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Demystifying STEM Together: Parents as partners in making engineering more inclusive (Work in Progress, Diversity)

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Introduction

The diversity of the U.S. population is changing with predictions indicating that by 2050 there will be no "majority race." Already, Latino and Black communities make up 30% of the country's population [1]. However, this current level of diversity is not reflected in the STEM fields. In engineering, there has only been a small increase in Hispanic graduates from 8.5% in 2011 to 11.9% in 2019 and almost no increase in Black graduates (4.2% to 4.3%). Over 50% of the engineering graduates nationwide continue to be White [2]. Increasing diversity in STEM is required to solve important problems faced by society through a wider array of solutions [3].

Unfortunately, Black, Latino, and Indigenous youth often close the door to STEM careers early in their lives. Unable to view this future as viable, they struggle with their sense of belonging in STEM [4]. A lack of representation amplified by unconscious and conscious messages from educators and mentors, often results in the perception that "engineering is not for me". Institutions frequently reward academic preparation, talent, and hard work as what matters for persistence in STEM. However, experiences in STEM are laden with inequities affecting sense of belonging, which can be much more salient in determining who persists in STEM spaces [3].

For historically marginalized youth to realize their significance in STEM, explicit efforts need to be made by the STEM community to not only help them see STEM as approachable, but also to represent the cultures of their communities in the field of STEM. Such efforts might include providing near-peer mentors or inclusive STEM outreach. According to Grossman and Porche, "Supportive figures can mitigate the effects of negative societal messages. Supportive influences that challenge stereotypical gender or racial/ethnic expectations can enhance adolescents' STEM engagement" [5]. Childhood experiences like talking with friends or family about science and reading or watching fiction and nonfiction science media can have significant positive influences on students' STEM identity. Informal STEM learning experiences have been shown to increase students' STEM interest, as well as their sense of recognition [6].

Research points to the importance of community, particularly family, on the interests and careers that students choose. Students develop higher self-efficacy and STEM outcome expectancies when parents stress the importance and value of these subjects and support STEM experiences both in- and out-of-school [7]. Parental encouragement including toy selection, access to technology, and high-quality community resources and formal schooling can provide children substantial advantages during elementary and secondary schooling [8]. The STEM community's goal should be to create culturally responsive partnerships with diverse families. These partnerships should be authentic and equal, empowering the families to become active participants, allowing them to show who they really are and celebrating the strengths and resources that they bring to the school and community [9].

The Program: IMAGINE Family STEM Nights

IMAGINE Family STEM Nights engages underrepresented 5th-8th graders and their families in enriching engineering design projects and discussions. This initiative began with a collaborative partnership between the University of Illinois' Grainger College of Engineering, and the community-impact organization, DREAAM which serves predominantly Black and low-income youth. Informed by the theory of Culturally Relevant Pedagogy [10], this initiative provides opportunities for students to bring their full selves to the STEM learning, providing opportunities for choice and self-expression, appreciation of cultural contributions and assets, and critical awareness of systemic and internalized bias and inequity. The activities foster a peer-to-peer relationship between the students and their adult family members, allowing them to both build their knowledge and interest in STEM as well as working through misconceptions and barriers in the field of STEM.

This multi-year initiative, funded by Grainger Engineering Institute for Inclusion, Diversity, Equity, and Access Grassroots Initiatives to Address Needs Together grants (GIANT2020-04, GIANT2021-11), is designed for out-of-school, informal-learning. Six family STEM sessions are implemented during the academic year with each session revolving around a different STEM major. Each STEM session's content and discussion integrates three primary components: (1) engagement in an engineering design challenge, (2) introductions to diverse role-models in STEM from similar backgrounds, cultures, and/or race of the student participants, and (3) activities to challenge myths and perceptions that often cause individuals to close the door to a potential future in STEM professions. Each month's STEM design challenge is constructed and facilitated by major-specific student organizations from the University of Illinois, and members of the local chapter of the National Society for Black Engineers (NSBE) played leadership roles in this coordination. Students and families interact and build relationships with college students who are involved in STEM fields, and these relationships help to build a sense of belonging and connection for the middle school students.

