How Do Students View Leadership Identity in Engineering?

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Introduction and Study Motivation

As evident by continued calls for increasing engineering graduates, societies around the world are recognizing the role engineers must play in solving the complex challenges of the future. However, the development of sheer numbers of engineers will, in and of itself, not solve these challenges. Building these solutions will require the perspectives and skills of a diverse group of professionals. Solid technical leadership is needed for these diverse groups to effectively work together. As skilled people trained in complex problem-solving methods and systems thinking, engineers should be well-positioned to provide this technical leadership. However, engineering students often lack interest in developing leadership skills or pursuing leadership roles or don't experience leadership in an engineering context and therefore are often not well prepared to provide technical leadership.

As part of a larger, multi-year project, our work hypothesizes that this lack of interest might be explained and overcome utilizing an identity framework (see Schell & Hughes, 2016). As summarized in Figure 1, we model leadership in engineering as a unique identity construct at the intersection of engineering identity and leadership identity. In this paper, we seek to answer the research question: How do engineering students differentiate between leadership and engineering leadership? We do this by exploring and contrasting how undergraduate engineering students define traits of leadership and traits of engineering leadership as proxies for two of these identity constructs. This exploration was completed using a qualitative approach based on data from 20 focus groups, encompassing 64 students, held at three different universities in the United States. This paper represents the first step into analysis of this qualitative data set.

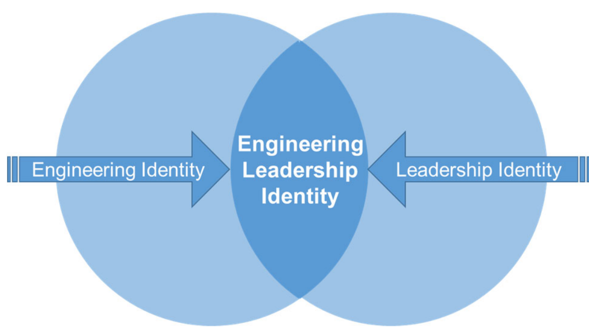

Figure 1: Hypothesized Engineering Leadership Identity Construct

Literature Review

In the U.S. and elsewhere, there is growing interest in understanding the role of leadership in engineering and engineering education (e.g. Knight & Novoselich, 2017; Schell & Kauffmann, 2016). While part of this interest is driven by accreditation (Klassen & Sá, 2019; Kotnour, Reilly, & Selter, 2014) the loudest calls for developing students' leadership skills tend to come from industry and national reports (e.g. King, 2008; National Academy of Engineering, 2013; National Research Council, 2005). While interest is increasing, our earlier work has indicated that much of the literature in engineering leadership simply highlights what actions faculties are taking with the intention of developing leadership skills in their students. There is little published about the foundation of the intended learning outcomes or the efficacy of the faculty actions (Schell et al., 2019). We are interested in closing these gaps and utilize an identity framework as an approach for influencing and measuring student development. Identity is a concept that reflects how an individual is positioned relative to broader society. Situated learning theory suggests that identity is central to human development as learning of all types is constructed within and defined by context (Brickhouse, Lowery, & Schultz, 2000). Therefore, identity is so critical to learning, that learning itself might be distilled as "a process of forging identities" (Lave & Wenger, 1991, p. 3).

Engineering Identity

Given the centrality of identity to learning, it is not surprising that the engineering education literature has a growing segment focused on identity. However, like many nascent areas of study, engineering identity has a variety of meanings, approaches, and measures present in the literature with only limited evidence of vectoring into an unified definition and measure (Patrick & Borrego, 2016). Despite these limitations, engineering identity (and various related measures called engineering identity) are shown to improve persistence (Meyers, Silliman, Ohland, Pawley, & Smith, 2012) and create a greater sense of belonging in the field (Godbole et al., 2018). This second outcome is especially important for educators seeking to expand the diversity of students successful in engineering. Readers interested in deeper treatment of how engineering identity is grounded in the more mature literature of professional identity and how other professions leverage identity to improve their educational efforts can see our earlier treatment of the topic (Schell et al., 2019).

