Making a New Path: Lessons Learned During the 'Making the Data' Phase of our Project

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Abstract

In this NSF-funded Research in the Formation of Engineers (RFE) project, we are broadly interested in understanding how makerspace engagement influences the identity formation of engineering students, with a focus on students from underrepresented groups (URGs). Makerspaces are becoming very popular and have started to become much more common in K-12 schools, libraries, community centers, and universities. Makerspaces differ from traditional shops or labs in that Makers—or those engaged in building or making in the space—are typically given free rein to build products related to their interests in addition to pedagogical deliverables. It is implicitly assumed that makerspaces promote pathways to STEM majors, and, ultimately, STEM careers. In this project, we are therefore interested in developing an understanding of how engaging in university-affiliated makerspaces impacts the engineering identity development of students. We are currently midway in our data collection and analysis phases of the project, also known as the 'making the data' phase of our project [1]. In this paper, we will describe our preliminary work and focus the discussion on lessons learned. We will conclude the paper with brief descriptions of three journal articles in preparation or press, as we wrap up the 'making the data' phase of our project.

Introduction

The lack of diversity in engineering environments sends a message opposite of inclusion and opportunity for all [2]. In a study of students leaving engineering, students reported a lack of identity or a sense of belonging to be more significant than academic issues [3]. Within both formal and informal learning environments, experiences which familiarize students to the disciplinary discourse, or broader ways of being, can provide the conditions to form an identity [4]–[7]. Yet, these opportunities are often lacking for underrepresented students within university engineering programs, which are taught by primarily male professors in a classroom with an overwhelming majority of male peers [8].

University makerspaces are unique learning environments with the potential of increasing the quantity, diversity, and competence of engineers through design experiences that align students with the epistemic identity of the engineering profession [9], [10]. Despite the makerspace momentum and substantial resources invested into creating more university makerspaces, little research exists on the potential of makerspaces to promote more inclusive pedagogical experiences. In other words, questions remain regarding whether these makerspaces are by default exclusionary, such that they implicitly mirror similar university-wide conventions of hegemonic practice and exacerbate the invisibility of historically isolated women or persons from underrepresented groups (URGs) within engineering.

Our broad purpose is to critically explore how URGs experience university-affiliated makerspaces and story how potential inclusivity or exclusivity within the makerspace impacts identity formation of URGs in engineering. Thus far, data has been collected at four university-affiliated makerspaces to include 37 undergraduate engineering students, comprising 43 interviews. Participants are from a diversity of engineering disciplines, differing in number of

years in the program, gender, and race and ethnicity. Through this NSF-funded RFE project, we aim to fill pressing gaps in the literature and achieve our purpose through answering the following research questions:

> **RQ1: What are the personal growth and identity development stories of engineering students who engage in and experience makerspaces?** Are there gender and/or race/ethnicity differences in these stories? What kinds of lived experiences have led these students to develop their identity as an engineer?
>
> **RQ2: What do these stories reveal about the culture of makerspaces?**
>
> **RQ3: How can supports and barriers, elucidated through students' stories, inform stakeholder efforts to increase makerspace engagement, especially as it relates to students from underrepresented groups?**

In this paper, we will describe details and lessons learned concerning our data collection and data analysis. We will conclude the paper with three journal articles in press or to be submitted, as we conclude our 'making the data' phase of the project and transition into the 'handling the data' phase [11].

