Middle School Robotics at WPI

An Interactive Qualifying Project

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by

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I. Abstract

This goal of this project was to determine the efficacy of a competitive robotics program in engaging underserved middle school students in the Worcester community in science, technology, engineering, and math (STEM). Experts in STEM education, pre-collegiate outreach, minors' protection, and related fields were interviewed to make an educated comparison tailored to the needs of the local underserved youth. Finally, a proposal was created for Worcester Polytechnic Institute (WPI) outlining the organization and maintaining of a competitive robotics team for these students.

II. Acknowledgements

We would be remiss without acknowledging and thanking the many people who made this Interactive Qualifying Project possible. Firstly, we would like to thank all interview subjects for their invaluable insight and experience and their willingness to share it with us. We would like to thank Francis O'Rourke for his input and assistance for the duration of the project. And finally, we would like to thank our advisor Colleen Shaver for her guidance and patience throughout the project.

III. Executive Summary

In this project, we proposed a competitive middle school robotics team to help increase interest in science, technology, engineering, and math (STEM) in the local underserved population. Robotics programs have been shown in the past to successfully increase interest in STEM. Accordingly, a main challenge for this project was to design a program that works specifically with underserved students. Unique considerations when dealing with the underserved must be made, most notably possible language barriers, cultural barriers revolving around the unapproachability of robotics, and the high fiscal cost of robotics. Another consideration that must be made is what if any parent organization the robotics team should have. Because of the prior work with WPI as well as the high quality of the programs, starting either FIRST LEGO League (FLL) or VEX IQ teams would be the best option for this new program. A major decision in this project was to determine which of these two programs we would choose for our teams to compete in.

The first step of our project was to fill in knowledge gaps specific to the potential program. WPI has much experience running various STEM programs with underserved youth, so interviews were conducted with staff in the Massachusetts Academy of Math and Science, Office of Pre-Collegiate Outreach Programs, STEM Education Center, and WPI's General Counsel. These interviews provided enormous insight into how a minors program needs to be run on campus, as well as how to work with the underserved effectively. We conducted additional interviews outside of WPI faculty to broaden our knowledge base before making any decisions and give us a better understanding about the functional differences between FLL and VEX IQ. We interviewed Donata Martin of the Leominster Boys and Girls Club, and Andrew Lawrence, a volunteer working with children to teach robotics. Since both interviewees had experience with both FLL and VEX IQ, important differences were determined for our consideration in the next step of our project.

With the knowledge gained from the interviews, we had enough information to assemble a list of criteria for choosing to compete in the FLL or VEX IQ competitions. The first criteria we chose was affordability. Cost is a major hurdle for the underserved, so the competition we choose needs to be as affordable for them as possible. The next criteria we chose was difficulty. This criterion is our way of quantifying how difficult it is for a rookie underserved team to build, program, and compete with a successful robot. We want our students to be having as much fun as possible and easily having a competitive robot is a way to accomplish this. In addition to cost of the programs, we also had a criterion for the location of the competitions. Travel expenses can be too much for the underserved, so the competitions for the chosen program need to be as local as possible. We want the students to continue exploring robotics after our program, so we created a criterion for available progression for the participants after middle school. Ideally, the next level of each program is available locally so that the participant students may continue to be involved upon graduating middle school. Our final criterion was for analyzing the additional components of each program. FLL and VEX IQ each have non-robotics components to their competitions. We want to choose the program that has the most appropriate non-robotics program for our needs, which is the least distracting one from robotics.

We then used the criteria to determine that VEX IQ is the better competition for the potential program. VEX IQ is slightly more affordable, but we recognize that WPI or an external sponsor needs to pay for the program, as the underserved families simply cannot be expected to pay. The VEX IQ platform and competition also is less difficult to produce a successful robot for, relative to FLL. VEX IQ and FLL each have competitions already run on the WPI campus, which is as close as reasonably possible for a competition to be for the underserved students. Both FLL and VEX IQ have excellent progression available for the future participants after middle school, as competitive high school teams for both organizations exist locally. Another major advantage of VEX IQ is the Engineering Notebook, something we found much better-suited for our use case. The Engineering Notebook is somewhat of an extension of the engineering design process, a skill we wished to teach, whereas the FLL project component feels off-topic. Overall, VEX IQ was decidedly the better parent organization for the future teams to compete in.

As the final step of our project, we produced a proposal outlining the essential details of running a successful competitive middle school robotics team for the underserved, with the goal of increasing their interest in STEM. This proposal encompasses all aspects of operating a program, from background checks to the sizes of teams, and all other requisite information.

Hours of interviews were conducted within the WPI community and with experienced professionals working with similar programs. We then used the information in these interviews to make important decisions about this potential program, including that the teams will be VEX IQ teams, not FLL. Finally, we crafted a proposal that completely and succinctly describes the important details of starting the potential program for real-world use.

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3 Introduction

Science, technology, engineering, and math, colloquially referred to as STEM, has been identified as a cornerstone of educational policy in the 21st century. Using concepts related to STEM, students are encouraged and instructed in principles of engineering as early as elementary and middle school. While many different types of classroom curriculum have been developed with the goal of teaching STEM at a young age, many programs have been created that allow a more in-depth STEM experience with some or all the instruction taking place outside of the conventional classroom.

Providing adequate education in science, technology, and engineering fields has been a goal of the American education system since the 1950's (Peters-Burton, 2018). Recently, the National Research Council and the President's Council of Advisors on Science and Technology have called for more STEM education to students at all levels (Peters-Burton, 2018). This goal for increased STEM education comes from modern society's demand for innovation. With the constant creation of new jobs in STEM fields, in 10 years when current middle school students have become adults, there will still be a high demand for employees in STEM fields.

Worcester Polytechnic Institute (WPI) has a mission of creating, discovering, and conveying knowledge at the frontiers of technological academic inquiry for the betterment of society (Worcester Polytechnic Institute, 2021). In alignment with these goals, WPI participates in various forms of outreach to share experiences in STEM with younger students. Presently, WPI supports many different activities for outreach to the middle-school demographic. However, most WPI outreach programs are limited in duration and in time of year – for example, many programs manifest themselves as week-long experiences or single-day events. Thus, there is an opportunity for a program to be designed with a longer duration for younger students to participate in.

The goal of this IQP was to propose a plan for running a competitive robotics program for underserved students in the local community. This proposal needed to address the unique needs of the underserved and the low attention span of middle school-aged children, while also providing an educational and fun robotics atmosphere for the students. The program would be hosted and sponsored by WPI, but the parent organization of the robotics program needed to be determined.

The development of a proposal primarily focused on exploration through interviews; a variety of experts in the fields and departments relating to the proposed program were interviewed for their insight into the running of a competitive middle school robotics program. This included WPI staff, volunteers in other robotics programs, and professionals in childhood development. Analysis was done with these interviews to form the proposal.

