BOARD # 408: NSF ITEST: Broadening Teens' Perceptions of Engineering through a Human-Centered, Accessibility-Focused Engineering Design Internship

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Abstract

Despite efforts to build and diversify the STEM workforce, many historically marginalized groups continue to be significantly underrepresented in STEM, particularly in engineering [1], [2]. Many teens have a limited perception of engineering, and often this fails to align with how they view their own interests and strengths [2], [3]. This paper describes an NSF ITEST project that addresses the need to attract, motivate, prepare and support a more diverse engineering workforce. The *Build a Better Book* (BBB) project (award no. 2049109) engages teens in an engineering design experience grounded in principles of universal design and focused on engineering for accessibility. From 2022-2024, the project team facilitated eight teen internship programs at four sites around the country, including a university, public library, high school, and science center. Regardless of location or format, all programs incorporated several key elements, based on the project's underlying theoretical framework, including: authentic engineering projects developed in collaboration with community clients that center empathy and accessible design; settings and processes that simulated real-world work environments, including an emphasis on intern agency, collaboration, and accountability; and mentorship, training and support provided throughout the experience [4]. Internship sites strived to engage a diverse cohort of interns who came to the program with varied levels of interest in engineering.

Using a mix of qualitative and quantitative methods, including pre-post surveys, audio reflections, and focus group discussions, the team assessed teens' motivations to participate in the program and measured the impact of the internship program on teens' perceptions of engineering, their confidence and competence in an array of technical and general workplace skills, and their awareness of disabilities and the importance of universal design. Over the three-year period, 184 teens across the four sites participated in the internship program and of these, 152 participated in the research study. Results suggest that the human-centered focus of the internship motivated youth to participate, and the experience expanded their perceptions of engineering, increased their confidence and competency with technical and general workplace skills, and significantly increased their awareness of accessibility issues. Ongoing and future analyses will examine the relative impacts of different educational environments and program formats on intended outcomes and assess the longer-term impacts of the BBB teen internship experience by surveying program alumni one to three years after their participation.

Introduction

In alignment with NSF ITEST priorities, the *Build a Better Book* project addresses the need to motivate, prepare and support a more diverse STEM workforce, particularly in the field of engineering. The continuing lack of diversity in engineering and other STEM fields limits the field's ability to tackle the world's greatest challenges, as more diverse teams tend to generate more innovative solutions [5]. The program leverages teens' interests in helping others to engage them in an authentic engineering design experience in which they create accessible materials (e.g., games, books, toys, tactile maps, etc.) for children or youth who are blind or have low

vision (BLV). Previous work suggests that this project's empathy-driven, human-centered focus appeals broadly to teens from diverse backgrounds, including those who do not otherwise consider themselves to be interested in STEM [4], [6]. By researching this internship model across four diverse learning settings, the project aims to advance the field's understanding of how to design and support effective pre-collegiate engineering internship experiences that motivate teens' participation in engineering and influence their self-perceptions related to persistence in this field. In this paper, we provide an overview of findings from the project's first three years, including data collected from eight internship programs delivered at four sites.

Program Design and Implementation

From 2022-24, 184 teens engaged in one of eight engineering design internship experiences offered at four sites around the country (in CO, NJ, and NM). Internship host sites were selected based on organizations' interest in and prior work with the program, their experience working with teens from diverse backgrounds, and their capacity to support a 50+ hour teen internship program, as well as to ensure that a balance of organization types and regions were represented. The internship model was implemented in an intensive summer format (n=5), a semester-long afterschool program (n=2), and a seven-month in-school program (n=1) (Table 1). Regardless of location or format, each internship program focused on the iterative design and fabrication of accessible books, games, toys, or other media requested by community clients who are BLV or have other special needs. Across all sites, the project's theoretical framework, which integrates two bodies of theory–The People Part of Engineering [7] and Persistence of Interest theory [8]–guided the design of the internship program by outlining several required program elements, including authenticity of projects, collaboration with community partners, opportunity to develop technical and STEM workplace skills, mentorship and support, and time and opportunity to approach prototype completion [4]. Endeavoring to model principles of authentic engineering design work environments (appropriate for teens), staff mentors provided coaching and training while teens collaborated in small teams to prototype, test, and refine client-requested products.

Table 1. Summary of internship programs held from 2022-2024.

	University (CO)	**Public Library (NJ)**	**High School (NJ)**	**Science Center (NM)**
# of Interns **(# in Research)**	44 teens (n = 44)	45 teens (n = 44)	85 teens (n = 54)	10 teens (n = 10)
Format (and #) of Programs	Extracurricular; Summer (3)	Extracurricular; Afterschool (2) Summer (1)	In-school Program (1)	Extracurricular; Summer (1)

