What Activities and Practices Sustain the Engagement of Highly Diverse Communities of Young Engineering Students in an Out-of-School Fellowship Program?

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Abstract

This paper reports on the process and findings of a participatory action research project with a diverse group of high school youth who were participants in an engineering design fellowship at a major urban science center. Participants were trained in action research techniques, explored the “engineering habits of mind” (National Research Council, 2009) as a framework for understanding their own work with visitors to the science center, and investigated how informal learning experiences can serve as pathways toward engineering for young people from under-represented backgrounds.

This project was designed to provide insight into the programmatic structures and practices that engage students from under-represented backgrounds with the perspectives and ways of thinking, working, teaching and learning that are distinctive to the engineering professions. A key finding of the young people's action research was that they had already become skilled in many of the social and communicative practices that have been shown to be characteristic of innovative and inclusive engineering programs through their earlier participation in the science center’s broader youth development program. However, their fellowship experience allowed them to discover the importance of those social and communicative skills to innovative and effective engineering practice. This deepened their understanding of the problem-solving processes of engineering. It also prompted them to consider how engineering can contribute to addressing broad social challenges, and shifted them away from earlier conceptions of engineering as a primarily technical field of study.

Engineering education research is urgently in need of a deeper understanding of how youth from non-white, immigrant backgrounds, particularly females, experience programmatic efforts to invite and engage them in the practices of learning and teaching others about engineering. The difficulties encountered by non-dominant youth in this field are broadly acknowledged, but program designers and educators continue to struggle to understand how to address these challenges in ways that are meaningful to their target audience. Findings from this project will provide detailed insight into how these young people are negotiating the process of building strong connections between their own cultural identities and their potential induction into a new identity as a student of engineering.

Background

Youth from non-dominant backgrounds often enter post-secondary engineering programs at a significant disadvantage, not only in academic training, but in terms of the social capital they bring to the experience (Aschbacher, Li & Roth, 2009; Foor, Walden, & Trytten, 2007; May & Chubin, 2003). Both demographic and ethnographic research strongly suggest that non-normative individuals are more likely to be recruited and retained in engineering degree programs or workplaces if those programs establish explicit, constructive norms for the collaborative and communicative dimensions of engineering, but these norms are not yet broadly realized (Anderson & Norwood, 2002; Coger, Cuny, Klawe, McGann, & Purcell, 2012). This suggests that it is important to induct under-represented high-school-aged youth who are interested in engineering into the social and collaborative practices that are characteristic of the most innovative, inclusive, and productive engineering environments. With these social and communicative skills in hand, under-represented youth can become leaders in their post-secondary programs, and critical contributors to establishing increasingly diverse, innovative and productive communities in post-secondary and professional engineering communities.

There has been little empirical work that has explored the specific practices and structures that effectively invite diverse groups of young people to recognize, participate in, and mutually validate the social practices that establish and sustain inclusive work environments for engineering or for STEM learning more generally (Aschbacher, Li, & Roth, 2009). Focused, in-depth research in the context of such programs can identify practices and program features that effectively invite diverse youth into the globally-oriented and socially complex ways of working that are necessary for the continued growth of engineering innovation in the United States.

The nature of engineering itself is also evolving to require more collaborative, more nimble, and more culturally-aware responses to the complex challenges faced by the U.S. and the world (National Academy of Engineering, 2004; Stevens, O'Connor, Garrison, Jocuns, & Amos, 2008). Establishing these new norms in the workplace will require a more diverse workforce that can bring diverse perspectives to bear on complex problems. These shifts can potentially generate a virtuous cycle, creating a more inviting and inclusive environment in which historically under-represented people will face fewer hurdles to becoming comfortable, vocal, and successful members of the engineering professions.