4 Background

STEM has historically been a field dominated by people who are white, male, or middle/upper income. This is being perpetuated by the universities that are still serving these over-served populations. Looking at WPI for instance, in 2018, 790 of the 1276 newly admitted WPI undergraduates were Caucasian (Office of Institutional Research, 2019). When looking at WPI's admissions statistics, improvement can be made to increase interest in STEM within underserved groups. It has been agreed upon by the educator community that early childhood STEM education is useful for fostering an interest in STEM for the long term (MacDonald, Huser, Sikder, & Danala, 2019). When comparing WPI's undergraduate admission demographics to the population of young students that have access to STEM activities, it is found that WPI has a substantially lower population of minority and low-income students than the national average. Low-income students make up the smallest population of students who visit informal science education centers, like science museums and planetariums (Godec, Archer, & Dawson, 2020). This same population also has less access to other common STEM activities appropriate for their age group, such as summer camps and clubs. In this paper, we define the underserved population as those not typically attending WPI: students who are not white, male, and/or below the average income level for the Worcester area.

To adequately serve the underserved in a STEM program, special considerations must be made. Linguistic barriers may exist, so proper handling through translators or contextual clues are a necessity (Harrison, Hurd, & Brinegar, 2020). While these linguistic barriers are important, one of the biggest hurdles for the underserved when considering joining a robotics program is cost to the individual (Dias, 2007). Robotics programs, such as the FIRST Robotics Competition, can cost thousands of dollars per team. As such, financial support may also be necessary, as students may be unable to pay for supplies, transportation, or food. Another consideration that must be made is skill level, which should be considered regardless of income. Every student in a given program may have a different amount of experience with other programs or may have never attended another program before, so this should be accounted for in the design of the program. Finally, there may be a fear of technology or cultural bias against robotics that is unique to the underserved. It is recommended to provide some sort of local relevance to robotics to make this topic seem more approachable to the underserved (Dias, 2007).

4.1 Working with Children

Working with children brings unique challenges. First, children have relatively low attention spans. To adjust for this, frequent breaks must be implemented. These breaks can include play time, snack, or other fun activities (Howard, 2013). By incorporating activities, children can learn better, as they associate fun with the topic they are learning. As Howard puts it, play is “unique and extraordinarily valuable for children’s development.” (Howard, 2013) By using breaks, children can gain confidence, allowing for them to try new things when they come back to a learning environment after their break.

Playfulness, whether in a separate activity or in a learning space, substantially helps children's development.

In addition to frequent breaks, children require special considerations when working together with others to comprise a team. Care must be taken to encourage growth in the children's teamwork skills. At this age, children often have minimal experience working in a team, and may struggle to collaborate well (Melchior, Burack, & Hoover, 2018). Providing students with opportunities to try all facets of the team is important to encouraging teamwork. Additionally, if there are multiple separate teams, collaboration between teams should be encouraged so that the students have exposure to varying approaches to solving a common problem.

4.2 Robotics Extracurricular

A popular method of engaging students in STEM outside of school are clubs. One type of STEM-related club is an after-school robotics program. Robotics programs are an effective method of increasing interest in STEM in K-12 students (Melchior, Burack, & Hoover, 2018). There are two typical approaches to creating a robotics program: creating a team to participate in an existing organization or developing an independent program. Existing organizations popular with middle school students are VEX IQ and FIRST LEGO League (FLL). Both organizations are popular due to their focus on developing both the children's STEM skills and their social skills, such as confidence and teamwork (FIRST, n.d.) These programs also have robust and developed child protection policies. These two existing organizations also have a pipeline for teams to excel, from local qualifiers all the way to a world championship. Additionally, programs also have extensive documentation on the hardware and software used by participant teams. Hardware is required to be purchased and used for each program, but this is required to compete and participate.

Creating an independent program allows for a tailored lesson plan and freedom to set custom deadlines. Child protection policies would need to be developed, as well as a robust lesson plan. Hardware would need to be purchased independently, and software would need to be acquired or purchased depending on the hardware. With an independent program, the only form of competition would have to be between the students in the program, instead of students from other teams in the larger organization.

4.3 Robotics Programs at WPI

Worcester Polytechnic Institute formerly ran a non-competitive robotics program called Robokids for students in local middle schools (Ochoa & Buchanan, 2013). This program was designed to have underserved students experience robotics in a fun and safe environment. Unfortunately, the host organization no longer supports Robokids, and the club has now transformed into a general STEM activity club that offers a robotics component rather than a completely robotics-focused program. This leaves a gap for students in the local underserved population that could have an interest in robotics.

Figure 1: A VEX robotics competition held in WPI's Harrington Auditorium.

There are two different types of robotics programs: competitive and non-competitive. Competitive robotics programs are orchestrated by organizing bodies that publish a specific "game" and run competitions that teams can attend to showcase their robots. WPI has a very successful track record for running competitive robotics teams for K-12 students, specifically with high-school students in the FIRST Robotics Competition. WPI also hosts several large robotics competitions for middle-school students including a variety of competitions for each type of program. Due to the partial failure of Robokids, a non-competitive organization, and WPI's frequent hosting of middle school robotics competitions on campus, hosting a competitive robotics team for underserved middle school students in the local community is the ideal choice.

Figure 2: A student and a mentor from the campus FIRST Robotics Competition Team 190 work on parts for a robot.

WPI has several other robotics programs for minors. There is a VEX IQ team for middle school girls. This team is run by the Office of Pre-Collegiate Outreach Programs (POP) and excludes any males from participating. It also is not specifically targeting the underserved. There is also a FIRST Robotics Competition (FRC) team on campus, but it is only for high school students.

WPI hosts several middle school robotics competitions on campus. The VEX IQ regional qualifier, the lowest tier VEX IQ competition, is hosted by WPI. There are FLL qualifying tournaments hosted on campus, and the FLL state championship, the last competition before the national competition, is hosted by WPI. It is worth mentioning that every VEX IQ team must compete in a regional qualifier, but most FLL teams do not reach a district championship.

4.4 Divergence in Programs

There are two primary competitive robotics programs aimed at middle-school students. One is FIRST LEGO League, administered by *For Inspiration and Recognition of Science and Technology (FIRST)*, a New Hampshire-based non-profit (FIRST, n.d.). The other is the VEX IQ Challenge, administered by the *Robotics Education And Competition Foundation (RECF)*, a Texas-based non-profit (REC Foundation, n.d.).

Both programs are similar in the construction of the robots. Each competition outlines a specific set of parts for the teams to use in constructing their robots. The robots can be assembled without tools, using simple parts that snap together, so construction is quick, and the robots can be easily modified if desired. Programming the actions of the robot is graphically based, so no experience is required, and students may easily create a program that completes the desired tasks. Each individual team needs a robot "kit". These contain all the various electronic and physical elements required to construct the robot and make it operational. While the contents of the kits vary with each program, they are generally similar regarding what sorts of things can be constructed using them.

