HOW DO ENGINEERING UNDERGRADUATES DEFINE ENGINEERING IDENTITY?

Brett Tallman, William Schell*, Tessa Sybesma, Monika Kwapisz, Shannon Ranch
Norm Asbjornson College of Engineering, Montana State University

Bryce Hughes
Department of Education, Montana State University

Christy Bozic, Daria Kotys-Schwartz
College of Engineering and Applied Science, University of Colorado

***wschell@montana.edu**

Abstract
Identity is central to learning in engineering, and development of an engineering identity is a core aspect of the education and training process for engineers. Identification with engineering has been shown to assist in the recruitment of diverse students into the field and improve student retention among all groups. For these reasons, engineering educators should consider the formation of professional identity as they make decisions about how to best prepare graduates to enter their chosen fields. In order to utilize professional identity, these educators must understand how their students conceptualize engineering identity.

This work seeks to promote that understanding by investigating conceptualizations undergraduate engineers hold of engineering identity, their self-view as engineers, and the sources of these views. Using data collected from pilot focus groups of ten undergraduate students at two different U.S. engineering schools, we applied a grounded theory approach to explore these topics. This exploration found many elements consistent with prior work in engineering identity (e.g. a focus on technical knowledge defining engineering) while adding new elements, such as students' surprise at the breadth of engineering and desire to use their engineering education as a vehicle to positively impact the world.

Keywords
Engineering identity, engineering development, engineering education

Introduction

As the challenges facing humanity increase in scope and complexity, the need for technical experts to participate in cross-disciplinary teams has only increased. To address this societal need, many are calling for more engineers to enter the workforce. However, of those who begin their training as engineers in college, only 60% persist, and only 43% of those who expressed interest actually enter the engineering profession (Lichtenstein et al., 2009). Substantial research suggests that a significant influence on this fallout may be misconceptions in engineering education: "Research in engineering education has shown that academic programs are often designed based on a projected image of engineering practice, which may be outdated or unrefined" (Lichtenstein, McCormick, Sheppard, & Puma, 2010, p. 315). Moreover, if societal interest is not only cultivating engineers, but preparing engineers to be successful, more must be understood about how engineering students' identities develop in their education. The concept of identity—how people see themselves, how others see them, and their role in society—provides a useful framework to understand the dynamics that lead to both degree completion and participation in a profession. In fact, evidence suggests that engineering identity growth significantly correlates with persistence in both degree completion and entrance into the engineering profession (Carlone & Johnson, 2007; Matusovich, Streveler, & Miller, 2010)

The purpose of this paper is to report how engineering undergraduate students think of identity, and the sources of these ideas. The research questions that guide this paper are:

1) How do undergraduate engineering students define engineering?
2) How do students see their identity aligning with that of their definition of engineering?

3) What experiences have been meaningful to their self-view of being an engineer?

Literature Review

Identity is a concept that represents the position of an individual within broader society. It is a complex phenomenon with a variety of types or perceptions, often based on role. Situated learning theory suggests that identity is central to human development (and learning, in particular) as learning of all types is constructed within and defined by context (Brickhouse, Lowery, & Schultz, 2000). As a result, identity is critical to learning, some even maintaining that "learning is…. A process of forging identities…" (Lave & Wenger, 1991, p. 3)

Professional Identity

Amongst the many identities that one may embrace in their life (e.g. an athlete, a spouse, a sibling), a person's professional identity is of particular interest to this research. This is because engineering education has two core foci: 1) develop competence in engineering technical material, and 2) prepare students for the engineering profession. The dual foci of technical and professional competencies are further reflected by the faculty; they represent leaders in an engineering professional community. While this community is led by recognized experts in their field, the community also includes new graduates who are just developing professional expertise. In summary, identity is central to learning and professional development, especially for engineers.

Lave and Wenger's (1991) Community of Practice (CoP) model provides a process-based approach to identity formation. The CoP model posits peer recognition of both technical competency and contribution as the essential currency for increasing recognition within a professional community. This model requires essential knowledge to be defined by the community and situated within context. Within this context, Wenger (1998) suggests three modes of belonging: engagement, imagination, and alignment. Engagement reflects direct experience within the community, cultivating shared meaning —performing engineering tasks or demonstrating technical mastery of engineering concepts (Stevens, O'Connor, Garrison, Jocuns, & Amos, 2008). Imagination reflects one's ability to be recognized as a member of the community — perceiving oneself as an engineer or being recognized as an engineer by others. The alignment mode of belonging describes the degree of alignment between one's values and those of engineers — values such as global agency (Godwin, Potvin, & Hazari, 2013) or social skill (Lichtenstein et al., 2010). Within the community of practice model, a sense of belonging may develop along any one of—or all—three modes. As a final note, Wenger (1991) strongly criticized academia for widespread insulation of students from their respective professional communities of practice, leaving graduates ill-prepared to navigate these communities effectively. The literature in professional identity provides the foundation for work in engineering identity.

Engineering Identity

While professional identities often form within communities of practice, the factors that influence identity development vary across fields, especially in the engineering profession. The complicated nature of the profession makes identity an ideal framework for exploring what it means to be an engineer. Complicating this discussion, there is not a current widely accepted definition of engineering identity. The lack of consensus reflects the relative novelty of the field, as well as the extent to which it borrows from adjoining fields (Borrego, Foster, & Froyd, 2014). To work through the varied perspectives, this work leverages Morelock's (2017) four-fold categorization of engineering identity definitions. In this definition, engineering identity is composed of an *overlay* of identities, defined by *perceptions*, formed by *engagement*, or developed by individual *action*.

