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INVESTIGATING THE EFFECT OF COMMUNITY-BASED EDUCATIONAL ROBOTICS PROGRAMS ON UNDERREPRESENTED YOUTH

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STUDENT AUTHOR BIO SKETCHES

Eric Flaningam is a junior studying industrial engineering at Purdue University. He joined the Ware Research Group his freshman year and has been the head undergraduate researcher since the fall of his junior year. He has been involved in various projects surrounding community engagement and well-being. Some personal research includes happiness studies, quality of life studies, and how technology affects mental health. After graduation, he plans to pursue graduate studies or a career in entrepreneurship.

Hanna Keyerleber is a senior in computer engineering at Purdue University. She began work with the Ware Research Group in her junior year. She has been involved with FIRST and LEGO robotics programs for the past 12 years as a student, mentor, and volunteer. In this article, she describes her experience in starting FIRST LEGO League teams in local Lafayette community centers. After graduation, she plans to pursue a career in systems and software engineering.

Christopher Embry is a senior studying economics at Purdue University. He has been working in the Ware Research Group for two years, focusing on well-being and community development studies. He has roughly three years of previous robotics and robotics education experience, including helping to start middle-school robotics teams as a high schooler. He plans to attend graduate school to continue studying the connections between economic conditions and community well-being.

INTRODUCTION

The Ware Community Indicators Research Group is a research group at Purdue University that researches community well-being through a variety of projects. The research group formed a service-learning agreement with the Northend Community Center, a community development center in the north end of Lafayette. This service-learning agreement allows the Ware Research

Group to complete service-learning research projects at the Northend Community Center while the Northend Community Center receives the benefits of these service-learning projects. One such project developed a robotics program for a youth community center within the Northend Community Center. The Hanna Community Center is a youth community center within the Northend Community Center with an afterschool program made up mostly of kids from underrepresented

minority groups. Initially, the team reached out to the Hanna Center to gauge interest in starting a FIRST LEGO League robotics program. The Hanna Center agreed due to their desire for a skills-development program within the center. The team selected FIRST LEGO League (FLL) robotics to address the community partner's requested need and develop relevant skills for the kids. The research group saw an opportunity to complete three main objectives through the project. First, the team would provide the kids at the center with tangible, relevant skills through the robotics program. Second, the team could study the impact of a robotics program such as this one on kids' development. Another long-term goal of the project is determining if a program like this could be scaled to help address the underrepresentation of minorities in STEM. As reported by the National Science Foundation, African Americans and Hispanics make up 35.4% of the U.S. population aged 18–24. However, only 27.1% of associate degrees, 19.1% of bachelor's degrees, 17.9% of master's degrees, and 11.1% of doctoral degrees in STEM are awarded to African Americans and Hispanics (*What percentage of S&E degrees do women and racial/ethnic minorities earn?*).

Within the rapidly expanding field of STEM education for primary and secondary students, robotics programs provide an opportunity to develop a well-rounded skill set. Able to be implemented at an early age and develop in complexity along with the student, robotics programs have the potential to create sustained, measured progress in how pupils learn life skills. Dr. Kristina Luckey (2011), an educational researcher, measured the skills development of FLL participants using a quantitative skill development survey and focus groups. She concluded that students increased their skills in leadership, communication, critical thinking, self-responsibility, marketable skills, and positive identity (Luckey, 2011). The ability to recontextualize science and math topics into actionable and engaging environments is of note in robotics due to the team-based nature of most programs, as a gamut of interpersonal skills are needed to handle teamwork and group responsibilities. Kaye Ebelt (2012), a science education researcher, studied the development of soft skills among FLL participants and concluded that they gained increased confidence and skills in public speaking and teamwork (Ebelt, 2012). As one of the largest design environments designed for this younger audience, FIRST LEGO League has the advantage of using pieces that are already popular in nonacademic settings, a further example of the focus on recontextualization. The topics of diverse skill sets, timely exposure to STEM, and barriers to entry were seen as the key

themes uniting the data of underrepresented minority students in robotics programs.

