Overview
Virginia’s Falls Church City Public School System (FCCPS) has consistently provided a strong robotics program at the middle and high school levels since 2004. The strength of the program has been demonstrated at the middle school level by the consistent participation of multiple teams in the FIRST Lego League (FLL) regional tournaments and qualification of a few to the state tournament nearly every year since 2011. At the high school level, the FIRST (For Inspiration and Recognition of Science and Technology) Robotics Team 1418-Vae Victis has shown the strength of the program through the consistent participation at multiple FRC district championships each year since 2004 and qualification for the FIRST World Championship in 2007, 2008, 2010, 2016, and 2017.

During the fall of 2016, a group of community stakeholders consisting of parents, teachers, and community volunteers, came together to explore options to further expand the program after the successful completion of the 2016 Falls robotics program initiative. Community stakeholders implementing a district-wide robotics program for students in elementary, middle, and high schools.

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Photo above: FLL Members Site Visit. (More than two dozen of the record 46 TJES students taking part in this year’s FIRST LEGO League robotics challenge visited the Griffith Water Treatment Plant in Lorton, VA, where they had a presentation, a full tour, and got some great swag! Each of the 6 TJ teams identify a problem within the human water cycle, design a solution, and share it with others, while also building robots to best complete as many water cycle-related missions as possible.)
Community partnership (Falls Church Police Department).

Church Regional FLL Tournaments. The stakeholders felt that it was the right time for the program to take the next step in its evolution, given the strong community outreach presence demonstrated by the Falls Church FRC Team 1418. The presence included activities such as adopting younger FLL teams, conducting FRC workshops for other FRC teams in the district, providing tech support and field setup for the FTC team, participating in elementary school STEM nights, sponsoring the Falls Church Regional FLL Tournaments, being involved with congressional awareness, and members offering workshops internationally in their native countries. The combination of the community outreach activities and stakeholders all led up to the realization by the group that additional structural and organizational management was needed.

Discussions led to plans for the development of a full-scale, year-long, comprehensive robotics program using the FIRST platform at multiple schools within the Falls Church City (VA) Public School System. A committee was formed to lead the efforts, comprised of FCCPS staff members and a long-time FCCPS robotics volunteer. A key component for the initiative was put into place two years prior to the system-wide initiative when a new elementary STEM teacher was hired in the fall of 2015 and joined the committee in the spring of 2017. The addition of this staff member allowed the program an opportunity to expand into the elementary school, allowing younger students to participate in the FLL Jr. and FLL programs prior to starting middle school, with a full-time staff member to sponsor and support the program's efforts.

The goal of the committee was to create a program that operates year-round with team formation/orientation in the spring, tournaments and trainings during the fall, and introductory or advanced technical workshops during the winter/early spring. This cycle is conducive to providing a holistic robotics program focused on developing students' knowledge and appreciation of STEM-related activities through competition, training, and collaboration. In the spring of 2017, workshops for new coaches and teams were conducted, with advanced trainings offered during the summer and early fall through partnerships with the Recreation and Parks Department, the city library, and other community organizations.

This narrative inquiry study used Labov's thematic organization theory to provide an understanding of the major events that took place during the district-wide robotics program initiative implemented in the Falls Church City Public School System during the 2017-2018 school year (Coffey & Atkinson, 1996). The Labovian analysis organized data into an abstract about the study, an orientation on use of integrative STEM applications in robotics programs, an evaluation of the FCCPS robotics program, the results of the initiatives efforts, and a coda.

Although all four levels of the FIRST robotics program are actively involved within the FCCPS, much of the information presented is directed towards the value of implementing the first two levels, FIRST Lego League Jr. (FLL Jr.) and FIRST Lego League (FLL), as a foundation for building a successful K-12 robotics program. The article focuses on the integrative STEM applications involved within the field of robotics, the overall organization of the district-wide initiative, and the value of school and community partnerships and collaborations.

Integrated STEM Applications

STEM education is the integration of the four disciplines; science, technology, engineering, and math, into one meta-discipline. STEM education, however, is "often an ambiguous acronym, even to those who employ it" (Saunders, 2009, p. 20). Over the past two decades, it has become abundantly clear to those within the field that there is a deficiency in research findings that illustrate specific methods, actions, supports, and resources that facilitate the process of integrative STEM application (Parr & Edwards, 2004; Stearns & Stearns, 2006; Washburn & Myers; 2010).