Data Collection

Selecting participants for this study has been context dependent. In the beginning, we were collecting data from local sites. Thus, we were able to spend time in the makerspaces doing observations and talking to students in order to request interviews with various students of particular interest. We also visited a class that had a required making project to request that interested students fill out a simple demographic survey. From there, we then selected students for interviews, based on their self-identifying as being from URGs. This "making the data' strategy emerged from our attempt to oversample students from these populations. When we began our three-day site visits, we then had to rethink our ways of recruiting interviewees. We have had two of these intense, three-day site visits, wherein our goal was to conduct three observations of the makerspace, to conduct one interview with the director or manager of the makerspace to provide context for our study, and to conduct eight interviews with undergraduate engineering students who identify as "Makers." At one site, the researchers were taken on tours to see all of the labs in engineering. This ended up cutting into the time spent at the makerspace and resulted in only conducting four interviews during the visit and two interviews on skype after the visit. At another site, the makerspace manager contacted all students who had completed a summer program in the makerspace. In doing so, the manager mentioned that we were doing interviews and that students would receive a $25 gift card post-interview. We ended up with so many students, 17 interviews, with 15 of those interviews being with engineering students, that in our third day of the site visit we had to begin turning students away. There are three more site visits scheduled for this semester. Additionally, based on the aforementioned lessons learned, we will adopt a student recruitment strategy that uses all three of the methods outlined in this paragraph: 1) through observations and requesting interviews, 2) through visiting classes that have required making projects and recruiting interested students through having them

fill out a demographic survey, and 3) through having our university contact pre-arrange interviews with students.

In this project, we have employed a narrative interview where we begin the interview asking a question that elicits a longer story of how a student got to where they are today, as an engineer and as a Maker. This is called the narration phase of the interview [12]. We then ask follow-up and probing questions as we enter the conversation phase of the interview [12]. Finally, we asked semi-structured interview questions if the answers failed to emerge naturally during the earlier phases of the interview. These included questions about their perceived experiences making, engineering, and, in particular, navigating their engineering program and university makerspace as a student from an URG. Final questions ask the student to reflect on and make recommendations for improving the makerspace and/or the engineering program (see Appendix for our interview protocol).

Throughout this project, we have struggled with how to ask students about their URG status and how that status impacts them as an engineering student or Maker. At first, we were concerned about being biased in our ways of asking questions about, for example, race and gender. We began with a question, "how does your experience compare to your peers." Yet, this did not result in students discussing their URG status and their experiences as being someone from an URG. After learning this lesson, we then began to ask more explicitly about their URG status. We always had them fill out a demographic survey prior to the start of the interview, so we began referring to that when asking questions. We learned that students are willing to talk about being an URG student, and that we need to directly ask about that aspect of their story and experience. Through the process of this project, we learned that it is helpful to be upfront about the purpose of this study and our explicit interest in students from URGs in the beginning of the interview while obtaining informed consent, describing the larger study, and describing their role in the study. Then, during the interview, we explicitly asked questions related to their experiences as URGs and their perceptions of others' experiences as URGs.

Data Analysis

This project is a large qualitative research project resulting in around 70 interviews from eight data collection sites. Therefore, it is critical for us to begin data analysis concurrent with data collection. In addition, it is helpful to begin data analysis so that we can, again, ensure that our interviews are yielding answers to our research questions. This study has adopted Johnny Saldaña's recommendations for coding, and, in general, some of his general recommendations include the following [13]:

1. Code as a "lumper" and not a "splitter." We will code using broad strokes, as results from the earlier stages of coding will be used for subsequent coding cycles and for discourse analysis.

2. Repeat codes. We will attempt to repeat codes to enable us to uncover patterns across the data and the data sources.

3. Develop broader codes and categories as we engage in coding. In many ways, coding is a process of recoding as we continue to take iterative passes through the data.

4. Engage in analytic memoing. Saldaña explains that "Coding is in service to thinking,"[13, p. 80] and we will record insights that are made throughout the process of coding.

5. Reduce data via code mapping. Code mapping is a viable data reduction strategy, wherein researchers first re-organize the full set of codes into a concise list of categories and next condense this list further into central themes or overarching concepts.

This will enable us to synthesize information and to realize greater insights as we engage in the process of coding.

We decided to use structural coding as our first cycle coding method [13]. In structural coding, the research team generates a set of codes that relate to specific research questions. Then, in the next iteration of coding, we will conduct more detailed coding and analysis of segments of the interviews. This first cycle coding method will work well with our large qualitative data set to enable us to do more detailed data analysis as we move forward in this project. In Table 1, we provide our code book which includes each code, a brief description, inclusion criteria, and exclusion criteria [13]. In Table 2, we provide a typical exemplar for each code as this will provide further details of our first cycle coding methods.