4.4.1 FIRST LEGO League

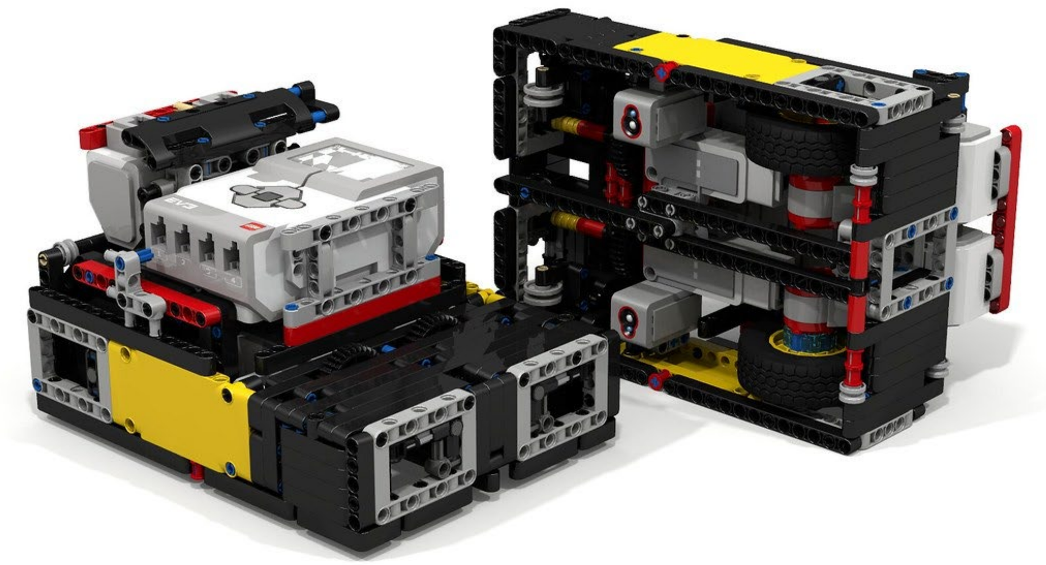

Figure 3: A FIRST LEGO League robot.

In FIRST LEGO League (FLL), teams compete directly against other teams for a 2.5-minute match where their robots must complete as many missions as possible in the allotted time. While not sharing the same field, there are two fields with identical missions placed adjoining to one another. There is also a shared mission between the two fields that is mutually beneficial for both competing teams to complete. Teams are awarded points for completing missions at a satisfactory level, and a winner is ascertained based on the total points. Notably, the entire robot match is autonomous - I.e., the robot is programmed by the students and completes its missions with no human input besides the team members selecting which program to run. Programming for FIRST LEGO League robots is conducted using a Windows computer and a software application that runs locally on the machine, or an application running on an Android or Apple iOS tablet.

In addition to this actual gameplay, teams are judged on additional merits. Integrated with the robot gameplay missions is a central theme about a societal issue affecting the world at present. Each team develops a project related to the theme of the year's competition and presents it to a judging panel. Additionally, the teams are judged on "Core Values", a measure of how the team members treat each other and their fellow competitors. (FIRST, 2020) All three aspects of the competition (robot, project, and core values) influence a team's performance and provide for a well-rounded competition experience.

4.4.2 VEX IQ Challenge

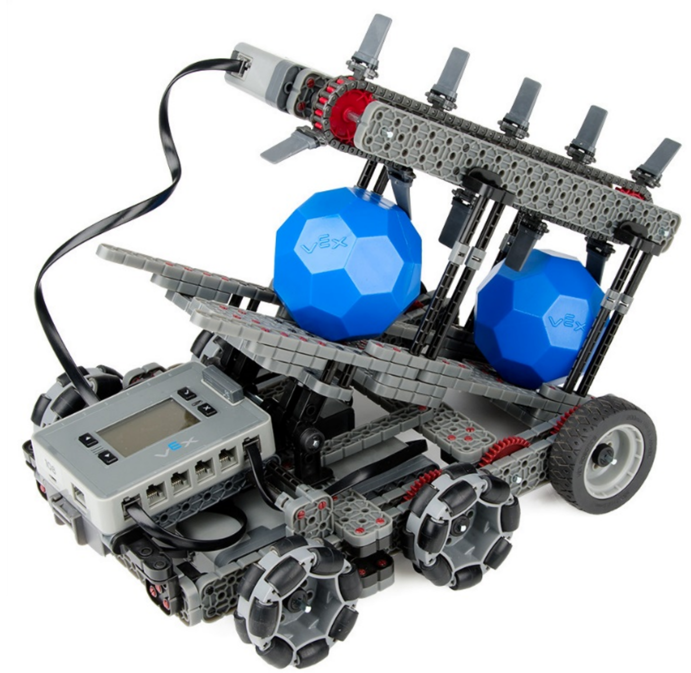

Figure 4: A VEX IQ Challenge robot.

The VEX IQ Challenge (VEX IQ) consists primarily of a "Teamwork Challenge" where two teams are partnered together in an alliance. The two teams work collaboratively to score as many points as possible by completing different tasks on the playing field with the robots being teleoperated, I.e., driven by the team members. There is also a "Skills Challenge", where individual teams attempt to score as many points as possible with the robot being teleoperated ("Driver Skills") and autonomously controlled ("Programming Skills") (REC Foundation, 2020). Programming VEX IQ robots is conducted with any sort of computing device with a web browser, so there are many potential computer choices for a prospective team.

VEX IQ does not feature a project or behavioral component such as FIRST LEGO League. Instead, there is a code of conduct that must be always followed while participating in the program (REC Foundation, 2020). It also does, however, require an engineering notebook for judging. This is a detailed collection of all engineering and design decisions made throughout the process of designing, building, and programming the robot (REC Foundation, 2015).

4.4.3 Project Goals

The goal of this Interactive Qualifying Project (IQP) is to develop a proposal for a competitive robotics team for underserved middle school students in the local community, hosted at WPI. We will evaluate potential existing competitive robotics programs at the middle-school. A comparison will be done of FIRST Lego League (FLL) and VEX IQ. The proposal will respect the needs and requirements of both the underserved community as well as WPI, the host organization for this team.

The IQP will study the needs of the local underserved community at the middle school age. This includes language barriers, financial need, and of course education. Goals will then be developed from this study that align with the needs of the local community. Best practices will be determined from interviewing WPI staff to ensure the longevity of the team.

Further study will be conducted to understand the policies and requirements of running a team with minors on the WPI campus. This includes requirements legally as well as recommendations for resources including program staff.

With this research conducted, a proposal will be developed to implement a middle-school robotics program hosted and/or supported by the WPI. This proposal will contain the research findings outlined in a manner that would enable the easy implementation of the robotics program should it be desired. The goal of this IQP is creating a complete plan for creating and long-term supporting a competitive middle-school robotics team.

5 Methodology

5.1 Objectives

5.1.1 Fill Knowledge Gaps

After the background research was conducted, more information was required about WPI policies regarding having children on campus, resources available to those running programs for middle-school students, best practices when working with underserved students, and many other project-specific details not present in literature.