Leadership Identity

Traditionally, leadership has been thought of in terms of behaviors leaders employ to direct followers, make decisions, and generate positive outcomes. This thinking leads to leadership development programs focused on skill development, which are generally found to have limited effectiveness (e.g. Collins & Holton, 2004; Day, Fleenor, Atwater, Sturm, & McKee, 2014). These shortcomings led our work to seek a more holistic approach grounded in identity. While a growing body of work has considered the role of identity in development of leadership (e.g. Munusamy, Ruderman, & Eckert, 2010; Van Knippenberg, Van Knippenberg, De Cremer, & Hogg, 2005) its focus has been on working professionals. For considering college student development of a leadership identity, the most widely utilized approach is the Komives, Owen, Longerbeam, Mainella, and Osteen (2005) Leadership Identity Development (LID) model. The LID model's central argument is students develop a personal sense of identity as a leader as they deepen their understanding of what constitutes leadership—namely, that leadership is a process within an organization, rather than a position. This starts with three stages: awareness, exploration and engagement, and identification of leaders. These stages provide structure for examining students' experiences with and definitions of leadership and the impact they have on their identities in this work.

Engineering Leadership Identity

As depicted in Figure 1, the combination of engineering and leadership identities provide the foundation for examining an engineering leadership identity. This literature is truly nascent with less than a handful of research teams publishing in the area. The leading perspective comes from a qualitative study of practicing engineers (Rottmann, Sacks, & Reeve, 2015). That study found three orientations to engineering leadership: 1) Technical Mastery – skilled at solving technically challenging problems and supportive; 2) Collaborative Optimization – a proven ability to build high performing teams; and 3) Organizational Innovation – apply entrepreneurial thought to bring solutions to market. Subsequent work in this area, including this one, has sought to investigate the existence of orientations for engineering students.

Methods and Approach

This work represents the latest phase of a multi-year project to explore engineering leadership identity in engineering students. The first phase employed extensive quantitative analysis of two national data sets of college students in the United States. That data was used to explore questions related to the impact of leadership experiences on engineering students in terms of both skill and identity development. Details of these studies can be found in (Hughes, Schell, & Tallman, 2018; Schell et al., 2019; Schell & Hughes, 2017; Schell, Hughes, & Tallman, 2018). The results of these studies were combined with findings from the literature, to develop qualitative protocols for this study.

Development of the Protocol and Questions

The qualitative protocols were developed to explore three distinct areas of student perceptions: engineering identity, leadership identity, and engineering leadership identity. Development began with compilation of interview protocols used by other qualitative studies in these areas. This review identified nearly forty studies and over 100 questions. Through a series of reviews and refinements, a final protocol was developed. It was designed to take one hour with a focus group of 3 – 5 participants. Table 1 provides an example of the questions utilized in each of the three protocol areas.

Table 1: Sample Protocol Questions by Area

Topic Area	Sample Question(s)
Engineering Identity	Think back to when you first decided to major in engineering. Can you recall what you thought an engineer was or does, at the time?
Leadership Identity	Do you see yourself as a leader? Why/why not? Can you provide an example of a time when you most felt like you were a leader?
Engineering Leadership Identity	Do you see leadership playing a role in being an engineer? What would that role be?

Qualitative Data Collection

Qualitative data collection began with two pilot studies at Montana State University. These studies provided an opportunity to test and refine the protocol and train new members of the research team in focus group techniques. Participants in the initial group consisted of undergraduate members of the research team. They then served as a starting point for a snowball sample of additional students. Over the next seven months, twenty focus groups were conducted at [three different institutions]. These focus groups included 64 total students representing 17 different engineering majors, resulting in over 22 hours of recorded material.

Qualitative Analysis

To prepare for qualitative analysis, recordings were transcribed by a professional service. Research team members then cleaned transcripts. This cleaning included listening to recordings of transcribed areas where crosstalk was present, correcting typos, and performing quality checks. All 362 pages of clean transcripts were imported into NVivo 12.

Coding and Consensus Building

To begin the development of coding, a single focus group was selected, and all six members of the team were instructed to read the transcript and write their list of initial codes. The group then spent several weeks discussing these potential codes and their applications to the sample transcript. The result was a simplified codebook of twelve codes (three categories with four codes each). The three categories were engineering, leadership, and engineering leadership, each composed of four codes related to development, identity, changes in perception, and traits (the code of particular interest in this paper). Once initial consensus was achieved, the group was split into two triads, with each assigned to a new transcript. Members of these groups then individually coded the transcript in NVivo and met to achieve consensus. These meetings led to further refinement of the simplified codebook.