The first of these categories views engineering identity as an *overlay* of other more elementary identities. Capobianco (2006) used these dimensions to explore ways in which students saw themselves in the context of engineering. This approach showed how gender-identity, institution-identity, academic-identity, and role models were central to professional identity amongst a small sample of women engineers. A later survey simplified this approach and demonstrated that a two-pronged measure of identity was more suitable: academic identity and engineering career (Capobianco, Diefes-Dux, & Habashi, 2009). Borrego, Patrick and Kendall (2018) proposed a similar overlay approach by comparing cognitive identity and organizational identity, finding high overlap (Cronbach's alpha of 0.84) between the "cognitive (i.e. self-categorization) component of identification" (p. 1) and engineering identification.

A second approach to engineering identity is defined by *perception*, such as how an individual perceives the world around them, how they understand engineering, and how they are treated by their environment. A popular model under this approach is Tonso's (2006) seminal qualitative quasi-longitudinal ethnographic research. This study included over 40 individuals, both engineering students and faculty to explore engineering identity, where acting like an engineer, being recognized as an engineer, and believing oneself to be an engineer were essential aspects of engineering identity. This approach to engineering identity has been widely used in the literature.

The third category is defined by *engagement*, in terms of affect, cognition, and behavior (Fredricks, Blumenfeld, & Paris, 2004). This is reflected in the CoP model discussed under professional identity. This approach has become more popular recently in the engineering identity literature and includes topics such as value-beliefs (affect), technical competency (cognition), and recognized performance (behavior) (Patrick & Borrego, 2016). The model was quantitively verified in an engineering context in a longitudinal exploration of the development of engineering identity amongst 6,772 freshmen engineering students (Godwin et al., 2013). An earlier ethnographic study of engineering students found that technical competence, navigating pathways, and recognition were three axes along which the process of becoming an engineer could be measured (Stevens et al., 2008). Matusovich, Streveler, and Miller's (2010) longitudinal case study examined 11 engineering students within an Expectancy-value framework (where engagement decisions are driven by competence and value beliefs), finding that engineering students were more likely to persist in engineering—a key indicator of engineering identity—when their values aligned with those values of the engineering profession. In addition, Faulkner (2007) and Lichtenstein, Chen, Smith, & Maldonado (2014), found differences between how men and women experienced engineering and identified with the profession. Further, the study showed that these differences related to values in the engineering profession that disadvantaged feminine aspects of the profession.

A final category of engineering identity is understood *by specific actions or decisions under an individual's control, or agency*. In a qualitative exploration of over 50 women engineers, Hatmaker (2013) explored ways in which women "…construct their professional identity in response to workplace interpersonal interactions that marginalize it" (p. 382). Using this agency-based approach, analysis found that impression management tactics and coping strategies were essential to identity construction in a marginalizing environment. Another study found that making competent design decisions, working with others to share ideas, and accepting responsibility were core components of engineering identity development (Meyers, Ohland, Pawley, Silliman, & Smith, 2012). This quantitative work included over 700 engineering students at one school and found students generally equated the process of becoming an engineer with becoming an adult.

Recent work investigating engineering identity bridges these categories of engineering identity to prior work in professional identity formation. Kajfex, Mohammadi-Aragh, Clark, Sassi and Petrie (2019) used the CoP framework to develop survey instruments that measure first-year (FY) experiences. They found students enrolled in FY experiences scored higher in engineering identity and other areas related to retention. Godbole, Miller, Bothwell, Montfort and Davis (2018) applied a lens of social identities to investigate belonging in engineering. Their findings reinforced other areas of the literature that those identifying with social identity categories typically associated with engineering (e.g. white, male) felt a greater sense of belonging than others.

In summary, ways of understanding engineering identity, while complex and multitudinous, have some common threads. The literature agrees that identity-based approaches to understand engineers are adequate to explain their development, heterogeneity, and communal connections. While there is no consensus on how this identity forms, trends do appear in the frameworks: Identity is central to an individual's self-perception (therefore within one's agency), it is reflected in an individual's behavior, it aligns with perceived engineering values, and—at least for the engineering graduate and engineering professional—it is positioned within the context of a broader engineering community.

Methods

The purpose of this study is to understand how undergraduate engineering students define and understand engineering identity. The approach taken for this study was informed by the procedures for grounded theory, developed by Glasser and Straus (1967). This particular study represents an early exploration of the data and does not develop a fully fleshed-out theory. The procedures for grounded theory provide a structure based on "generating theory and doing social research [as] two parts of the same process" (Glasser, 1978, p. 2). A core characteristic of this methodology is constant comparison between new data and existing concepts.

This study's data consisted of four focus groups and examines only three questions of a lengthier protocol developed for a larger research study to examine engineering leadership. Ten students were included in these focus groups. Exhibit 1 provides the basic demographics of these students. Participants were identified through purposeful sampling of engineering students involved in extra-curricular groups of interest to the broader study's focus on engineering leadership (Patton, 2015). Focus groups were then administered by two members of the research team using a semi-structured, in-depth interview protocol. Focus groups lasted approximately one hour.