Informal, out-of-school time programming offers a promising alternative pathway for programs that seek to engage under-represented youth in sustained explorations of STEM fields in general, and the complex challenges of engineering in particular (National Research Council, 2009). Out-of-school-time programming can offer young people opportunities to act as peer coaches or teachers; to work closely with professional scientists and engineers; to develop not only the content knowledge but the practices of engineering; and to pursue topics of deep personal interest (Bruner, 1996; Ivanova, 2003). These are all experiences of enculturation that are difficult to offer on a regular basis in formal settings, and are critical to young people's development of an emergent identity as a STEM learner or future professional in general, or as an engineer in particular (Tate & Linn, 2005).

About the research setting

The science museum where this project will take place is located in an urban center with a dense and highly diverse population, including many people who have recently immigrated from South and Central America and from South and Southeast Asia. The museum serves a geographically broad audience but the local community is central to the institution's mission and is a core part of our day-to-day audience. The science museum also supports a long-standing youth development and employment program. Participants work part time for the museum, and play a critical role as teachers and ambassadors to visitors and school groups in the museum. In addition to their role on the museum floor, they engage in a range of activities that support their exploration of STEM careers, including participation in career development and college-readiness workshops and peer leadership.

This group of young people are a unique population of potential future engineers because of both the length of their commitment to this program and because of their diversity as a cohort. At least 75% of participants stay with the program for two years or more, and many move through levels of the program over the course of four, five, or six years of consistent participation. The diversity of the participants reflects the diversity of the local community. Over half of the participants are female, the majority are immigrants themselves or children of immigrants, and members of the group speak over twenty different languages. Currently 24% of participants are Latino/Hispanic, 18% are Asian/Pacific Islander, 14% are South East Asian, 12% are African American, and 10% are West Indian.

Conducting the participatory action research

During this twelve-month project, researchers and program leaders worked with a cohort of eight New York City public high school and early college students who were already working for the science museum as docents with a focus on a major exhibition about design engineering. These young people participated in a research training and development period, carried out six-month participatory action research projects, and documented their project findings. Each participant's work contributed to our understanding of two overarching research questions:

1. What kinds of activities or interactions do participants feel most effectively invite them to draw explicitly on their own cultural assets and diverse life experiences (or those of their peers) to inform the engineering design work they are doing, teaching, or learning about?
2. What kinds of activities or interactions do participants feel most strongly influence their perceptions of themselves as engineers, or as contributors to an engineering design community?

Participants (called Design Fellows) were recruited from the larger pool of young people working part-time at the science museum and participating in a range of youth development opportunities available to all youth employees. The group was diverse in multiple dimensions. All of the participants came from backgrounds under-represented in STEM post-secondary education. Seven of the eight were female. Three were from South East Asian backgrounds, one was African American, one was Hispanic, one was Asian/Pacific Islander and one white. Four had been participating in the museum's youth programming for at least a year. One had only six months of experience in the program, two had been participating for more than two years, and one for more than three years.

Each Fellow had different motivations for their interest in engineering and their goals for their futures varied widely. They also varied in their perceptions of their access to family support as they sought to pursue their interest in engineering. Some spoke about the lack of STEM interests, resources and support to explore these ideas on their neighborhoods. Others spoke about their neighborhoods feeling like a big family that offered support in the ways they explored their STEM interests. These varying viewpoints and life experiences allowed for rich discussions, and diverse research, that looked at a variety of factors influencing how people engaged with engineering activities at the science museum.

Grounding the inquiry

The participatory action research process was grounded in a set of habits of mind articulated by the National Research Council's Committee on Understanding and Improving K-12 Engineering Education in the United States (2009; see Table 1). This list aligns closely to other, similar lists of communication strategies, work practices and perspectives that have been identified as optimal practices for creating innovative, inclusive engineering workplaces and learning environments (Engineering Accreditation Commission, 2015; National Academy of Engineering, 2004; National Academy of Engineering, 2014).