There have been many claims, but too few studies that demonstrate the benefits of integrative education across the disciplines of science, technology, engineering, and math to a student's acquisition and long-term retention of content. According to the National Research Council (2014), "most studies of STEM learning consider each discipline singly and do not measure students' ability to make connections across disciplines or their proficiency with 21st century skills such as collaboration or problem solving" (p. 8).
Integrative STEM education is traditionally conveyed through “problem-, project-, or design-based tasks to engage students in addressing complex contexts that reflect real-world situations” (National Research Council, 2014). The fields of technology and engineering do not stand alone. Unlike the structured approach of traditional academic fields of science and mathematics where learning takes place within a silo (single-disciplinary approach), technology and engineering courses, “create rich integrated units that are designed for students to interact, interface, and overlap with one another” (Davison, Miller, & Metheny, 1995, p. 227). As integrative STEM applications evolve, educators need to determine how the educational concepts are not isolated facts, but rather “elements of integrated bodies of knowledge that must fit together” (National Research Council, 2014, p. 10).

Lynch (2000) suggested that STEM educators consider constructivist approaches that allow students to build their own knowledge, acquire new knowledge, become proficient problem solvers, and allow the teacher to serve as a coach. It is now expected that STEM students use, “basic and higher-level skills to interpret data, apply new skills, solve problems, work in teams, generate unique conclusions about key concepts, and demonstrate mastery on technical tests” (Bock, 2008, p. 6).

Multiple researchers have found, “extracurricular activities to be an important developmental context, providing opportunities for adolescents to experience heightened levels of engagement, challenge, enjoyment, intrinsic motivation, and initiative” (Vandell, Pierce, & Dadisman, 2005, p. 899). According to Gura (2011), many robotics programs are successful due in part to their ability to provide real-life learning experiences and produce activities with higher student involvement and interest.

Many recent studies have provided support and evidence that robotics activities can result in the increase of 21st century skills such as critical thinking, problem solving, creativity, and collaboration (Afari and Khine, 2017; Ardito, Mosley, & Scollins, 2014). Shih, et al (2013) posited that, “LEGO Robotics empowers children to learn math and science concepts as they design, build, and troubleshoot different projects” (p. 78). One major factor to attract youth to the LEGO Robotics platform is its playfulness and familiarity to children (Shih, Chen, Wang, and Chen, 2013).

The LEGO Mindstorms and WeDo 2.0 robotics kits contain the necessary building blocks and programmable control units that enable youth to construct a plethora of robot models designed to address a specific challenge. There are numerous types and versions available for use that range in price, versatility, and capacity. The current LEGO Mindstorms software and EV3 robot are some of the most commonly used robotics platforms in STEM education. They serve as the main platform used by FIRST Lego League teams for competitions among elementary and middle school students.

Structural and Organizational Management

Spring Season (April – July)
The FCCPS robotics committee met one of its initial goals during an informational meeting held in May of 2017. The school’s cafeteria was near capacity, with over 150 parents, students, and committee members in attendance representing the elementary, middle, and high schools. The two-hour meeting consisted of three sessions. Session One included welcome messages, introductions, an overview of the FIRST program, and how the program would be implemented in the FCCPS. It emphasized the importance of volunteers, parent participation, and the successes of the high school robotics program over the past two decades. Session Two was comprised of three breakout areas with facilitators presenting on three of the four FIRST programs; FLL Jr., FLL, and FTC. The final session allowed the entire group to reconvene to discuss the next steps, such as training for the coaches, the level-specific handbooks, and to complete administrative forms. The next day, a follow-up email was sent to all participants to recap the meeting's minutes. Included was a link to the level-specific handbook created to provide an extensive overview of the program, FCCPS and FIRST policies and procedures, sample budgets, and a tentative schedule for the season.