Analysis of the focus group transcripts utilized in this study included only three questions from the lengthier interview protocol of the full project. These are:

- When you first decided to major in engineering, what did you think an engineer was or did?
- How do you think one becomes an engineer?

- Do you consider yourself to be an engineer?

Exhibit 1. Participant Demographics

Participant	Gender Identity	Year	Major
P-1	Woman	Sophomore	Chemical
P-2	Man	Sophomore	Computer
P-3	Man	Junior	Electrical
P-4	Man	First-year	Electrical
P-5	Man	Junior	Mechanical
P-6	Woman	Junior	Industrial
P-7	Man	Freshman	Aerospace
P-8	Man	Unknown	General Engineering
P-9	Man	First-year	Mechanical
P-10	Woman	First-year	Engineering Physics

These three questions provide an initial framework to begin modifying subsequent data collection and analysis approaches, following the constant comparison model (BG Glasser & Strauss, 1967; Strauss & Corbin, 1994). The first question (*ideal engineer*) explored participant perception of the values, norms, and behaviors of the engineering profession. Moreover, it provided a preliminary glimpse into the type of provisional identity that students might entertain during their identity development.

The second question (*become an engineer*) acknowledges the process-based nature of identity development and agency beliefs of participants, "…considering identity not only as who one is but also who one wants to become" (Patrick & Borrego, 2016, p. 10). It provides an avenue for exploring the landscape of the pathway to becoming an engineer, from an engineering student's perspective considering Wenger's (1998) modes of belonging and legitimate peripheral participation (Lave & Wenger, 1991). Furthermore, this question provided opportunity to identity structural influences on identity development, which are of interest to practitioners and administrators looking for specific practices that will cultivate engineering identity (Creswell, 2013).

The third question (*self-concept as an engineer*) explored the ways participants orient themselves within engineering, as well as broader questions surrounding their perceptions: they might talk about their interests, their perceived role in school, or their opinion of their skills as a problem solver. This also gave insight into overlay of identities, addressing issues such as gender-, race-, and cognitive-based identities, as relevant.

Coding for this work was thematic in nature, intending to highlight core themes addressed by focus group attendees, as well as discrepant cases, using concept maps. Transcripts for the relevant segments of four focus groups were reviewed by four researchers for themes pertaining to three core concepts: ideal engineer, become an engineer, and self-concept as an engineer. After independent coding was completed, results were compared, discrepancies were explored and themes were adjusted, creating the final thematic analysis presented here.

Results

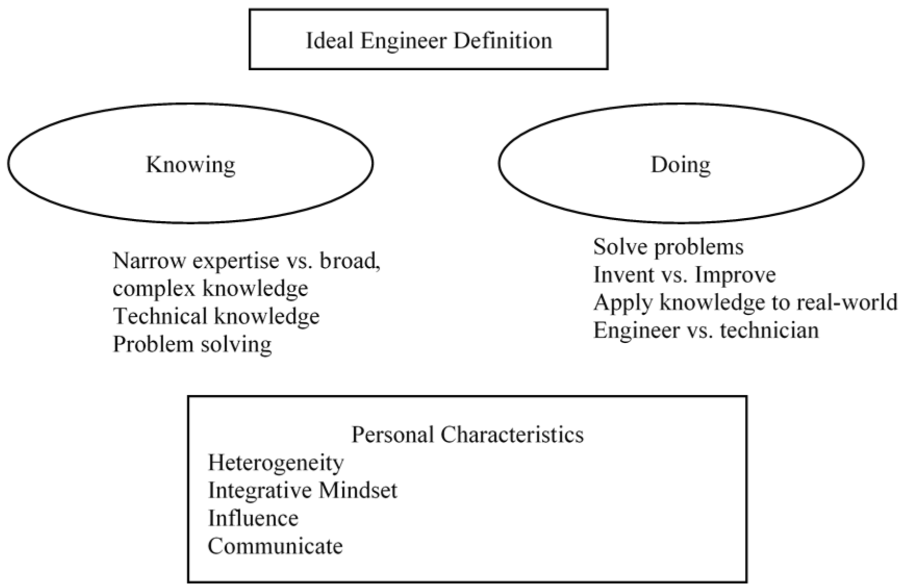
Review of the focus group partial transcripts resulted in thematic categories for concepts explored: defining the *ideal engineer*, participants' *self-concept* as engineers, and participants' process of *becoming* an engineer.

Defining engineering and the ideal engineer

Participant descriptions of an ideal engineer can be thematically categorized into what engineers know, what they do, and their personal characteristics, as illustrated in Exhibit 2. The first category—what engineers know—captures participants' beliefs about the ideal engineer's cognitive capabilities, using terms such as "…do math, do science…" (Participant-9) or "…seeing the forces, the mathematical nuances." (P-9). The most oft-mentioned idea is technical knowledge, either in terms of theoretical science or applied engineering, for example: as an engineer, "…you not only know how to understand that information [basic concepts], but also you know how to apply it" (P-7). A related cognitive skill that pervaded the discussions was problem-solving capabilities and innovation, expressed by "[an engineer] looks at a problem and thinks okay so I have to accomplish this task…" (P-1), and "…I always equate engineering to innovation…" (P-6). Finally, several participants mentioned how surprisingly broad and complex the technical knowledge (e.g. electricity and magnetism or material science or calculus) required for engineering success is: [engineering] is "… a lot more layered than I realized." (P-6)

The second thematic category relating to the ideal engineer is what they do. Engineers were seen primarily as applying technical knowledge to solve real-world problems. In addition, the nature of problem-solving was widely discussed: do engineers invent, or improve, or analyze? For example, "So I think a tinkerer [non-engineer] is somebody that has something that they want to create, or they want to improve. But an engineer is somebody who either fixes or improves something that's already there, or they create something to solve a problem" (P-10). They did agree, that while engineers were largely able to work with their hands to construct solutions, their primary task was mental, leaving daily 'tinkering' or hands-on work to technicians: "[engineers] are not technicians" (P-3).