We chose to provide participants with an initial set of organizing categories to support their discussion of their own interests and their work with visitors on the museum floor. While we were concerned that the list could constrain the participants' explorations, our time with the group was limited and the group had no prior experience thinking about engineering as a distinctive discipline. Throughout the project, we encouraged the participants to reflect on the utility and relevance of this list to their experiences.

During the coding process, the group did modify the list to better reflect their interests and experiences and to support shared communication. Most significantly, the group added a category they called "culture," which was defined as "considering how culture shapes individuals' experiences of and responses to problems and challenges they encounter."

Table 1: Engineering habits of mind

Systems thinking	Systems thinking equips students to recognize essential interconnections in the technological world and to appreciate that systems may have unexpected effects that cannot be predicted from the behavior of individual subsystems.
Creativity	Creativity is inherent in the engineering design process.
Optimism	Optimism reflects a worldview in which possibilities and opportunities can be found in every challenge and an understanding that every technology can be improved.
Collaboration	Engineering is a "team sport"; collaboration leverages the perspectives, knowledge, and capabilities of team members to address a design challenge.
Communication	Communication is essential to effective collaboration and to understanding the particular wants and needs of a "customer," and to explaining and justifying the final design solution.
Attention to ethical considerations	Ethical considerations draw attention to the impacts of engineering on people and the environment.

For eight months, the Fellows met twice a month with the program manager. Through these meetings the program manager was able to build a comfortable rapport with the group allowing them to have conversations around sensitive subjects such as race and gender in the world of science, technology, engineering and math. These meetings also allowed the group to build their own relationships, sharing out on their personal roadblocks and challenges, and allowing them to be supportive of each diversity each of them brought to this work.

These meetings were often used to develop Fellows' skills, both as researchers and as experience designers for the museum. Trainings included topics such as conducting field observations; iterating on activity designs to meet visitor needs; and developing a coding strategy for their field notes. Later in the research period, the Fellows used these meetings to code their notes and look for connections in the patterns they were discovering in their work. Core findings that cut across the Fellows' individual research projects are described briefly below.

Findings

This project engaged eight high school and early college students, all with gender and/or cultural identities that are under-represented in the engineering professions, in an action research process. Their research examined how their participation in a youth development and employment program, grounded in the design engineering exhibition space in a science museum, shaped their experience of themselves as engineers. While the Fellows investigated a range of topics in their own research projects, a common theme emerged throughout their work: the interpersonal and communication skills were much more deeply related to the discipline and practice of engineering than they had ever understood. Prior to their action research, they had understood engineering to be a technical field, requiring primarily mastery of complex bodies of knowledge like coding and advanced mathematics. Their research studies led them to recognize that their social and interpersonal skills were central to the work of engineers, because the problems engineers seek to solve are, ultimately, deeply interconnected with the social and cultural contexts in which they emerge. As one Fellow reflected near the end of the project:

"The first lesson [*this project*] *taught me was that I was already an engineer. In our opening meeting, we were asked to draw an engineer. My group sketched out a genderless person holding different virtues. My own work made me realize that I was at conflict with myself. I didn't consider myself to be an engineer because I had never tinkered with electronics and gadgets, yet here I was, drawing a genderless person surrounded by words such as "team", "knowledge", "work", and "failure." I fit my own description! Since that day, I began to consider myself an engineer".*

This self-realization was something that many of the Design Fellows experienced over the course of this project. This discovery shaped how they thought about themselves in the world of engineering, and how they thought about their roles at the science museum, and experience and knowledge they bring to their work with visitors and their efforts to get visitors excited about engineering. Through this project, the Fellows did not need to be given new identities - instead, they needed opportunities to connect the dots of their own experiences, to see that the social and interpersonal skills they were already developing were already critical engineering skills. Below, we present a brief example of how these realizations emerged for some of the Fellows.