After reaching consensus on this codebook, each triad returned to their most recent transcript, recoded it individually, and then met to reach consensus. This consensus building took place over several meetings at both the triad and team level resulting in robust documentation of rules for each code's use. These rules were then tested with an additional focus group by each triad. When consensus was achieved with minimal additional discussion and rule generation, the remaining focus groups were assigned to random pairs from the team. Each team member than coded each of their transcripts and met with their partner for that focus group to reach consensus. If the pair could not reach consensus, additional team members were consulted. The result of this effort was consensus coding for each transcript.

Comparing Leadership and Engineering Leadership

In the final steps of analysis for this work, NVivo queries were run to extract the text for the consensus codes *Traits of Leadership* and *Traits of Engineering Leadership*. This extract contained 92 pages of structured text and the coding ribbon for each of the more than 360 blocks of text. These blocks were then read and classified into a theme. Themes provide our second level of analysis. Through this process, a total of 72 themes were identified. For example, the following was consensus coded as *Traits of Leadership* and then classified as a <u>*Big Picture*</u> theme:

> *I think it's also important to have a big picture mentality. If you have somebody who is great at understanding human nature and the product or task at hand, you also have to have somebody that being a leader, especially like in a company, you have to not only be good at, if you're an engineer, at engineering, but you have to understand the finances, and kind of business sense. And I feel like there's just a lot of different things that you have to understand how your position works in with the grand scheme of things.*

These themes were then compared to look for differences and similarities between how undergraduate engineering students defined both leadership and engineering leadership.

Findings

A high-level comparison of the codes for *Traits of Engineering Leadership* and *Traits of Leadership* is provided in Figure 2 using word clouds generated by NVivo.

One can see the three most common words in each cloud are shared between both of the codes: "engineering", "leader", and "think". Certainly, one might expect that "leader" would feature prominently in both. "Engineering" might be less expected as a common term but can be explained by the nature of the participants. "Think" is prominent as a key component of the phrase many students utilized to answer most questions, as shown in the last quote of the prior section and likely unimportant in future analysis.

Common words are found at many levels beyond these top three, including "people", "things", and "project". Perhaps of more interest are when the words appear at a substantially different weight in one cloud than the other. Using the NVivo word frequency tools to better quantify these differences, we find that "skills" appears over three times as often (on a weighted basis) in the *Leadership* code as in *Engineering Leadership,* while "science" is the 41st most common word in *Engineering Leadership* and does not even appear in *Leadership.*

To better understand the similarities and differences between these codes we next investigated the themes appearing in each.

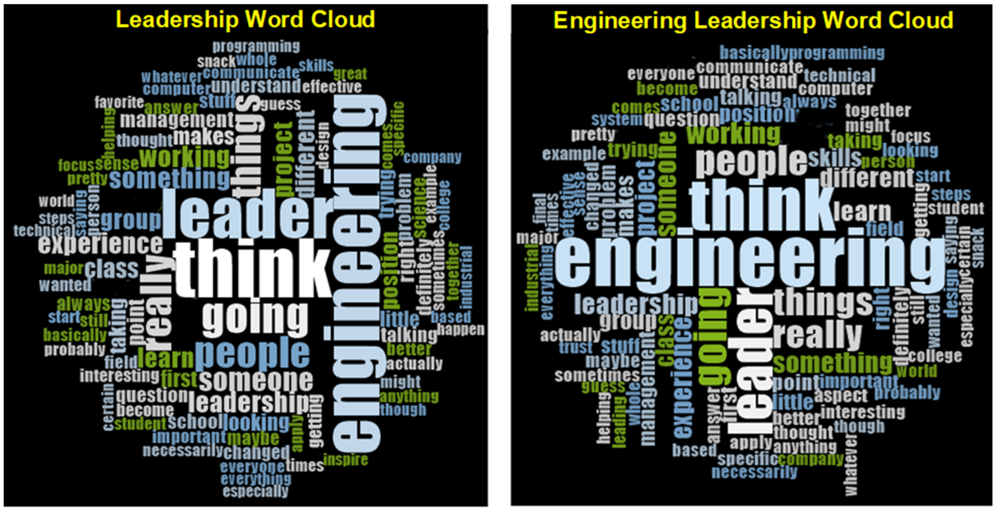

Figure 2 - Word Cloud Comparison of *Leadership* and *Engineering Leadership*

Comparing Themes in Leadership and Engineering Leadership

Figure 3 provides a summary of the 24 most common themes representing over 85% of the 360 text blocks investigated for this work. The placement of the theme indicates the theme's occurrence between the two themes and font size indicating its overall prevalence.