Exhibit 2. Concept Map of the Ideal Engineer



During discussion of concepts under the Knowing and Doing themes, participants commented about the difference between their initial idea of engineers and a more informed perspective. Participants were surprised by both the extent of technical knowledge that engineering entailed, as well as the broad conceptual mastery that an engineer needed to have, as opposed to pre-college visions of someone with much narrower expertise. Some had also been expecting to have much more hands-on training (more akin to a technician), as opposed to the knowledge-based work on which they were being educated. These changes were notably common and widespread.

The third thematic category was descriptive of personal characteristics, such as integrative thinking, heterogeneity, influence, and communication. Integrative thinking reflects the frequency with which participants mentioned cognitive capabilities and hand-on capabilities together: "if you are good with your hands and you are good at math you should be an engineer," (P-3) and "[engineers] designed all of the cool machines and then go and build them…" (P-5). Participants also acknowledged the heterogeneity of engineers: "…there is no actual set engineer… because everyone just has a totally diverse experience" (P-7), with P-8 giving an example: "… you have the technical side of engineering but then you have the people side where it is much more relational…" The influence of engineers on their environment was mentioned as important: "… [it is] kind of [characteristic] in engineers to like change something" (P-7). Finally, a number of the participants highlighted the need for effective communication skills for successful engineers, such as "[engineers] can put it together in their head and… communicate to someone else what was in their head, why it works, and how to put it together" (P-3).

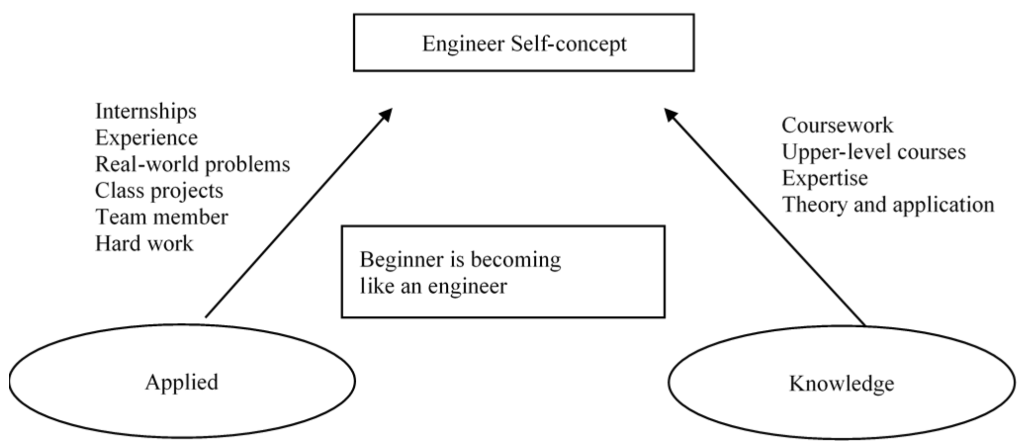
Self-concept as an engineer

Participants largely framed their idea of self-concept as an engineer in terms of how much their own identity was increasingly overlapping with their idea of ideal engineers. The framing of a self-concept could be thematically interpreted in terms of applied knowledge. The concept map shown in Exhibit 3 shows that both the "applied" and "knowledge" components of engineering identity were growing through specific experiences, such as internships or coursework. Integral to this framework is that participants described their own self-concept in terms of the process of becoming like an engineer.

Participants' self-concept as an engineer was closely linked to how they felt their skills and knowledge mapped to their conception of ideal: "I would not consider myself an engineer but I am definitely in that problem solving mindset like engineers now, just I feel like I need a little bit more uh knowledge and expertise in the field before I consider myself an engineer" (P-2). Internships or work experiences were critical to their self-concept as an engineer, with the importance of experience being mentioned often: "I am definitely not [an engineer] yet… because right now I just do not think I have the experience yet or the knowledge yet" (P-7). Many participants mentioned the impact of real-world problems, and class projects as reflections of how they felt like engineers, often in terms of problem-solving mindset: "I think I'm on my way and I think I am rewiring my brain [into a] problem solving mindset…" (P-1). In addition, participants included hard work and ability to function on a team as important to their self-concept as an engineer. Participants frequently mentioned the importance understanding theory, as well as to apply it either analytically or creatively, in their self-perception as engineers: "… my goal looks like being able to face a problem confidently and with creativity…being able to combine that analytical and creative side…" (P-8).

