Board 162: Engineering for Accessibility: Impacts of a High School Engineering Internship Model Across Different Settings (Work in Progress, DEI)

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Engineering for Accessibility: Impacts of a High School Engineering Internship Model Across Different Settings (Work in Progress, Diversity)

Abstract

This paper describes a collaborative effort to develop, implement and research an empathy-driven, accessibility-focused engineering internship program for teens underrepresented in science, technology, engineering and math (STEM). The program builds on a foundation developed by the Build a Better Book (BBB) project over several years (2016-21) and addresses a significant need to motivate, prepare and support a more diverse engineering workforce. Centered around principles of universal design, designing for accessibility, and engineering with empathy, the current NSF-funded project examines how high school interns' perceptions of engineering and self-identities as engineers are formed, nurtured, and cultivated as they design and create more accessible products for authentic community clients who are blind or visually impaired. Across sites, the project emphasizes building an inclusive and diverse community of interns, including many who may not initially view themselves as engineers. Underpinning this work is the People Part of Engineering framework, which emphasizes that engineering with people, as people, and for people influences teens' motivation and persistence of interest in engineering. To assess the effectiveness of the BBB teen internship model, the project team implemented and researched different formats of the program in two educational settings: an intensive, 4-week summer program at a public university and an out-of-school-time, semester-long program at a public library makerspace. Combined, these programs engaged 59 youth in an iterative engineering design process focused on the design and fabrication of accessible products (e.g., games, toys and STEM learning models) for children and youth who are blind or have low vision. (An additional year-long, in-school program reaching more than 70 students is currently in process.) Each program incorporates several key internship design principles, including authentic, client-based projects; a student-directed, collaborative work environment; and individual and team mentorship. The current project aims to impact teens' perceptions of engineering, their engineering identity, and their confidence and competence in engineering and 21st century workplace skills. These outcomes were measured through a combination of quantitative and qualitative methods, including pre-/post- surveys and audio reflections by students, interviews with site leaders, and culminating focus group discussions. Early findings suggest positive changes in the intended outcomes, across sites, including broader perceptions about engineering and a growing overlap in identity between participants and engineers, increased confidence and competency in engineering and technical skills, and gains related to interpersonal skills and other 21st century skills such as communication, critical-thinking and collaboration. The project's ongoing and future work will test the internship model at additional sites, including a school and science center, and continue to assess the effects of variation in program format, internship projects, work environment, and support and training on interns' engineering identities, their persistence of interest in engineering, and how they engage as young engineers with, as, and for people.

Introduction

The Build a Better Book (BBB) Teen Internship Program addresses the need to motivate, prepare and support a more diverse STEM workforce, particularly in the field of engineering. Leveraging youths' interests in helping others, the project engages teens in an authentic engineering design experience in which they create accessible materials for children who are blind or have low vision (BLV). As interns work to engineer an accessible product for a real-world client, they gain technical and STEM workplace skills and broaden their perception of engineering as a holistic discipline that may better align with their own interests and self-conceptions. By researching this unique internship model across four diverse learning settings–including a school, public library, university, and science center–the project aims to advance the field's understanding of how to design and support effective pre-collegiate engineering internship experiences that influence teens' self-perceptions related to persistence in engineering. In this paper, we describe how the program has been developed, implemented, and studied, and share early findings from two iterations of the program at each of two sites: a university campus and a public library.

Project Rationale

Broadening participation in engineering and other STEM fields is a national imperative. Many historically marginalized groups continue to be significantly underrepresented in engineering despite numerous efforts to diversify the field [1], [2]. Many youth have a limited perception of engineering, and often this fails to align with how they view their own interests and strengths [2] - [4]. Several studies have documented how gendered self-conceptions, professional identities, and expertise that is valued in engineering likely contribute to fewer women persisting in engineering study and a significant wage gap in engineering careers [5], [6]. The lack of diversity in engineering and other STEM fields perpetuates societal inequities and limits the field's ability to tackle complex global challenges, as more diverse backgrounds and experiences bring new perspectives to addressing big problems and generating innovative solutions [7].