Research Methods

In collaboration with site leads, the project's research team collected pre/post surveys and audio reflections and facilitated a focus group discussion at the end of each internship program. Following some refinement early in the project, the pre/post survey included measures adapted from validated instruments including the *Engineering Design Self-Efficacy Instrument* [9], the *Short Instrument for Measuring Students' Confidence with Key Skills* [10], and the *STEM Professional Identity Overlap* measure (STEM-PIO-1) [11]. These measures assess teens' self-efficacy in engineering and the design process and their self-perceptions as engineers. Based on

themes that emerged from the project's first two years, the team added a retrospective (post-only) survey in the project's third year to assess changes in teens' understanding of and attitudes toward issues related to accessibility. This included questions related to interns' abilities to consider accessibility issues in the design process, adapt designs based on the needs and wants of a person with a disability, and the importance of perspective-taking in the engineering design process. Qualitative reflections (collected via self-administered audio recordings) focused on participants' perceptions of engineering, their experience and sense of accomplishment, and their reflections on the most impactful and challenging parts of the program. Focus group questions asked about teens' experience in the program, including what they liked about the program, what was most challenging, the accomplishments they were most proud of, and ways that the program could be improved for future participants. Open-ended survey responses, audio reflections, and focus group responses were coded and analyzed for patterns and emergent themes.

As a design-based research project, the team used a cyclical process of design, data collection, analysis, reflection, and redesign. After each round of implementation and data-gathering, the PIs, researchers, and site leads collaboratively reviewed and discussed preliminary results to make any necessary modifications to the program or data collection measures. Insights from these sessions guided revisions to the internship program at each site, clarified key design elements of the internship program, and influenced research priorities for the next iteration.

Results

Of the 184 teens who participated in a BBB internship program, 152 assented to participate in the research study. Across sites, quantitative and qualitative data suggest that the internship's human-centered approach is effective in attracting diverse participants and broadening their perceptions of engineers in ways that align more closely with their own self-identities. As interns collaborate to design and fabricate an accessible product for a real-world client, they develop technical and workplace skills and deepen their understanding of issues related to disabilities.

• **Motivations to Participate:** The project's focus on helping others was a strong motivator to participate. 59% of interns cited helping others and/or their community as a primary motivator for their participation in the project. Other common themes included the opportunity to gain new skills (46%), create something tangible (27%), and further their STEM interests (19%).

• **Perceptions of Engineering:** Aggregated across all sites, quantitative and qualitative data suggest that the BBB program broadens teens' perceptions of engineering, with participants demonstrating a deeper understanding of engineering as a field. Prior to their participation, teens largely described engineering as being focused on 'building things' or by listing different engineering fields. After their participation, however, interns were more likely to describe engineering as being human-centered and being an iterative and collaborative process.

• **STEM/Engineering Identity:** Across sites, interns demonstrated a small positive shift in their engineering identity as measured by the STEM-PIO-1 measure, which asks them to indicate the level of overlap between themselves and their perception of an engineer. On the measure's 7-point scale, the average rating increased from 4.11 to 4.45 (paired t-test, $n=152$, $p<0.01$).

• **Technical Skills and Workplace Competencies:** Interns demonstrated increased confidence in their ability to complete a variety of engineering design tasks, as measured by the *Engineering Design Self-Efficacy Instrument*, with 68% of participants showing increased confidence (paired t-test, $n=152$, $p<0.01$). Technical skill growth was particularly noted in areas such as 3D printing, digital design and laser cutting, and computer programming. Interns also demonstrated positive and significant growth in key workplace skills, as measured by the *SICKS* measure. The largest shift was in communication, in which 58% of interns showed increased confidence; other growth areas included self-direction, critical thinking, creativity, and collaboration.

• **Accessibility Mindset:** In retrospective pre-/post-survey questions added in the third year, interns self-reported how well they understood several foundational ideas related to accessibility, including how to consider accessibility in the engineering process, ways to adapt designs to accommodate the needs of someone with a disability, and the importance of perspective-taking in engineering. On each measure, paired pre/post data indicated significant shifts (paired-t test, $n=109$, $p<0.001$). These survey findings were echoed in interns' self-reflections, which cited their growing awareness of accessibility issues (48%), importance of empathy and perspective-taking (46%), and importance of integrating empathy in the engineering process (42%). As one intern commented, "I have never really thought about accessibility and how not everybody has the same abilities that I have, and I took them for granted. But now I'm realizing there are so many ways and different views people have on the world and I should be more aware of that..."

Conclusion

Findings suggest that the BBB Teen Internship's human-centered approach and its emphasis on an authentic engineering design experience attracts teens from diverse backgrounds, broadens their understanding of engineering, builds their confidence, self-efficacy, and engineering identities, and deepens their awareness and understanding of accessibility. The model is adaptable for different settings, including formal and informal learning environments, but requires effective mentoring to support interns through an iterative engineering design process.

Although the project has completed its data collection, ongoing and future analyses will examine variation in impacts and outcomes among sites, including comparisons between informal and formal learning environments, and comparisons among programs with different levels of structure and support. The team is also examining longer-term program impacts with an alumni study, surveying program alumni 1-3 years after their participation in the program. This survey will assess the degree to which the internship experience influenced interns' interests, plans, and persistence in pursuing engineering or STEM in higher education and/or their career, as well as any enduring impacts on their awareness and understanding of issues related to accessibility.

Acknowledgements

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