Finally, participants mentioned the process of becoming an engineer frequently while discussing their own self-concept as engineers, using phrases like "…I'm on my way…" (P-1), or "I do not think I am an engineer yet, but I do claim to be like one," (P-6). In other words, participants expressed that they were like engineers, but at a lower level; they were beginner engineers that were in the process of becoming full engineers. Some participants felt they had a long way to go: "…I am nowhere near where my goals are at" (P-4), on where he was on the continuum of becoming an engineer; And others felt they had arrived as engineers, even if they were only beginner engineers: "I would say that I'm an engineer in spirit but I don't know if anyone should trust me being an engineer" (P-1).

Exhibit 3. Concept Map of Self-concept as an Engineer



Becoming an engineer

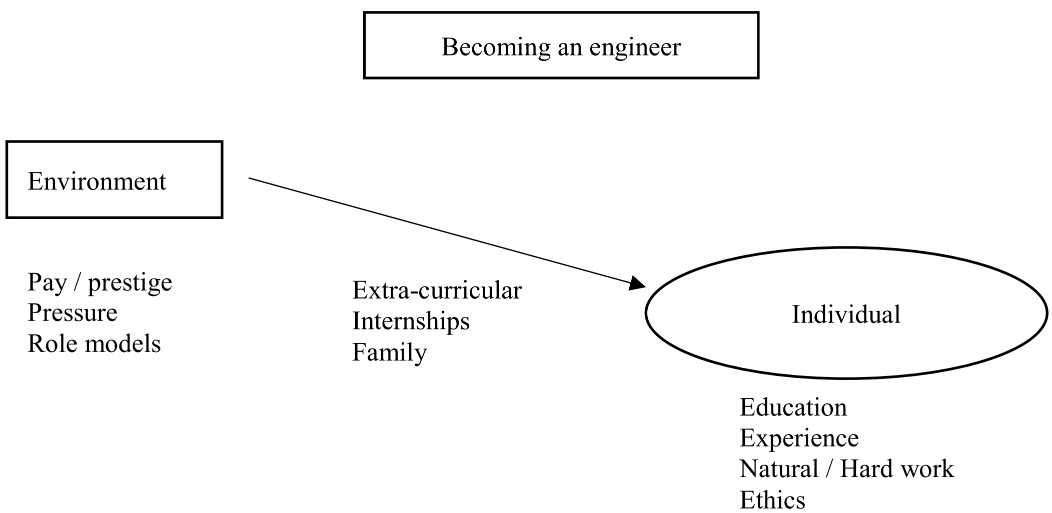
Participant discussion of the process of becoming an engineer can best be understood by viewing an individual positioned within the context of a broader environment, illustrated in Exhibit 4. Critical to the individual's development as an engineer were their education and experience. The necessity of their engineering degree was repeatedly mentioned, though a divergent perspective was offered by P-5, who "slightly disagree[d]" that the "…four-year degree" is essential to engineering, citing previous experience with a successful engineer who did not have an engineering degree. Education consisted of both growing technical expertise, as well as a problem-solving mindset: "…once you can frame [problems] that's I think when you would be an engineer" (P-3), or [engineers are] "…willing and able to use those skills that you have acquired and kind of your own skills that you acquire in extracurriculars… to be like innovative and to be a problem-solver in a new way, because I always equate engineering to innovation" (P-6).

Likewise, experience with engineering projects—in class or in the workplace—was central to their development as engineers. Participation in real-world projects were especially important to engineering development. For example, internships were cited as instrumental in developing as an engineer: "I'm doing an internship this summer… my big next step of kind of figuring out like is this the direction I want to go in my path to being an engineer…" (P-1) and "[my next step is] finding an internship… Um, that's my biggest concentration" (P-2).

In addition, individual characteristics were important to the becoming process. Students viewed natural ability as one aspect of their growth as an engineer, using phrases such as "…science and math come very naturally" (P-8), and "…I have the brain that can solve problems in a way that an engineer might…" (P-6). However, participants were also quick to point out the importance of hard work and persistence: engineering "… is a lot about just knowing how to not give up on something that is hard" (P-11), or becoming an engineer "…comes down to your qualities that are outside any like technical thing. Like self-control, patience and like work ethic…" (P-4).

Individual development is firmly rooted in and affected by the broader environment. Participants noted three significant impacts on becoming an engineer: pay / prestige, pressure, and role models. The heightened value for engineering within broader society—both in terms of salary and prestige—was an important idea in motivation to pursue and continue in the engineering field: "…everyone was just like 'do engineering because it looks good" (P-6). A second impact was external pressure to enter engineering, often from parents who wanted to ensure a stable profession for their children: "…my dad kind of pushed engineering a lot…" (P-4). Finally, role models encouraged participants to pursue engineering, or demonstrated what engineers did, making pursuing an engineering profession an easier decision, as nicely demonstrated by a negative case from a female participant: "… it did [bother me] a little bit [to be the only female in the department]. Cause then there was no female role models to look up to…" (P-10).

Exhibit 4. Concept Map of Becoming an Engineer



Summary

In summary, results indicated that the ideal engineer had components of knowing and doing as central to their definition, but also had important characteristics worth noting, such as heterogeneity, having a certain mindset, and impacting the world. This self-concept as engineers may be interpreted as how well participants believed they had applied knowledge during their experience as students thus far. Finally, the process of becoming seemed to follow a situated learning model, with the individual's education and experience being formed and influenced by the broader environment.