Two subsequent training sessions were held in June 2017 for new coaches. Session One included step-by-step training that focused on logistics for registering teams, completing background checks, picking up the donated EV3 kits, and answering general questions. Session Two focused on financing for teams (including organization, accountability, fundraising). A PowerPoint presentation and recording of the trainings were shared with all coaches. Upon completion of the training, five FLL Jr. teams (27 students) and six FLL teams were formed at the elementary school (46 students), and four FLL teams (16 students) and one FTC team (10 students) were formed at middle school. Due to a
larger-than-expected level of interest, the members of the committee tasked with team formation struggled to put the teams together and collect the necessary paperwork in a timely manner. After two weeks of collecting paperwork and a plethora of follow-up emails and phone calls, the teams were announced.

During the same period, an extensive review and revisions of the policies and procedures for after-school enrichment and club programs were underway. Members of the committee worked proactively with the administration and legal team to present information and scenarios for review and possible inclusion in the new school board policies handbook. Although many changes were made to the handbooks after the initial release, the results have been overwhelmingly positive and have provided more transparency and consistency as to how programs operate, with lasting impact for the future.

Although the teams could have met and begun working as soon as they were formed, this was not the goal of starting the teams in the spring. Rather, the purpose was to provide adequate time during the late spring and summer for team formation, coach trainings, registrations, parent meetings, fundraising, budget development, and team-building activities. The FCCPS Robotics Program, based upon previous years of experience, has found that starting the process of team formation and subsequent administrative tasks in the spring allows teams to ease into the fall season with most of the administrative tasks completed. With a strong foundation already in place, coaches were better able to focus on the year’s challenges rather than taking valuable training time to address administrative tasks that accompany building a new FLL Jr. or FLL team.

**Fall Season (August – November)**

The beginning of August signals a higher tempo for all levels. The yearly kickoffs are in August (FLL Jr. and FLL) and September (FTC and FRC). At the younger levels, many of the first-year coaches and parents have voiced concern that the teams did not meet regularly during the summer and have not completed much work. After consulting with multiple coaches and completing the 2017 kickoff, the committee decided that it will be invaluable to offer new teams three training sessions to be held prior to the yearly kickoff for each level. These trainings will be focused on the FIRST Core Values (FLL Jr. and FLL), the project requirements (FLL Jr. and FLL), and the robot game/design (FLL). The FIRST Core Values training will provide sample activities to use in meetings, an overview of how team members can demonstrate core values throughout the program, examples of past challenges used in FLL tournaments, and a review of the scoring rubrics.

For the project training, samples of work completed in previous years by experienced teams will be shared, along with the scoring rubrics used at both levels. A detailed description of the year’s theme will be shared and brainstorming sessions provided. The robot game/design training will focus on the field structure of the robot game for that year and how missions could potentially be completed. Examples of base model robots commonly referred to as push bots will be demonstrated and build instructions provided to all. The robot design session includes sample questions that judges may ask and samples of design notebooks that teams have completed. The session will culminate with the review of the rubrics used for scoring teams on both tasks.

By starting the team process early in the spring, most of the systems will have had time to fall into place for the teams so that they are prepared for a more accelerated schedule in the fall. It is recommended that the teams should conduct at least one “parent-only” meeting and one team meeting prior to the yearly kickoff. The “parent-only” meetings should focus on the team’s budget, scheduling, parent involvement, role selection, and other pertinent administrative items, whereas the team meeting should focus on establishing team rules, expectations, roles, season planning, and team-building activities. After the yearly kickoff and announcement, each level begins meeting regularly and focuses on the completion of the projects. For FIRST Lego League Jr. and FIRST Lego League, the FCCPS Robotics Program follows the FIRST recommendations and curriculum. The curriculum is structured to take place over a twelve-week period and culminates with the regional FLL Jr. Expo or FLL tournament, which is held at the middle school in late November.
The FCCPS Robotics Program's FLL Jr. programs are expected to meet one to two times per week for 30 to 45 minutes each session during weeks one through six. The goal during this time is for members to explore the assigned theme, start their engineering notebooks, and begin work on their challenge. During the same time, the FCRP FLL teams begin meeting once or twice per week for one to two hours each session. It is recommended that the teams complete the first of eight modules provided by FIRST prior to the kickoff, with two additional modules completed each week thereafter.