The team used those three topics as a foundation on which to design the curriculum for this project. The team designed activities to help develop not only STEM skills such as programming and mathematics, but also soft skills such as communication, teamwork, and leadership. Second, the literature points to timely exposure to STEM as a major precursor of STEM success. The kids participating in the program at the Hanna Center include ages 9–14. The relevant literature points to this age group as an optimal time to be exposed to STEM programs. Dr. Terri Varnado (2005) investigated the effects of FLL on students aged 9–14. Dr. Varnado concluded the effects of a robotics program are optimized during formative cognitive growth, and the developments increased most in students aged 11–12 (Varnado, 2005). Finally, barriers to entry for minority groups can predict underrepresentation in STEM. Rosen, Hendricks, Robinson III, and Sonnenberg-Klein (2013) examined the benefits of minority student participation in FLL. In the study, they noted common barriers to entry are lack of access to funding, lack of STEM-affiliated role models, and lack of established programs in which to participate (Rosen et al., 2013).

Our team funds the project, acts as STEM-affiliated role models, and provides an established program in which to participate. The main gap in knowledge this project is studying revolves around the community nature of the Hanna Center. Almost all other studies regarding minority students in STEM programs are based in academic settings such as schools. However, few studies investigate the impact of a community-based environment in FLL's impact on students. The team hypothesizes that academic settings might not be optimal environments for engagement for minority students. So, the team is studying how the presence of our project in a community center will help students feel more comfortable and more engaged than in a traditional academic setting. The team developed the research question: *How do community-based educational robotics programs affect underrepresented minority youth?*

METHODOLOGY

The Ware research group drew on a previous relationship with local community centers to establish several FLL teams. The two partnered Lafayette centers were the Hartford Hub, located in the Lincoln neighborhood, and the Northend Community Center, located in the Hanna neighborhood. Both community centers share a similar

mission set and core values and focus on providing space for neighborhood residents to build relationships and develop skills. Specifically, the community partners were in search of meaningful programs that would provide students with workforce-preparedness skills in addition to an educational supplement. After discussion with the community partners, the research team chose FLL due to its low cost and middle school reach. Students ages 9–14 who frequent the community centers after school were invited to join the teams. From the Northend Community Center, the focus of this paper, approximately 20 students in grades 4–8 attended regular program sessions.

Once a week, the research group went to the Northend Community Center to work with students on technical concepts and soft skills by using the FLL curriculum. A traditional FLL season is divided into three pillars: robot, project, and core values. The robot portion focuses heavily on the development and implementation of technical skills. Students are presented with “missions” that they must complete by designing, building, and programming a LEGO robot. These missions must be completed autonomously by the robot—that is, without any interference from its human operator. The project portion is centered around a seasonal theme, where students investigate a problem facing society and come up with an innovative and creative solution that addresses the issue. Finally, the core values are focused on the team’s soft skill development, which includes collaboration, inclusion, leadership, written communication, verbal communication, critical thinking, self-responsibility, and positive identity, emphasized by the program’s focus on working as a team.

Meeting in a modified conference room with smaller tables for group work, the research team initially began with introductions and icebreakers, followed by a structured “build period,” during which the 20 students broke into groups of 5 or 6 to work on constructing LEGO table models. As the students worked, the research team floated between groups to provide words of encouragement, ask questions, and observe the skill level of the students. Some were all-in to the building aspect and had taken control of their breakout group. Others ignored the pile of LEGOs entirely, choosing to chat with friends instead.

A typical FLL season is spent working toward a culminating event where teams compete against each other on the robot board and present their work to judges. The judges use three rubrics—one for each pillar of FLL—to evaluate the progress teams have made over the course of the season. The research team established these

rubrics to collect data on student progress. The rubrics are filled out after each meeting to understand how the program and educational material affect engagement and technical skill. Each of the three rubrics has category-specific benchmarks defined and is rated on a scale of “beginning” to “accomplished.”

Using this rubric as the tool for evaluating, a few students are randomly selected at each meeting to be evaluated. During the first meeting, the researchers observed that the majority of participating students were in the “beginning” category of the technical skills listed. The majority of students were not actively engaging and were taking much longer to complete the LEGO models. Nearly all were left unfinished at the end of the meeting. Based on these initial observations, the research team decided to develop “mini-lessons” to help direct attention and engagement in each of the three pillars of FLL. Some examples of these included learning how to “think like a robot,” what different types of sensors do, or even just learning to read the build instructions for LEGO models.

RESULTS

Due to time constraints stemming from the COVID-19 pandemic, the research group was primarily able to obtain qualitative data from participating students regarding their enthusiasm and willingness to engage with STEM concepts. The research team initially intended for meetings to run as one large group working on the same concepts, but quickly determined that smaller and more focused instruction was the most effective in encouraging participation. This conclusion was based on observations that many students would disengage from material during large group meetings, instead talking with friends or otherwise not paying attention.