Initial analysis found the ideal engineer concept could be described using themes of *knowing*, *doing*, and *personal characteristics*. Participants' self-concept as engineers could be thematically described in terms of *applied knowledge* within the context of the *becoming* process. Finally, experiences critical to the becoming process are described in terms of an individual's *education* and *experience* situated within an *environment*. These three concepts combine nicely to provides a relatively complete first look at engineering identity, as perceived by undergraduate engineering students.

Discussion

Participant discussion provided useful preliminary insight into the study's research questions: 1) How do undergraduate engineering students define engineering? 2) How do students see their identity aligning with that of their definition of engineering? 3) What experiences have been meaningful to their conceptualization of being an engineer? Participants answered the first question (regarding definition of engineering) by focusing on an engineer's technical mastery and its application to real-world solutions. In other words, engineering was generally defined in terms of capabilities—either cognitively or behaviorally—rather than specific positions or qualifications achieved. Morelock's (2017) characterization of engineering identity theories that follow engagement models seemed especially relevant within this context, as participants noted ideas such as technical competence, working with others, and implementing solutions to real-world problems. Notably missing from much of the discussion about the ideal engineer were non-technical aspects of engineering identity, such as interest, communal involvement, recognition, and values. That is not to say these ideas weren't mentioned; rather they were mentioned in terms of participant self-concept as an engineer and their own processes of becoming. This may reflect the way in which undergraduate engineering students are comparing their current identity with that of their idealized engineer, as part of the identity development process—looking primarily to outward, recognizable indications of engineering, rather than internal values or motivations.

In addition, participants recognized characteristics about being an engineer that were important but served more as a supporting role to concepts viewed as more essential. The heterogeneity of engineers was noted in the context of the technical and social aspects of engineering. This directly reflects discussions on gendered approaches to engineering identity (e.g. Faulkner, 2007; Tonso, 2006; Hatmaker, 2013). Pervading the discussion of both knowing and doing was an integrative mindset, often involving juxtaposing theoretical understanding with applied solutions. This mindset included being able to frame problems, as well as solve them. And, it involved creativity and innovation, while not excluding analysis or improvement. This concept was integral to the combination of technical knowledge and applied solutions for thematic development of both participants' ideal engineer definition and their own self-concepts as engineers. Finally, participant discussion of communication expressed two ideas: communication of ideas to the field (where engineered solutions are being implemented) and communication of ideas between colleagues (where projects require collaboration). Once again, further research should provide opportunity to explore more precisely how undergraduate engineers perceive the role of communication for engineers.

Central to participant discussion of their self-concept as an engineer, our second research question, was the idea of becoming. Repeatedly, students talked about their development problem-solving mindset, or ways in which they were *like* an engineer. While they were generally hesitant to assign themselves that title, many participants saw themselves on a pathway of continued growth. Within this context, Morelock's (2017) overlap identity characterization seems instrumental in explaining student perception. As participants talked about growth in engineering identity, it seemed both an overlap of their identities, as well as an alignment of their values. As with participants' definition of the ideal engineer, the idea of integration of knowledge and its application was central to their self-concept as an engineer. Here, our analysis agrees with Dehing's (2011) assessment that Ibarra's provisional self is a useful explanation of engineering identity development.

The third research question addressed the experiences or mechanisms that influenced student perception of engineering identity. The experiences that developed their self-concept as an engineer were different, based on whether the topic was "applied" or "knowledge." Growth in applied self-concept was largely in terms of real-world problems or projects. In other words, participants felt that much of their engineering self-concept grew out of larger projects during work experience, internships, or large class projects. In addition, they noted non-technical skills that were valuable in these applied experiences, such as teamwork and collaboration. On the other hand, growth in knowledge-based self-concept was largely in terms of specific cognitive expertise that they had developed. While the data indicates this expertise was developed through upper-level courses, there were some indications that it might be developed through broader mastery of fundamental theory, or expertise in a topic. Common to both topics of growth was the idea that participants experienced growth from continuous experiences that were a result of their own engagement and agency: Mann's (2009) ongoing process of identity negotiation supports this finding, as might any engineering identity approach that focuses on agency (e.g. Patrick and Borrego, 2016).

Pursuing the question of participants' self-concept of engineers seemed to most reflect Lave and Wenger's community of practice. While participants might have viewed themselves as less engaged during their pre-college and early years, their increased involvement in both technical mastery and real-world application found them feeling more like part of the community. While they clearly felt they were on the fringe of what it is to be an engineer, they just as clearly saw themselves developing engineer-like thinking. More bluntly, their belonging within the community of practice was increasing. Further research may be able to uncover how much of this perceived development was due to institutional support—one can only hope that the criticisms that Wenger (1991) waged on universities as a barrier to engagement with the professional community has been heard and corrected. We hope to explore this more fully in future analysis.

In summary, using identity to interpret undergraduate engineering student development was most effective when participants talked about their own pathways to studying engineering. Their stories and perspectives were firmly rooted in both their own agency and experiences, the impact of the environment on them, and how they navigated the interaction between the two. Here, engineering identity theory pertaining to perception seems somewhat applicable, as participants reported being influenced by their peers or parents to enter engineering, due to their perceived interest or ability in engineering-like behavior. In other words, being perceived as an engineering-like person influenced them along their current path. This reflects Tonso's (2006) suggestion that being recognized as an engineer is important in engineering identity development. Another influence on individual growth in engineering affinity is familiarity with the profession, either through a parent or family friend, consistent with the literature on influences on budding engineering students.

