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”Make it Be a Real School”: An Author’s Perception on Community Approach for Teaching Engineering (Evaluation)

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Introduction

With most K-12 public schools comprising students with varying backgrounds, experiences, strengths, and needs, STEM (Science, Technology, Engineering, and Mathematics) educators are key to integrating student interests with their lived experiences. In the current technology-rich era, where every teenager has a phone glued to their hands, it has become pertinent to design school-based educational activities that stimulate and build upon those interests. Students’ motivation levels increase when they combine their experiences with learning activities. Similarly, research indicates that integrating science, math, and engineering concepts positively impacts student engagement with engineering design and skills [1]. Furthermore, students who receive authentic STEM experiences outside of classrooms have an increased interest in STEM and a desire to pursue STEM careers [2].

Middle school years are prime years of career awareness, especially when students see adults in STEM careers; it resonates with them and piques their interest [3,4]. Moreover, when students engage in authentic hands-on activities and can see applications of STEM in their lives, it further motivates them to pursue STEM careers [3]. Therefore, keeping the research in mind, Introduction to Research and Innovative Design in Engineering (iRIDE) was initiated in the spring of 2019 for middle school students as an after-school extracurricular club followed by a summer academy to stimulate their interest in engineering. Using an asset-based community approach, iRIDE gauges middle school students’ interests in STEM activities. Therefore, this paper aims to evaluate iRIDE’s community approach with two guiding research questions: 1. How are student participants’ voices utilized to align engineering activities with their grade-level curriculum and future career plans? and 2. How do the facilitators engage the students in program activities to ensure a community-based approach?

Literature Review

Allowing students to bring their experiences into school-based educational activities is critical in fostering their interest, especially in STEM careers. Various schools nationwide have programs that aim to pique students’ interests in STEM, such as Engineering for All and I AM STEM [5,6]. Such programs instill confidence in students so they can make a difference in the world [5]. Moreover, it benefits students, especially Black girls, when connections between formal and informal learning environments are made [6]. These programs do not necessarily utilize the community asset-based approach in recruiting that iRIDE utilizes. Community-based education “is centered on the student’s ability to recognize and support the needs of the surrounding community” [7]. Using this approach, students, as responsible citizens of their communities, “gain understanding, use knowledge, and solve problems while developing a sense of self” [7].

Although STEM school-based programs, such as Engineering for All and I AM STEM, use a community-based approach in organizing their activities, iRIDE is unique in the way it recruits participants. The students consider the dynamics of their communities and discuss the issues their communities face, for instance, the lack of sidewalks, brainstorm solutions using the engineering design process and present the results to community stakeholders, including parents and teachers. Similarly, in iRIDE, students utilize the issues their communities face and their prior experiences to determine the scope of their Capstone Project, the hallmark of the Summer Academy. The following sections offer detailed information about the iRIDE program, methods for evaluation, findings, and future implications.

iRIDE Structure

The goals of the iRIDE program are for students to apply math and science concepts via curriculum-appropriate hands-on engineering projects, to encourage them to look at engineering as part of their lives, to influence their educational pathway towards a STEM endorsement in high school and to pave the way for them to embrace engineering and pursue engineering careers. In iRIDE, students get acquainted with different engineering fields through projects highlighting career paths, field trips, and talks by guest speakers that allow students to see role models with similar backgrounds (see Figure 1). iRIDE comprises two parts: an after-school extracurricular club and a Summer Academy.

Figure 1: Guest Speaker from NASA

During the academic year, students partake in STEM activities aligned to their grade-level curriculum weekly or bi-weekly after school, facilitated by a math/science instructor from their respective middle school campus. iRIDE program lead guides the facilitators and provides all resources and materials necessary to complete the activities at their campuses. The activities range from building a Mint-Mobile that explores gravity, friction, and unit rates to building a Straw-boat that explores carrying capacity, budgets, and surface area. Some activities can be explored in one club session, while others require 2-3 sessions. All activities encourage students to ask and explore questions to better understand the world around them and connect their learning to their classroom curriculum.