A transition period begins for both programs around the Columbus Day weekend. For the FLL Jr. programs, teams begin to create and test during weeks seven through nine, meeting twice per week for about an hour each session. During weeks ten through twelve, teams meet with an expert “in the field” and begin to share their work with others. This is a vital component of the FLL Jr. experience. For the FLL teams, this is the time the projects should be nearing completion, and the teams transition from research and planning to creating and evaluating the building of the robot and the project. The teams are repeatedly informed that the judges at all levels are looking for the team’s ability to complete a process from beginning to end, and for all team members to communicate the process, and not just the success.

At the end of the twelve weeks, the FLL Jr. teams participate in an FLL Jr. Expo, and the FLL teams compete in the regional tournament. The FCRP concludes in November after it has provided two capstone events and participated in the regional FLL tournaments/FLL Jr. Expo at the middle school facility and an end-of-the-season outing in December.

Winter Season (December – March)

During the months between the regional tournament and the start of the next robotics season, many of the team members could potentially compete in the state and world championships. Multiple enrichment workshops are planned for the members who do not advance to championships but wish to continue in the program in some way. One of the original goals of the FCCPS Robotics Program committee was to offer a year-round, district-wide robotics program that offered opportunities for student enrichment, parental involvement, and competitive/noncompetitive activities. This is a way for students to increase their levels of participation and further develop their interest within STEM-related activities.

A subcommittee of three FCCPS staff members was formed during the summer of 2017 to create three different workshops. The first workshop is a one-hour, eight-week, after-school session open to all students who wish to learn more about robotics and programming. The second workshop is a six-week intensive workshop offered during weekday evenings (5-8pm), and the third six-week workshop is an intensive weekend program offered on Saturdays from 9am-12 noon. The intensive workshops are restricted to robotics team members since a prerequisite is that members must have completed at least one FLL Jr. or FLL season.

The current plan is to engage an external vendor with appropriate expertise to administer the workshops. By allowing the vendor to manage the registrations, marketing, class lists, payments, and instructor compensation related to the workshops, the FCCPS staff and parent volunteers can focus their attention on student involvement, enrichment, fundraising, and new member recruitment. Since this format is in place at the elementary school, it can be replicated with some adjustments at the other schools.

Value of School and Community Collaborations

“Community support of the educational process is considered one of the characteristics common to high-performing schools” (Henderson and Mapp, 2002, p. 9). Researchers and practitioners routinely document how beneficial it is for schools and communities to work together to reach common goals. Many school systems struggle with limited resources and the ability to fully meet the needs of their student populations. In today’s educa-
a district-wide robotics program initiative

According to Bergstrom, et al. (1995), “collaboration is a process of participation through which people, groups, and organizations work together to achieve desired results” (p. 1). Anderson-Butcher, Lawson, Bean, Boone, & Kwiatkowski (2004) defined community partnerships as formal arrangements between, “a school and an individual, association, private sector organization, or public institution to provide a program, service, or resource that will help support student achievement” (p. 9.2). Multiple studies suggest schools, families, businesses, and community organizations gain from solid community partnerships that secure broad and strategically focused community engagement (Blank, Melaville, & Shah, 2003; Turning Points, 2004; Villarreal & Bookmyer, 2004).

Partnerships and collaborations are not always beneficial, as they consume valuable human resources such as time, capital, and energy. Based upon the premise that schools do not always yield the tangible results being sought through the partnership, Murray & Weissbroud (2003) suggest that “strategic, solid partnerships are developed in relation to a justifiable plan,” and that, “partners should be strategically recruited based upon the goals of the school and community’s needs” (p. 186). For more effective partnerships and collaborations to take place, each entity should “be able to achieve its own missions, goals, and accountabilities at the same time it contributes to the achievement of the school’s vision, mission, goals and accountabilities” (Murray & Weissbroud, 2003. p. 196).

The FCRP has benefited greatly from the support of the community partnerships and collaborations. Within the FCRP, these partnerships and collaborations have been established with other local government agencies, including the Falls Church Recreation and Parks Community Center, and the Mary Riley Styles Library, which offers many robotics workshops and provides meeting space for teams throughout the year. The Falls Church City Public Schools Business in Education (BIE) Partnership collaborates with over 500 businesses, nonprofits, government agencies, and individuals. Their mission is, “to promote the active participation of business personnel in support of school activities and to assist school staff in review of instructional programs to insure relevant instruction, to assist and advise in the development and approval of the Annual Career and Technical Education Plan (CTE)” (Falls Church City Public Schools, 2017). For the past five years, members of the Business in Education Partnership (BIE) have generously donated gift cards, supplies, and the food that has been distributed to the 500+ robotic team members attending the Regional Tournament.