It should be noted that participant discussion of their path to engineering was the one area where interest was clear. Engineering students talked about how interesting engineering fields were, or how meaningful it was to be a part of humanitarian engineering work. Here, it may be Patrick and Borrego's (2016) idea of agency beliefs have been influential on students choosing an engineering major, as they consider "…identity not only as who one is but also who one wants to become" (p. 10).

Finally, it is not surprising that concepts surrounding individual education and experience were common in the analysis: these are central categories in any discussion of development. Nonetheless, seeing these ideas emerge on their own, within an engineering context, provides evidence that engineers are like other majors in some critical ways: they are influenced by their environment, pressured by parents, and resonate with idealized versions of the fields that they eventually pursue.

Limitations and Future Work

As noted in the introduction, this work represents the initial analysis of a sample of focus groups conducted in the course of a larger project. As such, these results represent only a preliminary analysis, more rigorous analysis may yield richer insights, especially since the limited scope has not yielded a point of saturation

Over the course of the next several months, the project will complete transcriptions for an additional nearly 20 hours of focus group discussions and complete a full analysis of all areas of the protocol, adding investigation of leadership identity and engineering leadership identity to this initial exploration of engineering identity. The expectation is that the completion of the work will yield a ground theory of engineering leadership identity applicable to undergraduate engineering students. This theory will serve as a foundation to develop curricular and co-curricular interventions that develop students' engineering leadership identity.

Acknowledgements

This material is based in part upon work supported by the National Science Foundation under Grant Number EEC-1664231 through the Research in the Formation of Engineers program. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

Borrego, M., Foster, M. J., & Froyd, J. E. (2014). Systematic literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education, 103*(1), 45-76.

Borrego, M., Patrick, A., Martins, L., & Kendall, M. (2018). A New Scale for Measuring Engineering Identity in Undergraduates. Paper presented at the *ASEE Gulf-Southwest Section Annual Meeting*.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 37*(5), 441-458.

Capobianco, B. M., Diefes-Dux, H. A., & Habashi, M. M. (2009, October). Generating measures of engineering identity development among young learners. In *2009 39th IEEE Frontiers in Education Conference* (pp. 1-6). IEEE.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187-1218.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*: Sage.

Creswell, J. W. (2013). *Qualitative Inquiry & Research Design: Choosing Among Five Approaches* (Third ed.). University of Nebraska, Lincoln: Sage Publications, Inc.

Dehing, A., Baartman, L., & Jochems, W. (2011). Mechanisms of students' engineering identity development during workplace learning in the bachelor curriculum. *WEE2011, September 27, 30*, 2011.

Faulkner, W. (2000). Dualisms, hierarchies, and gender in engineering. *Social Studies of Science, 30*(5), 759-792.

Faulkner, W. (2007). Nuts and Bolts and People' Gender-Troubled Engineering Identities. *Social studies of science, 37*(3), 331-356.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research, 74*(1), 59-109.

Glasser, B. (1978). Theoretical sensitivity: Advances in the methodology of grounded theory. *Mill Valley, CA: University of California*.
Glasser, B., & Strauss, A. (1967). The development of grounded theory. *Chicago, IL: Alden*.
Godbole, A., & Miller, B., & Bothwell, M. K., & Montfort, D., & Davis, S. C. (2018, April), Engineering Students' Perceptions of Belonging through the Lens of Social Identity Paper presented at 2018 *CoNECD - The Collaborative Network for Engineering and Computing Diversity Conference*, Crystal City, Virginia. https://peer.asee.org/29530
Godwin, A., Potvin, G., & Hazari, Z. (2013). *The development of critical engineering agency, identity, and the impact on engineering career choices.* Paper presented at the ASEE 2013 Annual Conference & Exposition.
Hatch, M. J., & Schultz, M. (2002). The dynamics of organizational identity. *Human relations, 55*(8), 989-1018.
Hatmaker, D. M. (2013). Engineering identity: Gender and professional identity negotiation among women engineers. *Gender, Work & Organization, 20*(4), 382-396. doi:10.1111/j.1468-0432.2012.00589.x
Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, n/a-n/a. doi:10.1002/tea.20363
Kajfez, R. L., & Mohammadi-Aragh, M. J., & Clark, A., & Sassi, S., & Petrie, J. (2019, June), Board 29: Initial Qualitative Exploration into First-Year Engineering Community and Identity Paper presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida. https://peer.asee.org/32315
Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*: Cambridge university press.
Lichtenstein, G., Chen, H. L., Smith, K. A., & Maldonado, T. A. (2014). Retention and Persistence of Women and Minorities Along the Engineering Pathway in the United States. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 311-334): Cambridge University Press.
Lichtenstein, G., Loshbaugh, H. G., Claar, B., Chen, H. L., Jackson, K., & Sheppard, S. D. (2009). An engineering major does not (necessarily) an engineer make: Career decision making among undergraduate engineering majors. *Journal of Engineering Education, 98*(3), 227-234.
Lichtenstein, G., McCormick, A. C., Sheppard, S. D., & Puma, J. (2010). Comparing the undergraduate experience of engineers to all other majors: Significant differences are programmatic. *Journal of Engineering Education, 99*(4), 305-317.
Mann, L., Howard, P., Nouwens, F., & Martin, F. (2009, July 20, 2009 - July 23, 2009). *Influences on the development of students' professional identity as an engineer*.
Matusovich, H. M., Streveler, R. A., & Miller, R. L. (2010). Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values. *Journal of Engineering Education, 99*(4), 289-303.
Meyers, K. L., Ohland, M. W., Pawley, A. L., Silliman, S. E., & Smith, K. A. (2012). Factors relating to engineering identity. *Global Journal of Engineering Education, 14*(1), 119-131.
Morelock, J. R. (2017). A systematic literature review of engineering identity: definitions, factors, and interventions affecting development, and means of measurement. *European Journal of Engineering Education, 42*(6), 1240-1262. doi:10.1080/03043797.2017.1287664
Patrick, A. D., & Borrego, M. (2016). *A review of the literature relevant to engineering identity.* Paper presented at the American Society for Engineering Education (ASEE) Annual Conference & Exposition., New Orleans LA.
Patton, M. Q. (2015). Qualitative research & evaluation methods: Integrating theory and practice (Fourth ed.). Thousand Oaks, CA: Sage.
Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education, 97*(3), 355-368.
Strauss, A., & Corbin, J. (1994). Grounded theory methodology. In *Handbook of qualitative research* (Vol. 17, pp. 273-285).
Tonso, K. L. (2006). Student engineers and engineer identity: Campus engineer identities as figured world. *Cultural Studies of Science Education, 1*(2), 273-307. doi:10.1007/s11422-005-9009-2
Wenger, E. (1998). Communities of Practice. Learning as a Social System. *Systems Thinker, 9*(5), 2-3.