5.1.2 Find the Best Program

FIRST LEGO League (FLL) and VEX IQ are the two most well-established national robotics organizations with middle school competitors. With the knowledge gained from completing the first objective, we determined the best program for our specific needs.

5.1.3 Form a Comprehensive Plan

With the program determined and all information required gathered, we created a comprehensive plan for a sustainable long-term competitive robotics team at the middle-school level.

5.2 Objective 1: Fill Knowledge Gaps

Throughout E1 term in the summer of 2021, interviews were conducted with parties knowledgeable in areas relating to the project, to better understand the intricacies of running a competitive robotics team for underserved middle school students.

5.2.1 Interviews with stakeholders and community members

Interviews were conducted individually with stakeholders and community members with experience pertinent to the goals of the IQP. At WPI, representatives from the Massachusetts Academy of Math and Science, STEM Education Center, Pre-collegiate Outreach Programs, and Diversity Excellence and Inclusion were interviewed due to their relevance to the project. Interviews were conducted directly and individually, with questions asked to interviewees over Zoom video conferencing. Notes were taken, and the videoconferencing calls were recorded so that specific answers may be revisited after the interview had taken place. All participants consented to the recording as part of the interview process.

5.2.1.1 Massachusetts Academy of Math and Science

Michael Barney, director of the Massachusetts Academy of Math and Science (MAMS), was interviewed because of his experience working with children, running summer programs for middle school students, and his connection with MAMS. We thought that students at MAMS could leverage the program to fulfill their community service requirement, so Mr. Barney was an ideal candidate for an interview. Mr. Barney suggested marketing the team directly to principals and teachers at local schools. He also stressed the importance of the barriers of cost and transportation, as well as expenses for simpler items such as snacks. Finally, Mr. Barney said that learning skills such as teamwork at the middle school age was more important than technical robotics skills.

5.2.1.2 Pre-Collegiate Outreach Programs

The Pre-Collegiate Outreach Programs (POP) staff, namely Andreas Armenis and Jenna Noel-Grinshteyn, were interviewed because of their experience working with students and running after-school programs for children in the same target demographic at WPI. From this interview, it was found that substantial legal precautions such as background checks and waivers were necessary to have children on campus safely. It was recommended that an interview with Amy Fabiano to be conducted, a general counselor for WPI who often works with POP.

5.2.1.3 STEM Education Center

Kathy Chen of WPI's STEM Education Center was interviewed because of her experience working with educators and underserved youth. In this interview, Ms. Chen stressed to us the difference between having a program available to anyone versus having a program where everyone is genuinely encouraged to participate. Techniques on marketing to underserved youth, methods of effectively engaging with people of different backgrounds and genders, and other general requirements were discussed. Ms. Chen recommended that an interview with Donata Martin of the Leominster Boys and Girls Club be conducted.

5.2.1.4 WPI General Counsel

Amy Fabiano of WPI's General counsel was interviewed because of her expertise in the legal side of programs involving minors on WPI campus. In this Interview, Ms. Fabiano provided us details on how to ensure all WPI's minors protection policies are being followed, both by our adult staff and by minors who may be volunteering as staff. She also provided links to the policies we must follow for further study.

5.2.1.5 Leominster Boys and Girls Club

Donata Martin was interviewed because of Kathy Chen's recommendation and her experience with running robotics teams for underserved youth in the city of Leominster. Ms. Martin gave a top-down overview of the way her program is run, including the sizes of the individual FLL teams, the overview of a typical team meeting, and different ways to run the team. The importance of barrier of cost was again stressed, and potential solutions were discussed. She also discussed with us how she tried running a VEX IQ-based team, but preferred FLL.

5.2.1.6 Andrew Lawrence

Andrew Lawrence, FLL and VEX IQ mentor and FRC volunteer was interviewed. He provided valuable insight into what goes in to running a team for middle school students. Mr. Lawrence described the sizes of his teams, how a given meeting is run, and many other details about his teams. He described how to keep children's attention and have a competitive team at the same time. He stressed that students at this age do not understand "why" they are doing robotics, they just are there to have fun. Finally, Mr. Lawrence gave his opinion on FLL v. VEX IQ, favoring VEX IQ.

5.2.1.7 Diversity Excellence and Inclusion

Christelle Hayles, a Diversity and Inclusion Specialist with Talent & Inclusion/Diversity Excellence and Inclusion was interviewed because of her expertise with underserved populations, specifically at WPI. Ms. Hayles shared important details about how to provide for the program participants to be their most authentic selves. She also shared information on the best ways to encourage participation among the students in the program.

5.3 Objective 2: Find the Best Program

Following interviews with experts and stakeholders, various aspects of the programs were evaluated to choose the best program for serving the target community.

5.3.1 Determine criteria to evaluate programs

Using knowledge gained from the interviews conducted, a list of criteria to evaluate the programs was made. These criteria encompassed all essential parts to run a successful program.

5.3.2 Evaluate programs with criteria

Using the criteria determined in the previous step, FLL and VEX IQ were compared quantitatively. This was done by comparing VEX IQ and FLL through each criterion, weighing positives and negatives for each case. In the case of assessing affordability, calculations were done to see in what situations each was more affordable for the program. With these values determined from the comparison, a matrix was generated, and totals were calculated. With these totals, the better program for the target underserved group was chosen.

5.4 Objective 3: Form a Comprehensive Plan

With the program determined, we used the knowledge gained from the interviews and additional research to outline a comprehensive plan for running a competitive robotics program by WPI. This plan not only includes the outline of a given meeting, but also important legal and sensitivity ideas that must be included given WPI's policies.

6 Findings

6.1 Interviews

6.1.1 Massachusetts Academy of Math and Science

From the interview with Mike Barney, the director of the Mass Academy, we learned that Mass Academy students could be utilized as staff for the proposed program. This robotics program, as it works with underserved students, would be classified under Mass Academy's "High Needs" service hour category, making this program mutually beneficial for both the students and the Mass Academy student staff.

Mr. Barney also discussed with us what he has learned from his years of experience in running camps for middle school students. Firstly, the program should focus on building skills such as teamwork for the students, not so much technical skills. Mr. Barney also stressed how students of this age need frequent breaks, so the activities during breaks can also be designed to promote teamwork. These breaks should take place every one to two hours, by his recommendation.

Finally, Mr. Barney described how he advertises his summer camps, as a basis for how this program could be advertised. He recommends advertising directly through local schools: through principals, math, and science teachers, and over school announcements. He suggested that this could be a good way to reach the underserved.

6.1.2 STEM Education Center

From our interview with Kathy Chen of the STEM Education Center, many intricacies of working with specifically underrepresented students were uncovered. It was stressed that the biggest hurdle for low-income families to participate in robotics programs is, of course, money. To many of these families, robotics is a reckless way to spend their hard-earned and much needed income, so participation in these programs is minimal. As such, Ms. Chen recommended that any program we propose must be free. This includes robot parts, food, and transportation.