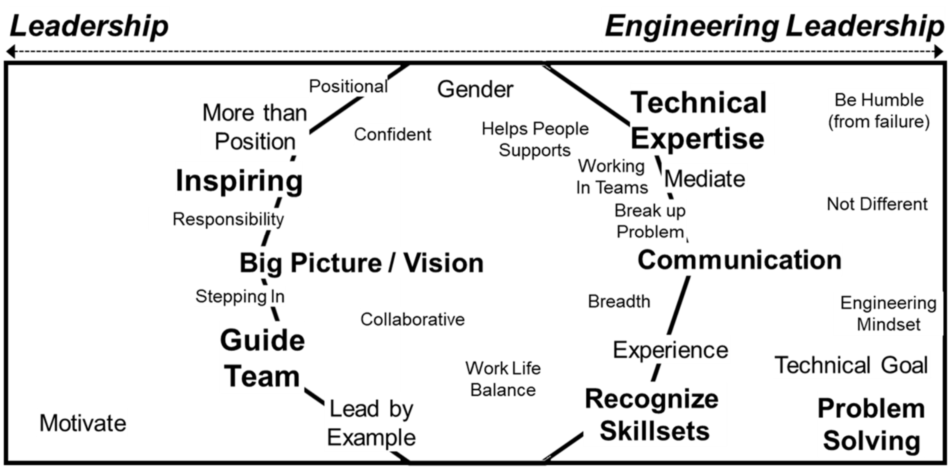

Figure 3 - Data Themes' Relationship to Leadership and Engineering Leadership

At first glance, we see a large number of themes with considerable overlap between the two codes (denoted by appearing in the center circle). However, we quickly see that most of these shared themes are minor. Conversely the three largest themes, *Inspiring*, *Guide Team (supportive behavior toward a goal)*, and *Technical Expertise*, are only partially shared between the two codes. *Technical Expertise*, the most common theme appearing 28 times total, appeared only twice (7%) in *Leadership*. Given this stark difference, it's important to understand how students' text blocks fit the *Technical Expertise* category:

> *I would go back to being able to step down as a leader when you're not in your area of expertise. We have a, I think it's just AICHE code of conduct, and one of those bits and pieces talks about only pursuing your work to the*

> *extent that you are capable of. I think that an engineering leader would . . . An engineering leader knows to do that, I guess, in short.*

> *[. . .] Unless you know everything about the topic and what the topic relates to, then you are not able to be a good leader to lead a team with good leadership. We have to know the topic more than anybody else [. . .]*

The first quote provides a typical example of a student's thoughts on how *Technical Expertise* is a part what they are defining as *Engineering Leadership*, while the second quote provides one of the only two times that *Technical Expertise* was tied specifically to the more general *Leadership* code. The idea that students separate *Engineering Leadership* from *Leadership* based on technical elements is further reinforced by the placement of *Problem Solving*, and *Technical Goal* to the right side of Figure 3. At the same time, prominent themes indicating skills and behaviors that are more people-centered, such as *Inspiring*, *Guide Team*, and *Motivate* appear on the left side of Figure 3. This is consistent with common conceptions of leadership. A notable exception here is *Communication*, where 86% of all occurrences happened under *Engineering Leadership*. The following quote may provide some insight as to why:

> *Going back to the whole idea of being able to interact and communicate with many different types of people, if you're just stuck around engineers all day, you get the one type of interaction which is very slow, very methodical, very scientific in method and approach. Versus interacting, I think of English majors off the top of my head. Cause the three that I know are sporadic, they do whatever comes to mind and then figure things out from there. So, forcing us into the corner of campus and keeping us away from everything else, in a way keeps us from learning how to interact with people like that, or other types of people. It's not a dichotomy at all.*

In this example, and many of the 13 text blocks with a *Communication* theme, students discussed the methods of their engineering education. Sometimes, as here, that discussion focused on the educational methods being a hindrance to building robust communication skills. Others noted how faculty repeatedly highlighted the importance of communication within their education, even if little training was provided to improve it. In a second exception, *Mediate* was almost only mentioned as a trait of *Engineering Leadership*. Investigation of these text blocks shows that students see this as a role steeped in technical expertise, where the engineering leader is responsible for mediating between engineers and other groups.