About the Authors

Brett Tallman is currently a Doctoral student in Engineering at Montana State University (MSU), with focus on engineering leadership. His previous degrees include a Masters degree in Education from MSU (active learning in an advanced quantum mechanics environment) and a B.S. in Mechanical Engineering from Cornell. Prior to his academic career, he worked in the biotech (Lead Engineer), product design, and automotive (Toyota) sectors for 14 years, and is a licensed Professional Engineer. He has also taught high school and attended seminary. You can find more of his engineering education work at educadia.org or on his YouTube channel.

William J. Schell holds a Ph.D. in Industrial and Systems Engineering – Engineering Management from the University of Alabama in Huntsville and M.S. and B.S. degrees in Industrial and Management Engineering from Montana State University (MSU). He is Associate Professor in Industrial and Management Systems Engineering and Associate Director of the Montana Engineering Education Research Center at MSU with research interests in engineering education and the role of leadership and culture in process improvement. His research is supported by the

NSF and industry and has received numerous national and international awards. He is an elected Fellow of the American Society for Engineering Management and serves as an Associate Editor for the Engineering Management Journal. Prior to his academic career, Schell spent 14 years in industry where he held leadership positions focused on process improvement and organizational development.

Tessa Sybesma is an undergraduate at Montana State University pursuing a B.S. in Industrial and Management Systems Engineering and an honors diploma. She is involved with the MSU student chapters of Alpha Pi Mu and IISE. She is working as a research assistant at MSU, a personal estate assistant, and a host at MacKenzie River Pizza.

Monika Kwapisz (they/them) is an undergraduate at Montana State University studying Industrial and Management Systems Engineering with a minor in Mathematics. Monika is the president of MSU's chapter of Out in Science, Technology, Engineering, and Mathematics (oSTEM), a cross-country ski coach, and an avid outdoors-person.

Bryce E. Hughes is an Assistant Professor in Adult and Higher Education at Montana State University, and affiliate faculty member with the Montana Engineering Education Research Center. He holds a Ph.D. in Higher Education and Organizational Change from the University of California, Los Angeles, an M.A. in Student Development Administration from Seattle University, and a B.S. in General Engineering from Gonzaga University. His research interests include teaching and learning in engineering, STEM education policy, and diversity and equity in STEM.

Shannon Ranch is an undergraduate at Montana State University studying Industrial and Management Systems Engineering with a focus in Aerospace. She is currently engaged in engineering leadership identity research as well as a proud member of Pi Beta Phi fraternity.

Christy Bozic is the Stephen M. Dunn Professor of Engineering Management and Faculty Director of the Undergraduate Program at the University of Colorado Boulder. She holds a Ph.D. in Curriculum and Instruction, an M.B.A. in Marketing, and a Bachelors degree in Industrial Engineering Technology. Dr. Bozic builds upon her extensive industry experience to develop undergraduate curriculum to better prepare undergraduate engineers for careers in business and engineering management.

Daria Kotys-Schwartz is the Director of the Idea Forge—a flexible, cross-disciplinary design space at University of Colorado Boulder. She is also the Design Center Colorado Director of Undergraduate Programs and a Senior Instructor in the Department of Mechanical Engineering. She received B.S. and M.S degrees in mechanical engineering from The Ohio State University and a Ph.D. in mechanical engineering from the University of Colorado Boulder. Kotys-Schwartz has focused her research in engineering student learning, retention, and student identity development within the context of engineering design. She is currently investigating the impact of cultural norms in an engineering classroom context, performing comparative studies between engineering education and professional design practices, examining holistic approaches to student retention, and exploring informal learning in engineering education.