Figure 2: Students actively engaged in hands-on project

The second part of the iRIDE program is a two-week-long Summer Academy facilitated by the program lead and teachers from the affiliated middle schools. Students from affiliated schools apply for the Academy and immerse themselves in an extensive engineering program through hands-on projects and other activities geared towards engineering. In the two weeks, students tour the university campus, participate in hands-on STEM activities, attend guest speaker sessions from varying engineering fields, and complete a Capstone Project using their prior experiences and community dynamics (see Figure 4 for Summer Academy agenda). Research indicates that transportation arrangements are sometimes associated with low participation in after-school or summer programs [8]. Therefore, to ensure iRIDE participants do not have such logistical issues, they receive complimentary transportation to and from their schools in the summer and free lunch.

Figure 3: Summer 2022 Cohort

Day 1 (Jul. 22)		Day 2 (Jul. 23)		Day 3 (Jul. 24)		Day 4 (Jul. 25)		Day 5 (Jul. 26)	
Engineering Focus: Engineering Design Process		***Engineering Focus: Architecture***		***Engineering Focus: Aerospace Engineering***		***Engineering Focus: Mechanical***		***Engineering Focus: Mechanical***	
9:00-10:30	Welcome & Orientation	9 – 10:30	Marshmallow Building	9 – 11	*Stomp Rockets*	9 – 10	Daily Challenge: *River Crossing*	9 – 11	Capstone Project
10:30 – 12	Campus Tour	10:30 – 12	Whirligig – Pin Wheel	11 – 12	*NASA Engineer Guest Speaker & Activity*	10 – 12	Get to the Chopper!	11 – 12	*TXDoT*
12 – 1	Lunch	12 – 1	Break/Lunch	12 – 1	Break/Lunch	12 – 1	Break/Lunch	12 – 1	Break/Lunch
1 – 2:30	Going the Distance! – Paper Airplanes	1 – 1:45 1:45 – 3	Kinder Institute Introduce iRIDE Capstone Project	1 – 3	Capstone Project	1 – 1:45 1:45 – 3	HCFCD Capstone Project	1 – 3	No Speeding!
2:30 – 3	The Engineering Design Process								
Engineering Type: *Campus Tour*		Engineering Type: *Engineering in many fields*		Engineering Type: *Aerospace Engineer*		Engineering Type: *Mechanical Engineer*		Engineering Type: *Mechanical Engineer*	

Day 6 (July 29)		Day 7 (Jul. 30)		Day 8 (Jul. 31)		Day 9 (Aug. 1)		Day 10 (Aug. 2)	
Engineering Focus: Engineering In Action		***Engineering Focus: Engineering Project #3***		***Engineering Focus: Engineering Project #3***		***Engineering Focus: Planning for the Future***		***Engineering Focus: Presentations/Showcase***	
9 – 10	Daily Challenge: What's my Weight?	9 – 11	Start with the end in mind! – SMART Goal Setting	9 – 10:30	Daily Challenge: Coding with Cups	9 – 11	Capstone Project	9:00 – 10:30	Reflection survey
10 – 12	Slime to Bounce	11 – 12	Radiation Spill	10:30 – 12	Scratch Programming	11 – 12	Communication is KEY! How to present.	10:30 – 12	Capstone project display set up
12 – 1	Lunch	12 – 1	Break/Lunch	12 – 1	Break/Lunch	12 – 1	Break/Lunch	12 – 1	Break/Lunch
1 – 2	BRC Tour – Nest 360	1 – 3	Capstone Project	1 – 3	Capstone Project	1 – 3	Submarine	1 – 2:30	Certificates and Recognition
2 – 3	BRC Tour – BIO Lab							2:30 – 3	Closing Remarks and Thank Yous
Engineering Type: *Bimolecular Engineering* *Chemical Engineering*		Engineering Type: *Electrical Engineer*		Engineering Type: *Computer Engineer*		Engineering Type: *Prep Projects for last day.*		Engineering Type: *Closing Ceremony and Showcase*	

Figure 4: Example of Summer Academy Agenda

Students spend some time working on their Capstone Project using engineering design skills each day. The first step in the Capstone Project is the identification of the problem. Each student determines their community's concerns - this allows students to look at their community critically and compare it with surrounding communities. Once all the issues are compiled, students work in teams, follow the engineering design process, and brainstorm solutions to one of the problems. They collect data and formulate hypotheses. For instance, one of the problems students have worked on in the past is the lack of or damaged sidewalks in their community. Students are asked to think through and brainstorm solutions - think about the logistics, from how it will work to how much it will cost and where it will be located and determine the engineering field that can solve the problem. In the case of sidewalks, students used the civil engineering field. In the past, for this particular problem, the students hypothesized that using a new type of cement would make the sidewalks last longer. They determined the materials needed, their quantity and price, and how long it would take to fix the sidewalks.