In contrast, the research team observed that small group sessions allowed students to work with their peers in a more focused environment. One group of students would chat constantly, regardless of the material being worked on. However, in smaller groups, they were able to balance talking with each other while working on building their LEGO model, which demonstrated they were still engaging with material despite simultaneously chatting. Another example of the benefit of smaller focused groupwork was observed when a particular student stood up and began wandering around the conference room during a large group discussion. It was clear that the way in which material was being presented was not engaging or effective for this particular student.

When it came time to work on the LEGO models in larger groups, this student was also frustrated and combative with their peers, since they were not able to have their desired level of agency in the construction process. However, when groups of 2 and 3 were given the task of working on the LEGO models, this student was much more focused and receptive to working with another of their peers, and together they were able to make substantial progress.

Concrete development in STEM skills was a challenge to properly evaluate and detail in the brief period the team spent with the students. The first two weeks spent with the students at the community center were almost entirely dedicated to introducing them to the concept of FLL, watching introductory videos, and determining that the large group setup would not be effective. The research team then worked to transition meetings to a smaller group configuration, where researchers and students worked on completing LEGO models, learning about sensors, and discussing how cities are planned. Instead of jumping into the technical detail of how sensors work, students first discussed how different animals, such as bats and dolphins, use echolocation to find their way. Before opening the programming software, students had to “program” each other to successfully navigate a maze of chairs set up in the conference room. These mini-lessons had direct ties to the FLL curriculum, but were much more manageable, appropriately engaging, and encouraged students to draw their own conclusions from these new experiences in order to better their technical and soft skills. Ultimately, most students were still marked as being in the beginning phase of skill development when the program was suspended due to COVID-19. Major observations in the short period of time were that a student’s comfort and eagerness to engage with the material taught was roughly correlated with the student’s previous experience in science, math, and robotics.

COMMUNITY IMPACT

Both the Northend Community Center and the Hartford Hub were extremely interested in establishing STEM programs to benefit the middle school population of their communities. Thanks to their willingness to collaborate and invest in their youth, the research group was able to engage with approximately 20 students. In partnership with the Ware Research Group, both community centers were able to expand their youth offerings and support their patrons through a fun and novel STEM program. The program also helped each center work toward their goal of neighborhood enrichment and academic

development, specifically as to how it pertains to middle school students.

Throughout the partnership, several challenges evolved within the research project. Most notable were those brought on by the COVID-19 pandemic. Due to the hands-on, project-based learning focus of the program, there arose an obvious concern for student and researcher safety and well-being. In response, the research team suspended its in-person mentoring. Additionally, due to the lack of resources to properly sustain a meaningful learning experience in a virtual environment for all involved students, the research team did not pursue a virtual option for the program. Other challenges experienced throughout the project included minor communication issues between the community partner and the research team. This could be attributed to the recent establishment of the Northend Community Center, as well as unclear communication within the research team.

After the first session, the research team determined that the standard FLL curriculum would need to be retooled to best suit the needs of the students. One challenge faced was how to best capture the attention of the students for meaningful amounts of time. After spending eight hours in school, many were unable to focus on learning new material. Another challenge was how to cater the material to a wide range of interests. Not every middle-schooler is immediately interested in the heavily technical aspects of robot design, nor is every student interested in the creative elements of designing a dream playground. To accommodate a wide spectrum of interests, the research team worked to know the students on a personal level, in order to connect material with individual interests.

STUDENT IMPACT (ERIC)

Personally, working on this project has been one of my most rewarding experiences since coming to Purdue. Seeing the joy on the kids’ faces when they solved a problem was priceless. My biggest personal development was the ability to work with kids in this setting for the first time. Before this project, I had only worked with kids coaching them in sports. However, academically, it was a totally different environment. It was terrifying at first, and it was a humbling experience. The ability to confidently work with kids will certainly help in the future. I also learned to become a better communicator, public speaker, and leader. I needed to be able to confidently deliver the goals of the project to the kids, my teammates, and outside observers. Professionally, I have been able to spread a lot of information about this

project through presentations and publications. My teammates and I have given multiple presentations on this subject. We are also working on two publications for this topic. These avenues to tell people about our research have helped significantly with both oral and written communication.