More recently, an important collaboration was initiated between Mary Ellen Henderson Middle School and a national youth leadership and education company headquartered within the City of Falls Church to offer the Explore STEM Workshops after school, with many of the workshops focusing on robotics and programming. As a part of the partnership, the company provided the robotics program with Mindstorm EV3 robotics kits for all FCCPS FLL teams. The kits, valued at $500 each, were provided with the goal to ensure that all FLL teams in the FCCPS system would have access to at least one robotics kit for 3-5 years (estimated life-span for the technology) to use during the tournament sea-
son. At the end of the season, teams not continuing the following year return their kits, which are then used for classroom exercises and workshops. Teams returning for the next season can keep their kits until the team disbands. This partnership, along with other partnerships and grants, has greatly benefited the robotics programs by taking away the main obstacle—initial financial outlay to start teams.

FIRST provides a matching contributions link, a sponsorship reference page for each level, a regranting procedure option, and a special grant program support page for teams throughout the United States and North America. Although each community is unique, companies with direct STEM connections should be contacted. Examples include, but are not limited to, manufacturing facilities, civil engineering firms, construction companies, automobile dealerships, accounting firms, legal offices (patents), electrical service providers, and colleges and universities.

Conclusion

It is the belief of the Falls Church Robotics Program committee that other FLL Jr. and FLL sponsors can easily incorporate the structure and organizational management techniques described in this article to better assist them in implementing the FIRST Robotics Program within their community or school system. The narrative approach used in this article is meant to serve as an example of how both newer and veteran robotics programs can change to be a district-wide robotics program encompassing all levels of the FIRST robotics program and the value of facilitating such initiatives.

Table 1. Standards Addressed Through FIRST Robotics Programs

<table>
<thead>
<tr>
<th>Student Action(s)</th>
<th>Standard(s) Addressed</th>
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<tbody>
<tr>
<td>Utilize Lego building blocks and programmable control units to construct robots.</td>
<td>STL 17:F STL 17:1</td>
</tr>
<tr>
<td>Construct a plethora of robot models curtailed to a specific challenge being presented.</td>
<td>STL 11:D STL 18:D STL 18:G</td>
</tr>
<tr>
<td>Communicate with an expert in the field and share work with others.</td>
<td>STL 11:E</td>
</tr>
<tr>
<td>Apply electrical concepts to power and operate a robot.</td>
<td>STL 16:C STL 16:G STL 16:H</td>
</tr>
<tr>
<td>Apply integrated STEM concepts (e.g., experimentation, energy transfer, programming calculations).</td>
<td>STL 3:F STL 16:F STL 16:H</td>
</tr>
<tr>
<td>Communicate the engineering design processes involved in the robotic design, including successes and failures.</td>
<td>STL 11:H</td>
</tr>
<tr>
<td>Research and explore a conceptual theme, complete an engineering notebook, and construct a working robot.</td>
<td>STL 18:D STL 18:G</td>
</tr>
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By the beginning of the 2018 season, it is anticipated that all teams in the FCCPS Robotics Program will be parent-/volunteer-led, and supported by a staff sponsor at each school to assist with the administration of the programs. It will be expected that parents contribute with personal financial support, through work-based sponsorships, and/or with the use of their time. The culture of successful programs focuses heavily on parent involvement and investment. It is communicated very early in the process that the amount and type of parental involvement will increase as the teams progress into the more advanced levels.

As the FCCPS Robotics Program develops, the author plans to share updates in two to three years after the initiative has been in operation for multiple seasons. Although viewed with apprehension by some technology and engineering educators, robotics is a rapidly expanding field that challenges and excites students.
into pursuing multiple STEM-related careers. Robotics provides a nontraditional avenue for technology and engineering educators to teach content such as design, construction, electronics, and programming while simultaneously providing for the hands-on, problem-based applications that are the hallmark of technology and engineering programs. It is the author's hope that this article will assist other educators, administrators, and community stakeholders in the development of robotics programs through the sharing of information, including the processes used and resources involved in developing a successful district-wide robotics initiative.

References


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