The COVID-19 pandemic forced the 2020-2021 pilot year to transition from in-person intentions to an online reality. The Zoom platform was used for online gatherings to share designs and interact with others. Instructional and informational videos, as well as activity handouts were made available on a password-protected website for the families. Activity kits were picked up or delivered at the beginning of an IMAGINE STEM week. The kits were used by the families to work independently on the design activities during the week. On Friday, the families and staff logged into Zoom to showcase and discuss their projects and processes. Discussions also included a myth busting topic. See Table 1 for an example of the components included in this virtual version of IMAGINE Family STEM Nights.

Table 1. Monthly Family STEM Modules

Module Structure	***Example: February Electrical and Computer Engineering***
Student Led	Challenge designed and led by the Women in Electrical and Computer Engineering (WECE) student organization. Members provided an hour of evening office hours and attended the Friday Showcase.
Design Challenge	Paper Circuits: "Create a card, picture, or other craft that includes battery-powered lights that can be turned on and off." Constraints: Must use at least two LEDs and contain one switch in the design.

Design Challenge Lab Kit	Supplies: Coin cell batteries, copper tape, colored paper, multiple LEDs of different colors, paper clips, decorative stickers, and pipe cleaners. Handout with the challenge and instructions for accessing the website and web conference
Challenge Video	Women in Electrical and Computer Engineering (WECE) students introduce the design challenge
Scientific Concepts Video	Animations, text, and images narrated by WECE members to explain the history and science of LEDs and circuits
Industry/ Career Examples	Video and online article of James Edward West, professor of electrical and computer engineering, inventor of the Electret microphone (and 250+ more patents). Video of undergraduate students discussing why they chose this major and what they most enjoy about the field of ECE
Showcase Guest	Members of the Illini Solar Car Design and Racing Team
Mythbuster Discussion	Debunking engineer stereotypes with examples of famous people with STEM expertise (e.g., Dwayne "The Rock" Johnson, model Lyndsey Scott, NFL quarterback Josh Dobbs, actress Hedy Lamarr)

Study Methodology

Nineteen 5th-8th grade students (15 families) signed up to participate in the IMAGINE Family STEM Nights' monthly activities. Of these, eight families (nine students) were able to attend one or more Friday showcase sessions. One third of the participants identified as female. Data collection occurred throughout the year and included pre- and post-surveys of parents and students; observation notes of the Friday Showcase Zoom sessions, submitted project artifacts; feedback forms for the engineering design projects, and end-of-year semi-structured interviews. An inductive qualitative analysis [11] across all data sources surfaced important themes to inform our future efforts and to begin responding to two guiding questions:

- To what extent does engaging in STEM activities as a family increase interest in STEM and beliefs about future success in STEM?
- How does explicit instruction into hidden rules, systemic biases and stereotypes, and untapped resources influence beliefs about future success in STEM?

Data Collection

Pre- and post-surveys were designed to measure changes in engineering knowledge and the attitudes and beliefs held by students about their ability to pursue and succeed in STEM courses and careers. Survey questions also assessed the attitudes and beliefs of the parents regarding their child's ability to pursue and succeed in STEM, as well as their perceived influence over this, particularly within racist and biased systems. Feedback forms were designed to collect ratings of interest and satisfaction, as well as lessons learned and emergent questions resulting from the activities. The pandemic-driven move away from in-person to online data collection resulted in low response rates to these surveys and forms. These data were incorporated into the qualitative analysis. Semi-structured interviews were conducted after the fifth session for the year to gauge student understanding, attitudes, and beliefs about engineering, as well as gathering feedback from the families. Zoom session observations and submitted student project videos were also included in the qualitative analysis.

Analysis of Data

An inductive data analysis process was used to review and identify themes within the data [11]. Independent reviewers thoroughly reviewed the data collected and identified recurrent concepts. This inductive method allowed for themes outside of the scope of the research questions to be considered, such as the contextual factors associated with implementation during a global pandemic. For increased trustworthiness of this analysis process, two researchers independently reviewed the data to identify initial codes [12], and then compared, critiqued, and negotiated the overlapping and divergent codes to reach agreement on an initial set of themes. These themes will be used for coding and triangulation of the current data set as well as the new data to be collected in the 2021-2022 school year.