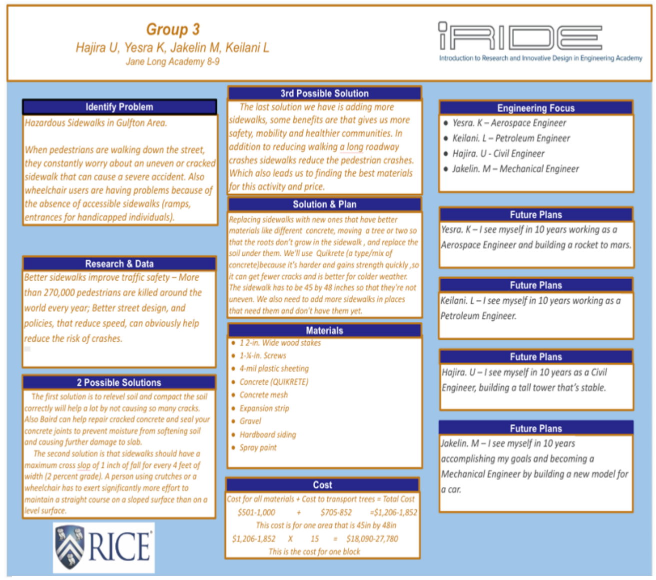

Figure 5: Capstone Project poster created by one of the groups in the Summer Academy 2022

This culminating project allows students to develop a growth mindset while solving issues of their communities using engineering design. Once solutions are determined, the students create a poster presentation organizing all the information from their project (see Figure 5 for an example poster). At the end of the two-week program, each team presents their project to other students, teachers, and community members, including the parents (see Figure 6). These presentations to an audience enhance their communication skills, boast their confidence in engineering, and allow them to grow as future STEM leaders.


Figure 6: Students presenting their posters to other students, teachers, and parents

Besides end-of-the-summer presentations, iRIDE enhances the participants' leadership characteristics and communication skills by allowing them to serve as mentors the following year for the new cohort of students. Past iRIDE participants apply to attend the summer academy, and at least 4 of them are selected to mentor the new group of students. By taking on leading roles and providing guidance and support to their mentees, mentors develop their own leadership abilities while also modeling leadership behaviors for others to follow. Moreover, through mentorship, new students gain valuable insights into what it takes to succeed in the Summer Academy and how to navigate the challenges that may arise along the way. Mentors share their own experiences and offer advice on everything from time management and study strategies to building relationships and networking.

Methods

Recruitment & Selection

Students are informed of iRIDE via flyers posted around the affiliated schools and through direct teacher-to-student notifications. The affiliated schools in the Gulfton Community are purposefully selected because they are part of the Complete Communities Action Plan in Mayor Turner's plan for a more equitable Houston [9,10]. The location of the community, right next to one of the most affluent neighborhoods of Houston, and the diversity of the members residing in it are one of the major assets. The Gulfton Community "is the most densely populated Super Neighborhood in Houston" [10] and 69% are Hispanic or Latino, 14% Black or African-American, 8% White and 7% Asian, and 59% are born outside of the United States compared to 29% in Houston overall. Therefore, based on the community dynamics, it is inferred that the students from this area have a plethora of unique experiences due to the diverse mixture of various racial and ethnic backgrounds. These experiences can be an asset, especially in the classroom [11].

Participation in the iRIDE program is open to all 6-8th grade students from affiliated schools. Each year (from 2019-2022, excluding 2020 due to the COVID-19 pandemic), approximately 30 students from three middle schools participated. Some students attended both the academic year activities and the summer academy. In contrast, others took part in one or the other. Although demographic information of the students was not collected, 100% of student participants were from underrepresented minority groups, and 100% qualified for free/reduced lunch.