Ms. Chen also discussed with us how to properly reach out to the underserved. She described how traditional methods for marketing robotics programs, say through other STEM programs, may be inappropriate as we are trying to reach new audiences. Instead, going directly to local teachers in STEM fields is a better idea. Additionally, the YMCA, the Boys and Girls Club, and other existing groups that work with our target group make fantastic places to market a new robotics program.

Ms. Chen also gave us ideas on how to run our program to specifically tailor to our underserved audience. A focus must be made in making our program approachable. This program must make robotics sound fun and not intense. The program should focus on social aspects such as cooperation and friendship. This is the same idea that Mike Barney gave us from his interview. Ms. Chen also recommended we teach basic engineering concepts, such as the design process.

Finally, Ms. Chen gave us general tips to help us run our program successfully with underrepresented students. The first tip was to have relatable staff for our students. She described how female students are often more comfortable with female teachers. She recommended having a diverse set of staff, so any potential student should feel welcome. To further welcome our students, Ms. Chen also said we should consciously work to ignore pre-conceived biases about our students. This means setting expectations high, and encouraging the students to go above and beyond, no matter if they are low-income or high-income. Our staff, simply put, need to be “very caring.”

6.1.3 Office of Pre-Collegiate Outreach Programs (POP)

The POP interview, with Andreas Armenis and Jenna Noel-Grinshteyn, opened our eyes to the legal side of the proposed robotics program. WPI has many policies and protections in place when minors are present on the WPI campus. Every adult participating in the program that is alone unsupervised with a minor must successfully complete a background check, pursuant to WPI's "Minors on Campus Policy". Funding for these background checks must be factored into program costs, as they typically cost $30-$50 per person and must be renewed on several year intervals. Additionally, minors that are participating as program staff (e.g. Mass Academy students and WPI students under 18) must also successfully compete the same background checks as adult participants should they be spending time unsupervised with minors. Staff of the program are also considered "mandatory reporters", meaning that program staff are legally required to report certain types of information, mainly regarding the abuse of children, to various legal authorities.

POP shared several "best practices" for working with groups of children in educational settings. At WPI, typical ratio for supervision is one adult for every ten children. Talks and discussion should be kept to a ten-to-twelve minute minimum so as not to exceed the attention span of the children participating. Teams of students working on their own specific robot should be kept to around four students, so everyone has the opportunity to be involved with all facets of the robot and competition. Odd numbers are not ideal, as this increases the chances of individual students being left out as children tend to pair together in even groupings. Children also need chaperones when moving throughout the WPI campus to ensure they are adequately supervised and do not become disoriented.

POP also outlined other programs that they host that target the intended age group (middle school students). Most programs offered by POP are focused around providing distinct STEM experiences through single-day visits to WPI as well as longer programs structured similarly to summer camps. Previously, POP hosted a VEX IQ team for female middle-school students. None of the students involved had prior experience and were mentored by WPI students in the Engineering Ambassadors program.

6.1.4 WPI General Counsel

We interviewed Amy Fabiano, the Deputy General Counsel at WPI to understand more about the University's processes and policies for protecting minors participating in WPI programs. A minor is defined by the University as person under the age of 18 who is not a Mass Academy student or a WPI undergraduate student. The University has several reasons for requiring special protection for minors – to protect against abuse and neglect, because insurance policies require it, and above all else because it is the right thing to do. WPI has an extensive collection of policies that govern minor participation, and there is a "Minors Committee" of various stakeholders that approve programs involving minors. Minor participants must also have their parents sign participant waivers releasing WPI from certain legal aspects.

Ms. Fabiano said that the primary point of contact for any minors should be their parents, and that these parents are responsible for signing any liability waivers for their child's participation. Regarding background checks, she additionally shared that in addition to those with direct one-on-one unsupervised contact with minors all the directors of the program working with minors must have background checks as well.

6.1.5 Leominster Boys and Girls Club

Donata Martin, one of the operators of the Leominster Boys and Girls Club, shared some information about the FIRST LEGO League team operated at the Boys and Girls Club. The teams at the Club have several students who have been involved for years and typically consist of six to ten students. Initially, Ms. Martin tried operating a VEX IQ-based team, but they ended up favoring FLL. Every meeting begins with a presentation, and then the students work on the robot and challenge. Showing demos of various engineering and robotics concepts tends to have a very positive response. The teams at the Club are either mixed-gender or all girls. For the all-girls teams the mentorship staff is completely female.

Most importantly, Ms. Martin stressed the need to have “skilled professionals” running the programs. She also said that kids are generally interested in participating but having demos and robots on-hand helps with recruitment.

6.1.6 Andrew Lawrence

Andrew Lawrence provided significant insights as a long-time participant and mentor with various pre-collegiate robotics programs. Mr. Lawrence stressed understanding the target age group. The children do not really understand “why” they are participating in the program, they’re just present because their parents placed them in the program, robots are interesting and fun, their friends are there, or some combination of all three. The students should be permitted to socialize and try new things. At the beginning of the program students typically spend a lot of time playing with the different robot components.

Regarding team structure, Mr. Lawrence shared the ideal number is six-ten students on each team. Because there is only one robot, it is important that the robot isn’t overcrowded, and everyone receives an equal chance to participate. It is important for the program to focus on personal management and working with children. Getting the students interested in STEM is the most important thing and is completely program independent.

Mr. Lawrence also shared that it is very important to set expectations and goals for the team before starting for the year. This determines the frequency and content of the regular meetings. The mentors should open each meeting with a short instructional period, so the students are not bored. As part of this a recap of the previous meeting should be conducted, so if students left early or could not make the meeting they are brought up to speed. It is important to get the students working on the robot as soon as possible once the meeting starts. And above all else, the students should leave the meeting feeling accomplished and proud of their work.

Finally, Andrew Lawrence compared FLL and VEX IQ. He was biased towards VEX IQ, as he is an employee of VEX's parent company. However, he did share objective feedback about the two programs, namely that the entry level is high for FLL, as every action must be pre-programmed. He shared that controlling a robot with a remote control is more fun than watching a robot just drive on its own.

6.1.7 Diversity Excellence and Inclusion

From our interview with Christelle Hayles, a Diversity & Inclusion Specialist with WPI's Office of Diversity Excellence and Inclusion, we learned more about working with underserved students. Ms. Hayles highlighted the importance of providing space for people to be authentic within the programs. It's important to allow for the person to speak without interruption and not to draw assumptions. Always ask questions and be conscious of how information is being used. Ms. Hayle shared that WPI does not have specific goals for the local community but is trying to invest more in global outreach.

6.2 Important Components of a Program

One of the main goals of the interviews was to determine what components of a robotics program are important when working with underserved students.

6.2.1 Social Skills

From the experts interviewed, it was stressed that the goal of an introductory robotics program is not so much to teach technical STEM skills, but to teach more applicable social and life skills.

6.2.1.1 Teamwork

From Mike Barney, we learned that learning the concepts of teamwork is an important skill to learn for middle school students in after school programs. Children at this age often do not have much experience working as a team outside of sports, so making the connection between subjects traditionally learned in school and working in a team is important.