To address this disparity, some have called for a reframing of engineering to shift from a focus on technology to a focus on the important work that engineers do [4]. This reframing–from engineering as technology-driven to empathy-driven with real potential to impact people's lives–may attract a broader group of students who otherwise might not identify as being interested in STEM fields. Empathy is often overlooked as a motivator in STEM programs, with many interventions continuing to focus on the technical aspects of engineering rather than positioning the field in terms of its humanistic value [8].

Theoretical Framework

The project's theoretical framework integrates two bodies of theory: The People Part of Engineering (PPE) framework [9] and Persistence of Interest theory [10], [11]. The PPE framework focuses on developing 'holistic engineers' in a way that meaningfully incorporates a people-centric approach, taking learners beyond technical and analytical skills and emphasizing engineering as a human-centered process done with, as, and for people [9]. Theories around persistence of interest focus on experience attributes that activate and sustain interest through competency [10], [11]. Several key attributes–including having a positive attitude toward the

work, feeling appropriately challenged by the work, sustaining focus and concentration on the work, and achieving proficiency or competency in the work–all contribute to youths' persistence, shifting attitudes from 'Do I want to do this work?' to 'Can I do this work?'.

Combined, these frameworks form the backbone of a BBB internship (see Fig 1). The PPE framework underlies the purposeful design of the internship model; from engaging interns, to framing their projects, to creating a work environment, the principles of engineering for/as/with people are consistently and intentionally maintained. Working alongside those strands is the continuum of growth articulated in the Persistence of Interest theory: as learners move from a positive attitude, they engage in productive challenges, and ultimately strengthen their engineering competencies. In elective out-of-school-time internship programs, students often bring some degree of prior interest in or positive attitude toward the idea of helping others. The internships then intentionally create a supportive environment that encourages students to engage with authentically challenging work while growing in their engineering competency. Our hypothesis is that an internship design that leverages these two theories simultaneously will lead to shifts in how teens think about engineering, develop skills in engineering, develop broader workplace skills, and even shift their engineering identity.

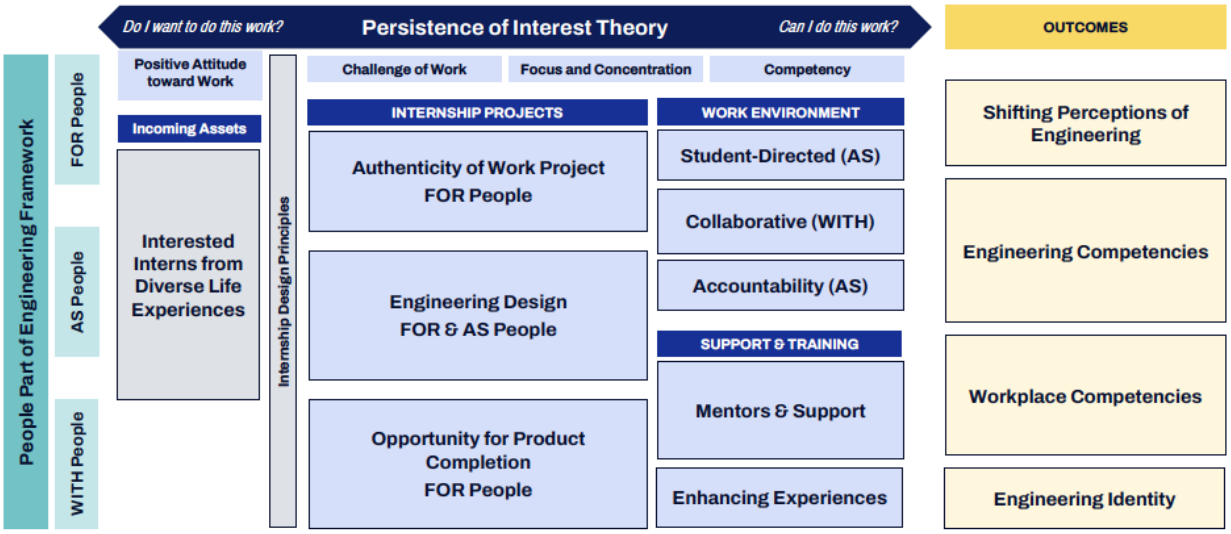

Figure 1. Diagram linking the underlying theoretical framework and emerging design principles for empathy-driven engineering internships.