Finally, two prominent themes are nearly balanced between the two codes. These are *Big Picture / Vision*, the fifth most prominent theme overall with a 56/44 split, and *Gender* with a 50/50 split. Within discussions of *Gender*, students were often highlighting the lack of gender balance in both engineering and engineering leadership. The *Big Picture / Vision* theme was more nuanced, with *Leadership* codes often mentioning the leader's need to understand and explain the big picture or vision to a team in a broad sense and *Engineering Leadership* codes commonly emphasizing the need to understand the big picture of a specific project and recognize the different skills that were needed to achieve the vision.

In addition, there are some surprising alignments between themes and the two codes. For example, *Problem Solving* is 100% aligned with *Engineering Leadership*, a direct conflict with most any writing on leadership. While *Motivation* is 100% aligned with *Leadership*, a sure recipe for failure if an engineering leader were to ignore the importance of human motivation. One might speculate that these alignments are driven by biases within the engineering identities of the focus group participants.

Comparison Against the University of Toronto iLead Model

As noted in the discussion of the literature, the most robust earlier work in an identity based approach to engineering leadership was completed by Rottmann et al. (2015), who studied practicing engineers. That study developed a grounded theory that identified three orientations of engineering leadership. Our findings studying engineering students fully reinforces their orientation of technical mastery (e.g. *Technical Expertise* and *Technical Goal*) while providing limited support to collaborative optimization (e.g. *Recognize Skillsets* and *Big Picture / Vision*). Almost no evidence of the Toronto model's orientation of organizational innovation is present, with the theme of *Bold / Risk Taker* being the only related theme to appear above a 1% level in *engineering leadership* codes.

Potential Limitations

While this study represents a general large sample for qualitative work and includes students from three different universities and a wide range of majors and demographics and our methodological choices have enabled the collection of deeply contextualized data, the reader is cautioned that we have not yet reached full saturation, so conditionality may not yet be understood. For these reasons, abstracting these conclusions to other conditions may require adjustments that are unknown at this time. The conditions of this sample are large research intensive institutions where engineering is a prominent field.

In addition, the analysis presented here is only preliminary with regard to themes and does not yet consider the impact of 10 remaining thematic categories, such as the role of engineering identity or development experiences codes in the comparisons. We expect that further analysis of our qualitative data will develop a far richer picture of the role of engineering leadership identity in engineering education and broaden the implications of this work. For example, additional analysis comparing differences in demographic groups might strengthen our understanding of how student views are shared or differ between these groups, potentially providing educators with different strategies to engage these groups or showing that current findings have broader applicability.

Implications, Conclusions, and Future Research

The comparison of leadership and engineering leadership provided in this work represents a first step into generating a grounded theory of engineering leadership identity using the focus group data collected in the study. By understanding the relationship between how engineering students construct the concepts of leadership and engineering leadership, educators will be better prepared to develop them in their own students. For instance, how might engineering students develop awareness of the role of leadership in engineering earlier in their academic careers? How might that awareness by leveraged into seeing the importance of things like human motivation for their future success?

Furthermore, this work identifies some potentially meaningful differences between how students and working engineers construct engineering leadership. This highlights an area of future research to understand these differences. By understanding these differences, we would hope to better identify the leadership needs of working engineers and trace the development of those needs back into their academic training.

As noted in limitations, a key component of future work is to take the analysis of the data to deeper levels. We expect this analysis will not only provide a nuanced picture of what engineering leadership means to undergraduate engineering students, but also ground it deeply within an engineering identity while highlighting impactful development experiences. This work will be used to refine course based interventions that are being tested at [the schools] during the next two semesters. Findings regarding the efficacy of these interventions will be utilized to design tools for engineering educators to deploy engineering leadership identity development throughout the curriculum.

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