6.2.1.2 *Confidence*

In our Pre-Collegiate Outreach Program (POP) interview, we learned that middle school students can often struggle with confidence, and already-confident students can steamroll over less confident students in a team setting. Related to the teamwork idea, teaching confidence through robotics is essential at this age, and can be done easily through the team environment in a robotics program.

6.2.2 Affordability

With the underserved, affordability is a prominent issue that prevents them from participating in robotics. One expensive component of robotics is of course the hardware. Robotics kits can cost hundreds of dollars. Our interview with Kathy Chen showed us that the underserved should not be expected to pay anything, so the kits would need to be provided. Another major cost is transportation, both to meetings and to competitions. After meeting with Donata Martin, we learned that bringing the robots to the students is the best way to encourage participation, and limit costs for the participants. This would mean having meetings in the schools of the students, instead of on campus. A final cost is food. Kathy Chen suggested to us that we should provide snacks for the participants.

6.2.3 Technical Skills

6.2.3.1 *Engineering Design Process*

Mike Barney discussed with us how learning fundamental engineering skills is more important than robotics-specific skills for students in middle school. These students likely have no experience in an engineering setting, so learning lessons such as brainstorming, and prototyping is valuable. Later programs in high school, such as WPI's FRC team, would teach more technical robotics skills.

6.2.3.2 *Meeting Length*

Nearly all our interviews concluded that middle school students have lots of energy and a short attention span. This should be kept in mind when designing our program. Many of our interviews had comments to make about keeping student's attention. Mike Barney recommended that in most cases, students should work for at maximum an hour before they take a break. In programs he ran himself, Mr. Barney would run two 2-hour classes. The number of breaks and the interval of the breaks is clearly dependent on the overall length of the meeting. Donata Martin has her meetings from two to three hours on Saturdays, with a break in the middle. They also meet a couple of times during the week. This is consistent with the interview with Andrew Lawrence. He suggested that for a casual team (a team not trying to win the world championship), there should be one meeting a week for two to three hours, with a break. He also offered that if the team wants to be semi-competitive (above average at local competitions), the team should meet at least twice a week.

6.2.4 Advertising

Mike Barney advertises his camps by emailing an entire database of STEM teachers and principals from various local school districts. He also advertises over targeted Facebook advertisements. Kathy Chen recommended to advertise directly to local STEM teachers as well. Kathy Chen also recommended advertising at organizations that already work with local underserved youth, such as the YMCA, the Boys and Girls Club, and other federally funded low-income associations.

6.2.5 Legal Details for Students

Our interviews with POP and Amy Fabiano made it clear that specific precautions must be taken when working with any type of child. WPI has specific policies regarding working with children on campus. The Participation in Minors Program Policy would be applicable to the proposed robotics program. In summary, this policy requires the program to be directly approved by WPI. A Participant Waiver and Permission Form to be signed by every parent or guardian of every minor who participates. Background checks must be conducted on any adult who will have direct and unmonitored contact with a minor. All adults working with minors must receive proper training to ensure they are responsibly working with the children. Behavioral expectations must be set, and any inappropriate behavior must be reported to the appropriate WPI faculty.

6.2.6 Legal Details for Faculty

After meeting with POP and Amy Fabiano, we learned about policies when working with children. The most important idea is background checks. Any adult working in direct and one-on-one contact must be background checked. Also, the director of the program must be background checked. This should not be an issue, as all WPI staff is background checked after they are hired. A Mass Academy student staff member would not need to be background checked, as they would not have one-on-one contact.

6.2.7 Potential Staff

6.2.7.1 Massachusetts Academy of Math and Science

From the Mike Barney interview, we learned that Mass Academy students could potentially serve as volunteer staff members. Mass Academy students are required by their school to have 50 service hours a year, and at least 10 of those hours must be "high-needs." Mike Barney told us that our program would be considered as a "high-needs" opportunity, as the program works with underserved students. Mass Academy students are often over-achievers as well, so this could be a good leadership opportunity for the Mass Academy students for their college applications. This would be mutually beneficial for the participants and the Mass Academy student staff. The Mass Academy, according to Mr. Barney, could be a long-term source of staff for the proposed program.

6.2.7.2 Engineering Ambassadors

The Pre-collegiate Outreach Programs has a group of WPI students known as the Engineering Ambassadors. They are trained to work with children in a STEM education setting and would make ideal candidates for skilled staff for the proposed program. This program is the exact kind of program that the Engineering Ambassadors work with.

6.3 VEX IQ v. FLL

From our interviews, we determined the following criteria to compare the FLL and VEX IQ programs for proposing a WPI-based team:

- Affordability: How expensive are the robot components for the program?
- Learning curve: How difficult is it for an inexperienced student to join the program?
- Competition location: How close is the nearest entry-level competition?
- Student participation: How involved are students in the actual program?
- Progression post-middle school: What pathways are available to students to continue related robotics programs after middle school?
- Additional program components: How good are the non-robotics components of the program?

With these criteria established, we can compare the FLL and VEX IQ programs quantitatively. Each criterion will have an independent score, and the program with the higher overall score will be the program we choose, as the program will be objectively better for our situation given the criteria.

	Affordability	Difficulty	Competition Location	Progression Post- Middle School	Additional Program Components	**Total**
FLL	5	6	10	10	6	**37**
VEX IQ	6	8	10	10	10	**44**

Table 1: A quantitative comparison between FLL and VEX IQ. Higher is better, scores range from 1-10.

A 10 in this table represents perfection: for instance, the transition for the students leaving FLL and joining the FIRST Robotics Competition (FRC) is most desirable due to the natural progression of programs. Progressively worse scores are awarded on a case-by-case basis. Finally, each criterion is weighted equally.

6.3.1 Affordability

The underserved cannot be expected to pay the thousands of dollars necessary to run a robotics program. As such, WPI or a third-party sponsor will have to pay for this program.

The VEX IQ and FLL programs have similar products that need to be purchased, so a side-by-side comparison can be made.

	Kit per team	Field per 4 teams	Total one team	Field yearly	Registration per team	Yearly costs per team
VEX IQ	379.00	320.00	699.00	100.00	100.00	200.00
FLL	445.00	90.00	535.00	90.00	237.00	327.00

Table 2: Cost comparison of VEX IQ and FLL programs. Lower is better. *(FIRST, 2021), (REC Foundation, 2020).*

Both a VEX IQ and FLL program will cost multiple thousands of dollars to support the dozen or so teams necessary for a successful program. The initial cost for starting the program is much higher than the yearly cost as every team needs to have a robot kit, which can be reused each year.

To better understand why VEX IQ is more affordable in the long term than FLL, there is the below graph.

