Three comments centered on the structural features or expectations of FLL such as the mentoring students receive, the focus on gracious professionalism, or the problem-solving nature of the competition. As a mentor explained, "The collaboration and gracious professionalism mentality establish by FLL allows students to build confidence and learn from each other as they work to exceed expectations and self doubt." Another coach described the impact of the "cool factor" of robotics, stating

> *From what I witnessed it made robotic[s] cool. I mean being on the robotic team became more popular [than] being on the football or basketball team. I had students who came to me everyday asking can they be on the robotics team. So just the buzz that FLL created around our school was worth [it] because it got a lot of students interest[ed] who normally could care less.*

When we asked coaches to describe the barriers that existed for students to be to take part in FLL, three of the six respondents provided answers related to cost. For example, one coach stated,

> *Our major barrier is finances. The entry fee and robot are both expensive and our school [doesn't] have that much funds to spend on something extra like robotics. Therefore we were very blessed when [this] opportunity came along because it was the only way we got involved with FLL.*

On another part of the survey, this same coach wrote about the lack of STEM exposure in typical inner city schools, explaining,

> *I think FLL is doing a great job!! It's just inner city schools need much exposure and it's not that they don't care but they have not been exposed and [there's a] financial barrier. Thanks to you all we were able to get out [there], and it has ignited interest in a field that otherwise students would have never been interested in.*

Along these same lines, another coach wrote, "I work in an economically challenged school, resources for transportation and other expenses is a huge barrier." Other barriers were the challenge of students being able to participate on Saturdays and having too few elementary school level competitors. Another coach's response focused on adult support. He stated, "Having consistent adult support is our greatest barrier. We would like to expand our program to 100 students however, we lack the support needed to meet this mark."

On the final survey question, we asked coaches what else we should know about FLL. There was wide variation in coaches' responses, with some coaches providing accolades for the program and others offering suggestions or insights based on experience in the program. One coach wanted to know more about hosting a competition at his school and another described the effect of FLL participation, stating "FLL is a great platform for students to see themselves performing in an academic arena that initially was intimidating but has become a attainable goal." One other coach wrote that FLL "needs more exposure to minority students."

Conclusions and Future Directions

Results of this study indicated that FLL participants had a positive experience in the competition and benefited from the competition. Students learned how to work with teammates and cooperate to solve challenges. Their responses were overwhelmingly positive about their experiences in FLL, and pre-post comparisons reveal small gains in students' interest in science, math, and science/engineering careers. Feedback from coaches was also positive, indicating that students benefited from FLL participation by learning to work in teams and being exposed to robotics and STEM. Coaches described the confidence and empowerment students gained through FLL. These positive outcomes can be hampered by the challenges coaches and teams face in their high minority inner-city schools, which include funding issues and lack of sufficient personnel to field additional teams.

It should be noted that this study is limited due to the very small sample size. This year, as in past years, one barrier we have faced in our research is obtaining parental consent for students to participate in the study, which greatly reduces the number of participants. Further, it may be that those students who do return consents and assents are not representative of the larger population of students on our regional teams. For this reason we are cautious in our interpretations of results.

Even with limited respondents, our results warrant the continuation of initiatives to increase minority participation in program such as FLL. As we look forward, the management of expansion is critical to the continued success of the initiative and minority growth. This model is being used for other efforts that will focus on Hispanic students in the coming year and with continued funding the current initiative will invite new sites to the program. The management of new teams will require additional mandates to assure participation and data collection to allow for broader, more generalizable results.

Expanding the Model to Other Locations

This model has the ability to expand to any area of the country, though replication does require an advocate for the project and obtaining some level of financial support. The FLL program is established in most areas of the country with infrastructure in place for teams to compete, but to increase minority participation, it is necessary to provide initial training to coaches and students as well as support these teams financially. The financial need is approximately $1000 per targeted team. This total includes all materials and registrations (based on our state's tournament entry fees of $50 per event) and covers a percentage of the costs to conduct the training workshop based on our model. As for the competition structure, the state partner arranges the system and the decisions tend to be based on total team participation. As the state sees more team entries, a growth model to manage the numbers is already established through FLL. If the participation does not demand a multi-level structure, a valuable plan for such an initiative is to offer a pre-event scrimmage that allows teams to test their designs and learn from others. In most states, this starts with a single Championship event, and as growth occurs additional levels of competition are implemented to help manage advancement to the Championship event. This model was designed for locations where two levels of competition are required to provide secured advancement opportunities for the minority initiative teams.

For others interested in starting minority initiatives in competitions such as FLL, we offer these guidelines for successful implementation:

1. Locate and Communicate with potential funding sources
    - 1.1. Local businesses
    - 1.2. Local foundations
    - 1.3. Part of a large grant proposal
        - 1.3.1. Community proposals
        - 1.3.2. University proposals
2. Communicate with the local FLL Operational Partner
    - 2.1. www.usfirst.org/regional-contacts
    - 2.2. Determine competition structure in state

    2.3. Dates for competitions
    2.4. Share details and intended outcomes
3. Identify local partners to recruit and secure teams
    3.1. Schools systems
    3.2. Minority Youth Organization
    3.3. Minority Serving Community Centers
4. Conduct informational meeting with targeted sites
    4.1. Identify coach/teacher
    4.2. Requirements to participate in initiative
        4.2.1. Attend workshop
        4.2.2. Attend scrimmage
        4.2.3. Attend competition
    4.3. Secure commitments from sites
5. Secure resources
    5.1. National FLL registration
    5.2. LEGO Robot Kit
    5.3. FLL Field Challenge set
    5.4. Field Tables 1/site
6. Workshop
    6.1. Secure convenient location of workshop
        6.1.1. Minimum 4 classroom spaces
        6.1.2. Large group gathering area
    6.2. May offer additional mentoring days during the season
7. Scrimmage
    7.1. Use a participating school
8. Attend the competition

In conclusion, when STEM initiatives to attract and retain minority participants are enacted, positive outcomes are possible. The effort to introduce minority students to engineering and robotics is important to sparking the students' interest. Many minority students lack the resources to participate in these types of programs, and by making them available, students are exposed to STEM in a new way, allowing them the opportunity to grow in areas they might not have known would be interesting to them. The key is to make the program available to the students with a solid role model support chain and set the stage for success regardless of their experience.

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