Data Collection

Qualitative data was collected from the participants and facilitators to understand the program's impact on students. 40 students completed reflections via Google Forms at the end of the Summer Academy. At the same time, two facilitators participated in semi-structured interviews. Using a grounded theory approach, we discerned the potential influence of iRIDE on the students in instilling a desire to pursue engineering to solve community problems, identify students' level of engagement in activities, and communicate the program's successes and challenges.

Findings

In the end-of-the-summer student reflections, it was noted that the students were intrigued by the countless possibilities within the engineering field. Various themes emerged from student reflections, as displayed below in Table 1. Students thoroughly enjoyed the activities as they were fun and challenging at the same time. Moreover, students learned about the various engineering careers and how their daily life utilizes engineering. Student feedback allowed the facilitators and the program lead to understanding what works and does not work within the program. Moreover, it allowed the students to voice their opinions without hesitation.

Table 1.
Qualitative Analysis of Student Reflections

Theme & Frequency	Description	Student Quotes
Fun & Engaging (83%)	Students learned and enjoyed the activities	*"It is a fun camp; as you have fun, you learn a lot."*
Did not know this before (73%)	Engineering-related facts that students did not know prior to attending the program	*"There are different types of engineers that I didn't know about…"* *"I learned that there is literally an engineer for almost everything and that engineers have to think outside the box for a lot of the time"*
Challenging (40%)	Students were challenged during activities and their project	*"it's a great program that gets your brain working really fun"* *"It challenge[d] my brain in a way that school never has"*
Changes (33%)	Some students suggested some changes to the program	*"Do more activities in the communities"* *"Make campus tours more exciting"*
Friendships (23%)	Students formed friendships within the program	*"[Summer Academy] helps you make more friends as well as help be more smarter in a fun way."*

Besides students' feedback, the facilitators participated in semi-structured interviews to demonstrate the program's impact on the students. They noted that "more exploring and hands-on activities impact students positively." They recognized that students feel more comfortable exploring hands-on activities and learning from mistakes, especially with less emphasis on marks. Students are not afraid to "screw up as there's no pressure." Facilitators apprised that after participating in iRIDE, the student's confidence levels increased, especially those who returned the following year and served as mentors. The facilitators noted that students were challenged by the Capstone Project as they utilized their lived community experiences and connected them with engineering.

Discussion and Future Implications

The primary objective of this study was to evaluate iRIDE's community-based approach to teaching engineering by examining how student participants' voices are utilized to align engineering activities and how the program facilitators engage students in activities to ensure a community-based approach. A community approach in STEM, which emphasizes collaboration, shared responsibility, and collective learning, can be particularly effective in promoting students' creative thinking, perseverance, and STEM career interests [12].

Overall, the student participants found the program to be a fun, engaging, and challenging experience. They utilized knowledge from engineering fields acquired through the program to solve issues within their communities. The program piqued their interest and allowed them to make connections to their lived experiences. Providing such positive and enjoyable experiences to students helps maintain their motivation to persist in STEM [3, 13, 14]. Moreover, the student responses suggest that the program exposed them to various engineering fields and aspects they previously did not know. This unfamiliarity of engineering fields in middle school highlights the importance of providing meaningful exposure to STEM activities to impact student STEM trajectories significantly [2, 15].

Collaboration was integral to the iRIDE program, and the students appreciated the opportunities to problem-solve, think critically, and subsequently form friendships. Research shows that teamwork activities foster positive learning environments, and with peer and educator support, students develop positive beliefs about success in STEM [13]. Therefore, to have a lasting impact on students and their trajectories towards engineering, it is important to continue utilizing asset-based community approaches to foster STEM engagement and make students aware of their communities' needs from an engineering perspective. Moreover, continuing to provide hands-on opportunities to practice engineering skills is pertinent. Having a year-round extracurricular club followed by additional extensive summer programs attempts to do just that. In the future, we would like to formulate research questions and collect more data to understand the implications of this program on student STEM endorsements in high school and beyond.

Conclusion

For students to become valuable citizens of their communities, it is pertinent that educators allow them to explore connections between their communities and engineering design. Programs and projects, such as iRIDE, with a strong community focus, are necessary to change student trajectories toward engineering. The information presented in this paper can allow others with similar interests to execute such programs and see their impact in their communities. Although further research is required to understand the program's impact on the students in the long run, the community approach of this program is a good starting point for embedding STEM learning into real-world issues.

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