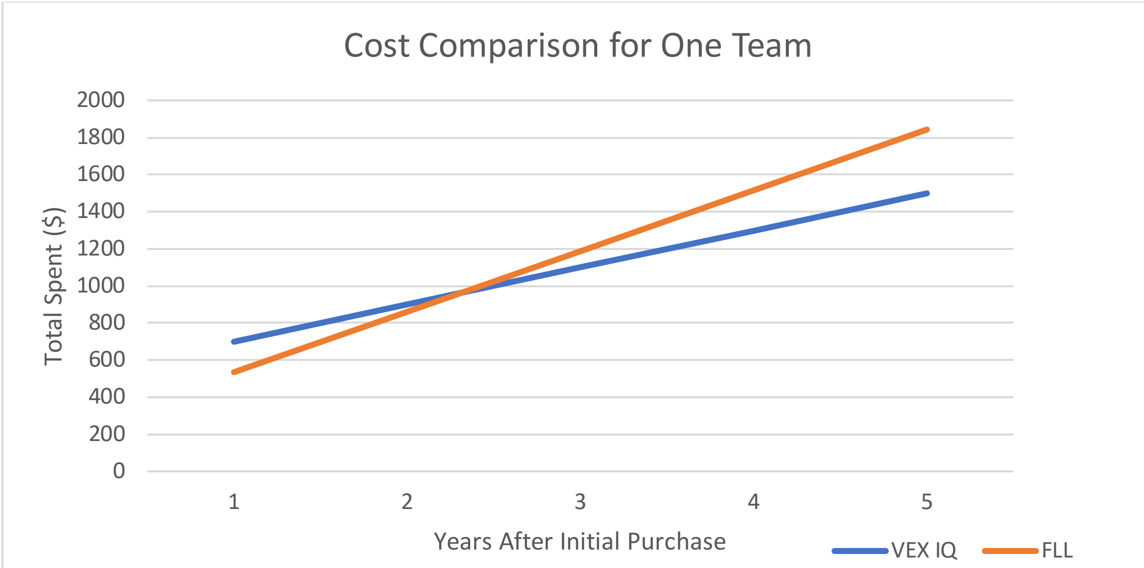

Figure 5: Total dollars spent with a one-team program over the course of multiple years. Lower is better.

In Figure 5, it is shown that after year three, a one-team VEX IQ program would begin to cost less overall than an FLL program. Because the goal is to serve middle school students as best as possible, the hope is to have the program run for more than three years. As such, the VEX IQ program is less expensive by a small margin.

When considering that the program should have multiple teams to serve a larger number of students, we can compare the total cost of the program depending on how many teams are in the program.

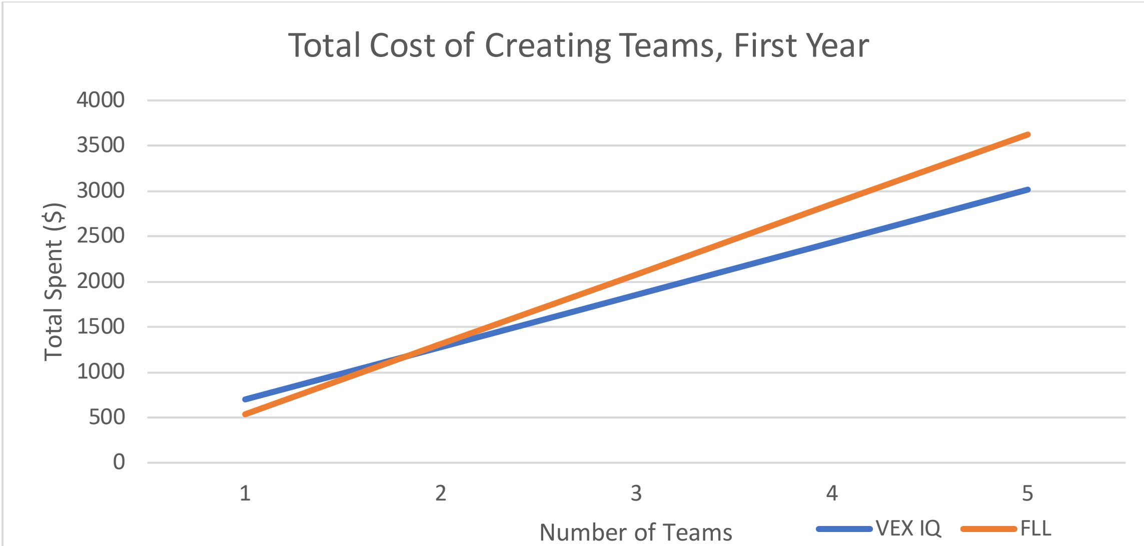

Figure 6: Total dollars spent with a multiple team program, depending on the number of teams. Lower is better.

If the program has more than two teams, then a VEX IQ-based program would cost less, even in its first year, where additional expenses such as new robot kits and a new field would need to be purchased. Figure 6 shows that in any reasonably sized program (more than two teams), VEX IQ is less expensive.

Overall, the VEX IQ program is less expensive than FLL by a small margin. To determine scores for VEX IQ and FLL, we will compare the programs as if there were five teams run for five years. This is a reasonable estimate for a long-term successful program. Using data from Table 2, we can generate a final comparison table with these chosen numbers.

	Kit per team	Field per 4 teams	Initial costs for 5 teams	Yearly costs per team	5 years, 5 teams
VEX IQ	379.00	320.00	2535.00	200.00	3535.00
FLL	445.00	90.00	2405.00	327.00	4040.00

Table 3: Cost comparison of running 5 teams for 5 years in both FLL and VEX IQ. Lower is better.

FLL is 14% more expensive than VEX IQ, meaning VEX IQ will score 1 point higher (rounded) in Table 1. Even with VEX IQ, WPI must still pay $3535 to run this program. Given that the participants pay nothing for this program, but WPI must pay for it instead, the base score for FLL is a 5. It is not ideal to have the program cost so much for WPI, but at least the undeserved do not have to pay. VEX IQ scores a 6, as it is 14% less expensive.

6.3.2 Difficulty

In this criterion, we compare how difficult the VEX IQ and FLL programs are for the students to compete in. We want to ensure that the participants are having fun and succeed in the program, so choosing the objectively easier program is our way to solve this.

The VEX IQ program has done a fantastic job in making it easy for a rookie team to become competitive. Robots are constructed out of simple plastic parts that are assembled without tools. These parts are like toys that the students may have played with, making it naturally easy for the students to build. Programming the robots is as simple as dragging blocks on a laptop. Controlling the robot is done by means of a video-game-like controller that many children have grown up using. All-and-all, the VEX IQ system does not require much training to have a fully functional and competitive robot. However, there is a high ceiling, and many hardware and software improvements can be made to make a robot with a chance of winning a competition. The only hurdle for most students to make a semi-competitive robot is learning how to use the graphical programming interface. As discussed, it is also relatively simple to progressively make a more competitive robot. With all of this in mind, we assign VEX IQ a score of an 8. Two points were docked because students who have never programmed before may have some trouble, but it is easy to get started building the robot, and with minimal experience the students could make a fantastic robot.