Results and findings

Despite the challenges associated with the COVID-19 pandemic shifts from in-person to virtual implementation and data collection, this initial analysis surfaced four relevant themes that will be used to guide the next round of analysis.

The Role of Relationships: Relationships played a frequent part in the student and parent experience of the Family STEM Nights. From pre-surveys, adults were of the mindset that they had an impact on their children's interests and capabilities. Session observations and student responses indicated that the adult family members were present and persistent through the activities, and assisted their students in completing their design projects, giving them insights based on their understanding. For instance, one of the parents advised their student to think about how fragile items are shipped in the mail as they considered design options for the egg drop challenge. Parents not only encouraged their own students, but also appreciated and commented on the learning processes and designs of other students. We also observed eager collaboration with siblings to help build the project, displaying an investment of the entire family in these sessions. Relationships through the DREAAM organization seemed to also be related to online participation decisions. Some student participants seemed more hesitant to interact with university students and staff than with the staff and families of the organization. The role of relationships stretched beyond family to also include broader community relationships.

Engineering Understanding: In pre-surveys and early session discussions with the students, when asked what an engineer does, students mostly provided a generic description of someone who builds things like buildings, bridges, and rockets. By the end of the year in interviews and surveys, the students were able to identify the role of different types of engineers (mechanical, electric, computer, industrial, environmental, etc.) and also recognize the process of engineering as one that they carry out in their daily life. This helped ground their understanding of engineering in the real-world. As an indicator of the role that relevance plays in understanding, students referenced pop-culture in their designs and design decisions. They envisioned engineers developing designs and solutions connected to their day-to-day lifestyle (like making glowing nail polish and a machine to fold clothes), as well as for more diverse applications like making hearing aids, medicines, cars, batteries, generating electricity etc. Through completing their design projects, the students also developed a better understanding of the iterative design process in engineering, and realized that they are, as one student put-it, “every-day engineers.”

Identity: The students were able to interact and hear the stories of people that they related to, including the founders of the National Society of Black Engineers. The parents appreciated this connection, claiming that it allowed their students to be inspired, and strengthened their sense of belonging by seeing themselves represented in all fields. The students also displayed surprise and engagement in guest speaker talks. For instance, engaging with Psyonic’s CEO, students mentioned that they didn’t think they would ever get to talk to a CEO. The students were able to imagine a broader future for themselves, opening up opportunities of going to college, and how to engage in studying, playing sports, or joining clubs like Illini Motorsports. From post-surveys and interviews, we see evidence that students were able to see themselves as becoming different types of engineers in the future.

Impacts of the Pandemic: Conducting the Family STEM Nights activities virtually impacted the family and student learning experience. Families frequently faced technical difficulties, especially during the first few sessions, resulting in incomplete projects and difficulty in understanding instructions. Instead of face-to-face collaboration, families had to upload videos of their projects and complete survey forms online. Through feedback forms, students also indicated interest in being able to collaborate with other groups of students, which was not feasible at the time. Interestingly, when students were asked where they could apply engineering solutions, multiple students identified pandemic-related problems and designs. During the post-interview a student came up with the idea of making a sensor that would alert you if someone came closer than 6ft. This showed that they were able to apply an engineering mindset toward the present context of the pandemic within intention to make their lives better.

Next Steps

With funding for a second year, we will expand the scope (new engineering fields represented) and reach of the content (added partner organization and publishing content for public access) while also strengthening the research based on lessons learned from this first year. In this second year, we are adding parents to the planning team. The 2020-2021 pilot showed us that parents were keen on the activities but challenged to participate regularly, thus including their knowledge and experience on the leadership team along with additional interview efforts will provide new perspectives on the design of the events and participation challenges. This will help us attenuate the sessions to better serve more of the families. We also anticipate that with a return to in-person events, the participation in research activities (surveys, feedback, and interviews) will improve. We will also be able to better capture photographs and observations of the design and discussion processes. With the current findings and themes in mind, we look forward to the next phase of analysis as we further investigate the impacts of each of these themes applied to new activities, new settings, and new participants.

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