Emerging Design Principles

After the first iterations of the program, the researcher-practitioner team began to articulate key design principles that were being used across locations to embody the theoretical framework. Regardless of site or format, all BBB internship programs task interns with an authentic project for a real client, completed in an authentic workplace environment with mentorship, support, and training along the way. While these principles are still in development, the team's current thinking is presented in Figure 1.

1) *Internship projects* provide authentic opportunities to address real clients' needs. Products are developed through an iterative engineering design process that centers universal design and empathy, and the program is long enough to allow for product completion and delivery.

2) *Work environment* aims to replicate real-world engineering design work environments (although in educational settings) by prioritizing intern ownership and agency over project design, decision-making, and process, emphasizing collaboration with other interns and clients, and holding interns accountable for their work plans, deadlines, and deliverables.

3) *Support and training* are essential to the process and provided by adult and near-peer mentors who provide interns with structure, general guidance, and technical training. Internships may also provide experiences that expose interns to post-secondary options and STEM careers.

Program Implementation

The early findings presented here include data from two iterations of the teen internship program at each of two sites–a public research university in Colorado and a public library makerspace in New Jersey. Additional iterations of the program, taking place at a high school and science center, are currently in process and in preparation, respectively.

Site selection: The project team selected internship sites based on its prior collaboration with a national network of community partners. Sites were selected based on organizations' interest in the program, experience working with teens, and capacity to support a 50+ hour internship program, as well as to ensure that a diversity of organizations and regions were represented.

Intern recruitment, application, and selection: Each site recruited and selected interns through an application process, with a focus on recruiting teens from groups underrepresented in STEM. Each site selected a cohort of 8-16 interns based on applicants' interests and their potential to develop new skills through the program; prior experience in engineering was not a requirement.

Program Design: Although each host organization designed its program to align with its unique structure, audience, and goals, each worked intentionally to incorporate the emerging design principles identified by the research team. These included focusing on an authentic design project in collaboration with a community client, creating a workplace setting that emphasized 21st century skills, such as critical thinking, collaboration, and communication, and providing sufficient work time to allow for iterative design and ideally, project completion.

Program Implementation: In summer 2022 and 2023, the university ran a 4-week (120-hour) internship for 11 and 15 students, respectively. Prior to each program, the site solicited project ideas from community clients, including teachers who worked with BLV children. Projects included interactive tactile books, light-up books and toys for children with cortical visual impairment (CVI), and tactile garden signs for young BLV children. The library ran its program in fall 2022 and 2023 (for 14 and 19 students, respectively) as a semester-long (50-hour) experience held after-school and on weekends. The library developed project ideas in collaboration with a nearby school for the blind.

Methods

Site leads collaborated with the research team to collect pre/post surveys and audio reflections from interns and feedback from site leaders and clients. Interns participated in a focus group at the end of their internship experience. To date, the survey has adapted measures from validated instruments including the Fit of Personal Interests and Perceptions of Engineering Survey (F-PIPES) [12], Engineering Design Self-Efficacy Instrument [13], Short Instrument for Measuring Students' Confidence with Key Skills [14], and STEM Professional Identity Overlap measure (STEM-PIO-1) [15]. These measures assess youths' perceptions of the work of engineering (F-PIPES), self-efficacy in engineering and the design process (Engineering Design Self-Efficacy Instrument; Confidence with Key Skills Instrument), and their self-perceptions relative to engineers (STEM-PIO-1). Qualitative reflections (collected using self-administered audio or video recordings) focus on participants' perceptions of engineering, their experience and sense of accomplishment, and reflections on the most impactful and challenging experiences.

As a design-based research project, we used a cyclical process of design, data collection, analysis, reflection, and redesign. After implementation and data-gathering, teams convened at key points in the development cycle to review preliminary results from data gathered with interns about their outcomes and experiences. Insights from these data informed revisions to aspects of the internship program at each site, clarification of the critical elements of internship design (see emerging design principles), and refined research directions and emphases for the next iteration.