As previously mentioned, working with kids in a setting like this was challenging. They were so unpredictable, and it was a bit chaotic at first. I addressed the challenge with a few solutions. First, I learned I had to bring as much energy as the kids, which meant I could not show I was nervous. Once I matched their energy, I immediately learned how to better manage the environment. Second, we came with a full schedule of activities, so there was no downtime in which the kids could get off track. Next time, I will have this knowledge to help me.

I will absolutely work with kids more after this experience. The opportunity to impact a kid's life is special, and I do not take it for granted. Whatever community I am in after college, I would like to start a program like this. I believe its potential for impact is vital for both kids and the community. The project was put on pause due to the pandemic. However, whenever it is safe to do so, we will continue to work on this project. The North-end Community Center, which houses the Hanna Center, has been a valuable partner to the research team in the past. This project further solidifies that relationship. They provide us with an opportunity to do meaningful research, and we provide them with community-enriching data and projects. So, there will be future projects with the community partner. The LEGO League project will start again as soon as possible.

STUDENT IMPACT (HANNA)

This research project was especially important to me because I grew up within the FIRST ecosystem. I have been involved with FLL as a student, a mentor, and a volunteer. Working with this research team has challenged my ability to adapt on the fly and meaningfully reflect on the impact that the program has on its students. Sometimes it is easy to get caught up in the competition elements, causing us to lose sight of the real success that is student growth.

For example, all the teams that I have previously mentored are comprised of veteran students—those who have been involved with FLL for several years and are ready to dive deep into dense technical concepts. By working with a completely rookie team, I was challenged to think differently about what it meant to be

a mentor. I constantly worked to retool mentoring sessions when it was obvious my teaching was inefficient or ineffective. I also encouraged students to let me know if my explanations were unclear, or if they were frustrated by a concept. Not only was it a learning experience for my students, but for me as well.

The time spent with this research project has only reinforced my commitment to service within FIRST. I have always intended to continue with the program as an alumna but working with this group of students has only shown me a small fraction of why programs like this are so important. To help the next generation succeed, we need to provide them with as many resources as possible—and I know this program is one of the best.

STUDENT IMPACT (CHRISTOPHER)

As someone who participated in two years of robotics and took four years of engineering classes in high school before suddenly deciding to switch into a business field, I was surprised to come full circle in assisting with this project. In my junior year of high school, I changed my future major from civil engineering to economics but continued to participate in robotics and my school's engineering classes until I graduated. At robotics competitions, I was often the only one around who could not answer "some form of engineering" when asked what I would be studying in college. However, as the leader of my team, I tried to focus on organizing our team members and managing specific objectives for competitions while being an overall handyman in case any individual member was unavailable. This holistic approach is what I think most prepared me to work on this project, as I had to look at the design and presentation processes in their entirety as a high schooler and then help find a proper method to teach those concepts to students as a member of this group.

What stuck out most for me during this project is how important abstraction and conceptualization were for the students early in the process. Attempting to move to building stages too early would have been both unfeasible due to lack of commonly set expectations and ineffective, as students would not have had a shared framework from which to begin tackling team challenges. Working directly with the students was personally the most enjoyable aspect of the project, and seeing them slowly warm up to and recognize our team each week was something I always looked forward to. I believe that this has solidified my feeling that I want to continue teaching and working with students in the future, even if it is not in a traditional classroom context.

CONCLUSION

The importance of this research can be summarized through the objective statements. First, the project provides important skills to a group of young people who would not otherwise have these opportunities. Second, the research team can gather important data and make conclusions about projects of this nature. That can be scaled to the third point. Third, through this research, the team could find a viable path to help address minority underrepresentation in STEM. Once the COVID-19 pandemic allows, this project will be continued for the foreseeable future. Its impact is too great to not continue the project. The same process will be followed; however, the curriculum will continue to be revised as the research team learns more about what works well. The team will apply for grants to help continue the project.

In the future, potentially more teams will be founded. It is possible we will partner with other organizations to found teams in other areas. Reciprocity could mainly be improved through increased communication. As students, we constantly have communication at our fingertips. However, when working with community partners, they may not stay up-to-date on their emails as rapidly as we do. So, to maximize the impact we bring to the project, we should make the most of our communication opportunity with the community partner. Finally, the reason my co-authors and I have written this article is to spread information about research about which we are passionate. We hope this article gives insights into efforts students are making into impacting our communities. We would encourage readers to pursue opportunities to make the same impact in their communities.

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