The FLL program has many similarities to VEX IQ. Constructing the robots is done with LEGO building blocks, a toy many children are familiar with. The software used for programming the robots is also nearly identical to VEX IQ's. The core difference between why VEX IQ makes it much easier for a team to succeed is the method of controlling the robot. In FLL, robots function during the match completely with pre-programmed actions. The students do not have a controller like in VEX IQ. Andrew Lawrence said in his interview that watching a robot move is much less fun than controlling a robot yourself. There is also a ton of work necessary to have these pre-programmed actions succeed, and a lot of time. This time could instead be spent on more interesting things. Mr. Lawrence told us that the method of controlling robots in FLL is so much more difficult and less fun than in VEX IQ. With this in mind, we awarded FLL a score of 6. Two points were docked because of the difficulty of learning how to program an FLL robot, just as with VEX IQ in this same criterion. Two additional points were docked as substantial programming knowledge is needed to make a robot competitive, as there is no remote control.

6.3.3 Location of Competitions

The location of each program's competitions is very important, especially with the underserved. It can become expensive to travel far from home, so having a competition for the proposed robotics program close to home is necessary. Luckily, WPI hosts both an FLL and VEX IQ qualifier. A qualifier is the first competition a team would compete in, regardless of their skill. WPI also hosts the FLL state championship, which is the next competition students in the proposed program would attend if they succeeded at the qualifier. Having competitions on the WPI campus is as close as any competition reasonably could be, thus FLL and VEX IQ both receive a score of 10 in this category.

If one or more of the teams in the program succeeds and makes it to the state championship or beyond, then either WPI or an external sponsor would need to provide funding for transportation, food, and lodging. The top priority for these students is for them to succeed, so they should not at all be hindered financially while apart of this program.

6.3.4 Progression Post-Middle School

VEX and FIRST each offer programs for all ages of students, allowing for learning progression as the students get older. After FLL, the next FIRST program logically is the FIRST Robotics Competition (FRC) for high school students. WPI has a FRC Team on campus, FRC 190, which is available to Mass Academy students as well as any high school student in the area who does not have access to a FRC team. There is also FRC Team 1735 based at Burncoat High School, which is a public school in Worcester that many potential members of the program may attend. Both FRC teams are fantastic choices for the students to progress to after middle school. In comparison, WPI does not have any VEX teams currently on campus, beyond the VEX IQ team specifically for middle school girls. South High Community School in Worcester hosts several VEX Robotics Competition (VRC) teams, the VEX equivalent of FRC. These VRC teams recently competed at a VRC competition in Worcester in 2020 (Robotics Education & Competition Foundation, 2020). WPI does have a VEX U team available to college students as well if they continue to WPI. Both VEX IQ and FLL have excellent pathways for graduates of our program in the Worcester area, so both FLL and VEX IQ receive a 10 in this category.

6.3.5 Additional Program Components

Both VEX IQ and FIRST LEGO League have non-robotic components to their competition. In VEX IQ, teams are expected to produce an engineering notebook. The notebook is a good exercise in technical writing and communication of complex ideas, and so VEX IQ was awarded a score of 10 in this category. FLL fails in our eyes in its additional component. The project each FLL team must complete is related to the theme of the robotics game but does not necessarily connect to robotics. As Andrew Lawrence said, students do not come to robotics to do the project, they come to do robotics. The project component is well-organized however, so we award FLL a 6 in this category. Four points were deducted due to the non-robotics nature of the project, that must be completed regardless of the interest level of the involved students.

7 Conclusion

This goal of this Interactive Qualifying Project (IQP) was to propose a competitive robotics program that would pique underserved Worcester middle school students' interest in science, technology, engineering, and math (STEM). After much research and interviews with a diverse array of professionals, we proposed a potential program bound for success (Appendix A).

One of the biggest conclusions drawn from this IQP was that a VEX IQ-based program would be more successful in engaging underserved students in STEM than an FLL-based program. While both programs could be successfully run by Worcester Polytechnic Institute (WPI), it has been proven in this paper that there are more benefits in choosing VEX IQ.

To address our goal of serving the underserved middle school students in the local community of Worcester, many considerations were made throughout the proposal. Some of these considerations include running the program at the participants school instead of on WPI campus to prevent incurring travel costs and supplying laptops if computers are unavailable, because the participants cannot be expected to have personal computers. The underserved participants and their families should not feel burdened by this program; our proposal accomplished making an ideal competitive robotics program for specifically the underserved.

The program also was designed to be both fun and educational for the participants. This was done by designing a curriculum based on building teamwork and friendship, while also touching on fundamental STEM skills like the engineering design process. By tailoring our proposed program to teach appropriate skills for the age of our participants, we can ensure the students will get the most out of our program. The program factors in the much-needed breaks that students at a middle school-age need to stay focused when working on robotics.

Based on the information gathered through our research and interview process, we can be certain that the proposed program (Appendix A) will successfully motivate underserved middle school students interests in STEM.

7.1 Recommendations for Future Work

7.1.1 Advertising the Program

The first step of making this program into a reality is determining where to advertise the program. Narrowing down exactly where to advertise would be the first step. Initial thoughts were to advertise through federally funded groups that already work with the underserved, such as the YMCA, the Boys and Girls Club, and through public schools in the Worcester area. From there, advertising materials need be created to make robotics seem approachable for the underserved. An idea is to stress teamwork and fun in the advertisements, instead of robotics, as robotics may carry a stigma with underserved families as something unaffordable.

7.1.2 Locating Funding

As stressed throughout the findings chapter, the underserved cannot be expected to pay anything for the program. As such, we recommend locating funding either within WPI or from an external sponsor. We recommend first approaching WPI for funding, but if there is not enough money from WPI, local companies often sponsor robotics teams, which could make for a suitable alternative (FIRST, n.d.).

7.1.3 Preparing Staff

Staff must be located for the program. As described in Appendix A, staff could be gathered from both the Massachusetts Academy of Math and Science (MAMS) and the Engineering Ambassadors from POP. There also exists the “RoboKids” program at WPI, a group of WPI students who volunteer within the local community to do very similar robotics-related outreach and could be used as program staff. A partnership would need to be made with the executives of the “RoboKids” club. The MAMS staff would be volunteers, so advertising would need to be done to encourage volunteers.

After staff members have been chosen, training will be necessary. The staff must be sensitive when working with underserved students to make the participants feel as welcome as possible. We recommend meeting again with Christelle Hayles of the Office of Diversity Excellence and Inclusion. She and her office are an excellent resource for ensuring that everyone involved is properly trained in being sensitive to issues relating to the underserved participants.

7.1.4 Making the Program Official

From our interview with POP, we determined that registering the program must be done through POP. By registering through POP, they will help with getting staff properly background checked, getting participants to sign the proper waivers as described in Appendix A, and all other legal issues. They will also be able to help provide contact emails for advertising the program to students.

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Appendix Notice

For paper with Appendices, please view eProjects submission from Grant Perkins.