Results

In its first two years, 59 teen interns participated in the program and, of these, 56 participated in the research study. Preliminary findings suggest the internship approach is achieving positive changes in several of the intended outcomes, across different sites. These outcomes include broadening teens' perceptions about engineering, developing stronger identities as engineers, increasing confidence and competency in technical skills, and gains in interpersonal and 21st century workplace skills. Important emerging findings from the preliminary data include:

Shifting perceptions of engineering: Following their experience in the program, BBB interns demonstrate a broader understanding of engineering, particularly that engineering is for the benefit of people, rather than just about building or fixing things. Interns' open-ended descriptions of engineering shift to include more references to working for and with people and fewer uses of technology-focused definitions. From qualitative data, participants exhibit an improved understanding that engineering as a field is more complex than they previously understood. The program's emphasis on human-centered design resonates with teens, and they value the opportunity to make the world more accessible for others.

Developing an engineering identity: Evidence also indicates that BBB interns may be developing a stronger sense of shared identity with engineering. In particular, interns' responses to the STEM-PIO-1 measure indicate an increased overlap between their view of self and their view of engineers; on this seven-point scale, there is an overall increase in average ratings from 4.58 to 5.05, with over 40% of interns showing a greater sense of overlapping identity with engineers. A

paired t-test revealed these changes were significant ($t(54)=-2.96$, $p<.01$). These quantitative findings are echoed in interns' reflections; when asked about what they accomplished during their internship, almost two-thirds (64%) described themselves as capable of doing engineering-related tasks and feeling empowered to do the work of engineers, and almost half (43%) said they are motivated by or proud of their work in serving others. Combined, these indicators illustrate a growing engineering identity among participating teens.

Growing competence in engineering design and technical skills: There is also very strong evidence that the internships are growing youths' competence in the suite of engineering design skills. The ten-point scale used to measure confidence in engineering design tasks shows a significant increase, from an average self-confidence rating of 7.19 pre-program to 8.15 after the program ($t(55)=-5.48$, $p<.001$); over two-thirds of interns showed an increase in self-confidence. In interns' qualitative reflections, they describe gains in technical skills such as 3D printing and laser cutting, coding and digital illustration, and in general engineering skills, such as prototyping and iterative design. Interns also demonstrated a decrease in anxiety about their skills in these tasks, although the decline was not as strong as their growth in confidence, shifting from 3.48 to 2.68 ($t(55)=2.37$, $p<.05$). Qualitative data suggest that teens continue to have some ongoing anxiety about their own abilities because they have learned so much more about engineering work and its inherent challenges; essentially, that there is so much more to learn.

Improving 21st century skills beyond engineering: There is also emergent evidence that the authentic workplace experience allows interns to exercise and develop transferrable skills that can be leveraged within or beyond engineering careers. Interns have shown the most consistent growth in communication (3.32 pre-test; 3.71 post-test; $t(55)=-3.73$, $p<.001$) and self-direction (3.90 pre-test; 4.19 post-test; $t(55)=-3.14$, $p<.01$). Moreover, in reflections and focus groups, interns describe developing greater confidence in collaboration and empathy-related tasks, and professional skills like project management. Some interns also reflected positively on their ability to embrace failure, take risks, listen to criticism, and take greater personal accountability.

Conclusion

Early findings suggest that the program's authentic engineering design experience resonates with teens from diverse backgrounds, broadens their perception of engineering, motivates them to persist through challenges, and builds their confidence, self-efficacy, and engineering identities. Looking across sites and iterations, a set of key design principles is forming. Close involvement of a community client is critical, as it drives the authenticity of the design challenge, motivates students to persist in their work, and underscores intern accountability. Ongoing interaction with the client supports the iterative design process, as interns who received more regular feedback tended to have better focus on their project. Sites have learned that supporting consistent client communication can be challenging, as they are often unable to control the level of participation by clients. Interns who struggled to connect with clients reported feeling more challenged by client management than the design work itself. Building on this work, the team is currently testing an in-school version of the internship and preparing to run three additional summer programs, at a university, library, and science center. Through these additional iterations, the project team aims to further refine the model and examine the impacts of integrating a more collaborative co-design process with community clients who are blind or visually impaired.

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