Table 1: Code book

Code	**Description**	**Inclusion Criteria**	**Exclusion Criteria**
Pedagogical experiences that shape identity	Experiences and learning environments that influence a person's professional or personal identity formation (within university space).	Experiences must occur within spaces of the university/ makerspaces/ engineering/ formal or informal/ clubs	Does not include work experiences (outside of internship/co-op), K-12 experiences prior to university, experiences with friends and family outside of university/ engineering affiliated experiences.
Other experiences that shape identity	Experiences and learning environments that influence a person's professional or personal identity formation (outside of university space).	Experiences can include work experiences and those past experiences from K-12/prior to entering university	Does not include university or pedagogical experiences (informal/formal/clubs)
Productive pathways to engineering	Activities, interactions, exposure, or experiences that influenced a student's interest, desire, or pursuit of engineering as a major or as a career. This includes experiences or events that happen after initially choosing engineering as a major that reinforce the decision to pursue engineering.	Experiences can include university, work, engineering, personal, family, etc. These are any experiences that influenced a person to initially pursue engineering or to continue to persist in engineering.	
Deterrent pathways to engineering	Activities, interactions, exposures, or experiences that push students away from engineering as an end goal.	This can be prior to being an engineer, or during time as an engineering major but decided to pursue a non-engineering career.	

Code	Description	Inclusion Criteria	Exclusion Criteria
Road of trials in engineering	Difficult experiences or events that are faced by the participant and ways that they overcame (or get past) those events in engineering school. These could be difficult classes, learning to make something, or significant relationships. These experiences may be positive or negative.	Inclusive of anything related to their academic pursuit, including engineering school, extracurricular engineering activities, or internships.	Struggles that could more readily fall under cases of bias/prejudice/stereotype.
Stories of bias/ prejudice/ stereotype (sub-code under road of trials)	Experiences of being marginalized.	Experiences of being marginalized through identity or affiliation with at least one of these groups: woman, racial/ ethnic minority, low socioeconomic status, person of disability, first generation student, LGBTQ status, transfer student.	Struggles associated with engineering that would reflect academic/social unpreparedness due to factors outside of race/class (e.g., personality, intelligence, sibling rivalries, dysfunctional peer/family dynamics).
Stories of values, knowledge, skills, practices, and norms in engineering classrooms	This code includes any discussion of values, knowledge, skills, and practices that students describe in engineering classrooms.		If the excerpt aligns with identity, do not use this code. Use the 'pedagogical experiences that shape identity' code.
Stories of values, knowledge, skills, practices, and norms in makerspaces	Articulated characteristics that distinguish makerspaces from engineering classrooms. This code includes any discussion of values, knowledge, skills, and practices that students describe in makerspaces. This differs from other pedagogical experiences that shape identity code in that it describes experiences within the space or the environment/ context that does not align with identity.	If students refer to a lab as a makerspace, it includes labs.	If the excerpt aligns with identity formation, do not use this code. Use the 'pedagogical experiences that shape identity' code.
Recommendations for makerspaces	Could be local recommendations or recommendations for policy. Ideas for makerspaces.	Recommendations must be for university-affiliated makerspaces.	Not valid if referring to a makerspace outside of the university (e.g. high school makerspace). Not valid if referring to engineering labs.
Aspirations, goals, desires, or plans	This is related to future goals after graduation, short term goals, such as making more and developing more skills, or more aspirational goals such as helping people or pushing themselves.	These goals must be described in the future from the moment of the interview forward. Can include future coursework or careers.	This does not include a student describing an experience prior to the interview and a future goal; for example, “In third grade I wanted to be in the robotics club in high school.”
Miscellaneous	A code to capture everything else. Provide a memo attached to the code to describe the possible code name.		