Iteration of a costume design activity

One of the key trainings that the Fellows participated in was an iteration training led by another museum staff member. Fellows were already experienced facilitators of design engineering activities, but they had previously been trained to facilitate activities as they had been designed by professional staff of the museum. The iteration training invited them to view themselves as designers who were learning from their day-to-day interactions with visitors, with opportunities for meaningful input into activity design. This workshop was a critical step in the evolution of the Fellows' understanding of themselves as experts who could study and make changes to the complex environment in which they worked. One Fellow noted she felt that she now "had the power to change the space" and that "little changes could lead to larger effects." Learning about the ways they could make changes also sparked the Design Fellows to look more deeply at how visitors were engaging with the activities, materials, and facilitators. Through numerous hours of data collection, one Design Fellows began focusing her research question, landing on "Is there a way to change the intimidation of engineering by using culture as a tool within developing activities as a way to engage people?" Her investigation was one of several that were informed by the work described below.

As a result of this training and their data collection, the Fellows felt empowered to make decisions around the design of the activities. This pattern, in which empirical observation supported participants in making new connections among culture, engineering, and agency, which in turn sparked new ideas and a readiness to pursue and implement those ideas, was a critical outcome of this research project.

A key example of this shift occurred among a subset of Fellows who were interested in improving a design engineering activity that was called *Costumes* and focused on clothing construction. Visitors were invited to design a costume for themselves or for large mannequins using fabric and other knowable materials. The Fellows were interesting in identifying productive ways to integrate more culturally relevant examples into this activity, reasoning that this might invite visitors to create more, different kinds of garments. Their first intervention was to add into the space pictures of clothing from different cultures, such as an Indian sari, a Japanese kimono, and others.

However, as they worked toward their goal of creating a more culturally inclusive environment, they discovered a gap between their intent and another feature of the activity - its title. Through observations and interviews with visitors, they discovered that visitors, as well as their peers, did not define culturally-specific clothes that were familiar to them personally as "costumes" - and hence did not draw on those reference points when they engaged with the activity. If they wanted visitors to feel welcome to incorporate their culture into their designs, the activity name needed to change. As a result, the name of the activity changed to from costumes to *Fashion Design*. With these changes, the Fellows began seeing the kinds of things visitors were making also diversify.

An unanticipated change that happened during this period was that more visitors of different genders started to engage with the activity. Through their observations, they had previously seen that boys were often encouraged by their caregivers to try other activities, and the boys that did come to Fashion Design were usually unsure how to start or what they should be making. Fellows used several iterations of this activity to encourage more culturally inclusive explorations of the construction and functions of clothing but ended the study period with many open questions about what kinds of approaches might best attract and retain all genders for this activity. Some of their proposed next steps were to change the kinds of fabrics being used, introducing camouflage, and featuring clothing designed for occupations, such designing for military use.

Another area Fellows were able to iterate in was the scale kinds of materials being used. The Fellows added smaller mannequins and materials for smaller hands, as we observed many young children in these spaces. This allowed our younger audience to do more on their own rather than being dependent on adults in the spaces. These smaller designs also allowed visitors to take their products home, but many of them chose to display their designs in the space, leaving examples for future visitors that represented both engineering solutions and a range of cultural approaches to the challenges of designing clothing that meets aesthetic and practical needs.

Conclusions

Both the process and the outcomes of this participatory research process have influenced not only the participating youth, but also the broader youth development project they participate in, and the science museum as a whole. Participating youth developed new research skills, and new perspectives on engineering as a discipline and on themselves as engineers. In turn, they demonstrated to their peers in the youth development program how they can all draw on their own perspectives and cultural knowledge to inform their interactions with visitors and to contribute to future programs and exhibits within the museum. Leaders of the youth development program have gained a fresh perspective on the intersection of the work they do to build the social capital of their program participants, and the ways that they engage those youth with the STEM disciplines. And finally, the science museum as a whole has developed a broader awareness of the importance of inviting visitors to explore the intersection of cultural diversity and engineering.

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