Table 2. Typical exemplar of quotes within each code

Code	Typical Exemplar
Pedagogical experiences that shape identity	I'm in one actual engineering course this semester, and it's an intro to engineering designing graphics. That class has kind of made me feel very like, "Oh! This is what the engineers do," because we are learning how to 3-D model and design pieces and how to sketch. Compared to my chemistry and my calculus courses, they just feel like courses, but that class has actually made me feel like, "You know, I'm doing what engineers do."
Other experiences that shape identity	Time I remember feeling like an engineer. For my friend's birthday, I 3D printed him a little figurine from a show we watch, and he looked at me and was like, dude, how'd you do this? I was like, I 3D printed it. I found the model online then I clicked a couple buttons. He was like, dude, this is so cool, I would never be able to do this. Him saying that, I know it's not like, yeah, I'm better than my friends, it's not like that, it's hearing that someone would just be totally as lost as I was in an area that I just barely learned, felt very empowering. It's not empowering because you can't do it, but I can. It's empowering because I went from, I have no idea what I'm doing, to just learning how to click three things, which seemed like ancient technology to me just a couple months ago, and now it's just click, click, click, right?
Productive pathways to engineering	Really good family. I feel like they're what's really motivated me to at least stay here and try it out and then meeting all the people here and doing well, made me feel like I did make a good decision in the end.
Deterrent pathways to engineering	When I was young, obviously math, science, that's really important, but there was the point, and there always will be, when you're stuck on something really confusing in physics or chemistry, or math, and you're like, if I pursued something else, I wouldn't have to deal with this. It's just those small moments where you get really frustrated on a math problem or a science concept, that makes you feel like, this is really hard. How am I supposed to become an engineer if I can't even figure this out? You get over those, like you would any other hiccup in life. In terms of a big obstacle, I wouldn't really say there has been anything.
Road of trials in engineering	Then got here and everyone you're around is brilliant and they've never struggled with school so it's hard, it's different. A lot of these kids took engineering classes in high school, which I'd never had any exposure to it. The first day, I walked into class and everyone has their laptops with all this software on it and I was like they know how to do everything. I was definitely behind. I watched some Youtube videos and practiced building things. It's getting better. It's still pretty tough but it's fine. It's going to definitely get harder down the line.
Stories of bias/ prejudice/ stereotype (sub-code under road of trials)	I've never experienced a problem with a professor at SWU, [name changed], as far as feeling judged by my gender. I have experienced way more problems with the students here. That has definitely come through in group work, where I feel like I'm being dismissed for being the only female. A lot of times I'm one of two females in my entire class. I'm one of five females in my entire major. It's not often that I get to work with another female.
Stories of values, knowledge, skills, practices, and norms in engineering classrooms	The class I really loved definitely this semester, more than any of the classes I've taken here so far, was my materials and manufacturing process class, [course letters/numbers]. That one was great. I loved to see the breakdown of pretty much building all this stuff, and seeing the stress points of everything. I thought that was really cool. The thing I think I enjoyed more than anything about that class was, this is the class that was taught by Professor Boxwell, but to actually be taught by not an SWU professor but actually an engineer that taught on the side. Everything he showed us, taught us, we had labs ... It was pretty much a lecture class, but there was so much hands-on in it. He would really try to show, this is what actually happens once you're out of college and actually are working for a company. This is the real world, and this is how you're going to use this course in the real world.
Stories of values, knowledge, skills, practices, and norms in makerspaces	Yeah. I think what they do ... The maker's space, obviously, I was really shocked. It's very inviting. I thought it was going to be everyone just sits at their little table and does their own thing and no one's talking and everyone's mean and they look at you funny if you don't know what you're doing. Honestly, my partner and I definitely looked out of place, and someone came up and helped us immediately. It was so nice.
Recommendations for makerspaces	Have people there that are, I guess, kind of just asking around more so than just kind of walking around doing their thing. Have them talk to you, be like, hey, do you want to make something? Did you want to help me with something? Or like that. Be a little bit more inviting. Do you want to try and screw this in for me? Even if it's not something that's important, if it breaks it's whatever, just something like that. Just have a more inviting kind of vibe to it, I guess. That would be one example.
Aspirations, goals, desires, or plans	I had always thought I would go to medical school. Get an engineering degree, go to medical school. Then I have pretty much figured out I can't do the blood and the needles. That went off the table about a

Code	Typical Exemplar
	year ago, maybe. My mom's a lawyer. She works for BP, actually, she was working some acquisitions. I always thought law school, maybe, we'll see. I can be an IP lawyer, I can get an engineering degree and do patents and go to law school after that.

Papers in Preparation/ Under Review

One submitted manuscript combines a critical pedagogy framework with narrative inquiry to story specific examples of one female student's pedagogical experiences when navigating oppression and empowerment within the makerspace. The primary participant in this project is an undergraduate mechanical engineering female student of Middle-Eastern descent who is also a first-generation college student.

The second manuscript is aligned with our second research question and takes a macro level approach to understanding the impact of the institution specific profiles of the makerspaces' parent university. Questions revolve around who utilizes the makerspace, for what purposes it is used, and the experiences described by those navigating the environment. This investigation will include and compare several predominantly white institutions, a Historically Black College and University (HBCU), a Hispanic Serving Institution (HSI), a liberal arts university, and an Asian American Native American Pacific Islander (AANAPI) university.

The third manuscript is aligned with our first research question and focuses on the personal growth and identity development stories of engineering students, who engage in makerspaces. Lived experiences of these students will be shared to help develop a rich, complex, and nuanced understanding of the role of makerspaces in engineering student's identity development as engineers.

The fourth manuscript is focused on storying the personal growth and identity development of students from URGs, as this will help us begin to develop an understanding of the potential of makerspaces to be a space of empowerment for URG engineering students. This manuscript will conclude with recommendations to makerspaces for ways of creating makerspaces that become spaces for empowerment.

Conclusion

In conclusion, this paper gives an in-process perspective of this broader research project. We have provided the motivation for our project and details of our data collection and analysis phases of the project with a particular focus on lessons learned (e.g., better manage participant recruitment, ask explicitly about URG status). We concluded with a short description of four manuscripts (under review and in preparation), which will contribute significantly to our empirical understandings of the role of making in the identity development of engineering students.

Acknowledgements

We wish to thank the reviewers of this manuscript for their support and thoughtful suggestions. This material is based upon work supported by the National Science Foundation under Grant No. 1636475.

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Appendix

Interview Protocol

I am interested in hearing your story of how you got to where you are today. What are experiences that you had that helped steer you to where you are as an engineering student? Consider the full spectrum of your experiences, these could be from your childhood, family interactions, interactions with friends, experiences working, etc.

Engineering Experiences

- Describe a time when you really felt like you were an engineer (or meant to be an engineer).
- Who were "influencers"/mentors throughout this experience? Describe your sources of mentorship and support in pursuit of your studies.
- Tell me about a recent experience that would help me understand your experiences as an engineering student.

Making Experiences

- Describe a time when you felt like you were a maker.
- Tell me about your experiences making (or in makerspaces)? Begin with what first got you involved in making.
- What were your first impressions of the makerspace? Did anything stand out about the makerspace? How does it compare to your classrooms or to labs?
- Could you describe one of your making projects from start to finish?
- In what ways, if any, have the makerspace faculty, management and/or staff influenced you as a maker?

Comparisons to Peers

- In this study, we are interested in students from underrepresented groups and their experiences as engineering students and as makers. How has being a _____ [refer to responses in demographic survey, e.g., black woman] influenced your experiences as a maker and as an engineering student? How does your experience compare to your peers? Can you tell me about how that has influenced how you have gotten to where you are now?
- Underrepresented groups include aspects of race, ethnicity, gender, socioeconomic status, veteran status, disability status, and/or sexuality. Have you noticed any students from these groups in engineering or making? Have you noticed them having any problems as they navigate these spaces?

Life Experiences/ Future Goals

- Tell me about yourself, your background, your life outside of engineering.
- What are your desires, goals, plans or aspirations after college?

Final Question

As a _____, how could your experience be better in engineering and in the makerspace? If you could tell the university something to make your experience better, what would it be? What could the university do better for _____(e.g., women, black student) in engineering (or other group)?