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An Approach to Understand the Role of Identity in Engineering Leadership

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Abstract

In order to most effectively contribute to the development of solutions to society's greatest challenges, engineers must learn to lead the interdisciplinary teams required to develop these solutions. However, most undergraduate engineering programs do little to develop leadership skills in their students. Perhaps, one reason for this gap between needs and education is a conflict between the development of an engineering identity and a leadership identity. To date, the literature contains little work that illustrates the role leadership concepts play in the formation of an engineering identity. Therefore, more work is needed to understand the formation of a leadership identity within the formation of an engineering identity. Together, these development processes constitute the formation of engineering leaders.

This paper presents the methods underway to validate and refine a proposed theoretical model of engineering leadership identity development. This model can be used to reshape existing engineering leadership education programs and integrate leadership into the engineering curriculum in an innovative manner. The model starts with a fundamental assumption that the engineering leadership formation process is, at its core, an identity development process. This assumption is also central to two established theoretical perspectives that informed the construction of this model. Lave and Wenger's (1991) communities of practice model argues that the development of a professional identity is the outcome of learning within a community of practice, and is frequently used to explain the process by which undergraduates develop a sense of engineering identity. The communities of practice model is then combined with Komives, Owen, Longerbeam, Mainella, and Osteen's (2005) Leadership Identity Development Model to outline how engineering students might cultivate a self-concept as a leader. A key argument within this model is that college students develop a personal sense of leadership as an identity when they view leadership as a process, not merely a position.

This paper first explains the development of this theoretical model of engineering leadership identity development combining the literature from engineering identity development, leadership identity development within collegiate populations, and engineering leadership. Following this explanation, this work focuses on the methods developed and currently being deployed to validate and refine the model, including initial findings from this research.

Introduction

As society finds itself facing ever more complex challenges, many in government and industry have called for training greater numbers of engineers to provide our workforce with the skills needed to successfully design solutions to these challenges. However, designing these solutions is difficult not only due to the complexity of the problems faced, but also the very nature of the engineering design process. In a seminal work in the area, Bucciarelli (1994) revealed that design is a social process that only exists in a collective sense. In order to lead this social process and ensure that the capabilities of an expanded engineering workforce are successfully harnessed, new engineers must be more than just technical experts, they must also be technical leaders (National Academy of Engineering, 2013; National Research Council, 2005). This need provides the impetus for developing greater levels of engineering leadership in undergraduate students.

While the Green Report called for inclusion of leadership in engineering education over a generation ago (Dowell, Baum, & McTague, 1994), the engineering education community has only recently built momentum in this area as shown by increasing research activity and, in 2014, developing a leadership-focused division of the American Society for Engineering Education (American Society for Engineering Education, 2014). Perhaps the most visible aspect of this momentum is the establishment of engineering leadership certificates and minors through centers at universities throughout the country (Graham, 2009; Klassen et al., 2016). While the implementation of these programs is a step forward, most programs tend to focus on leadership as a set of skills or experiences bolted onto a traditional engineering education (Palmer, Birchler, Narusis, Kowalchuk, & DeRuntz, 2016). This approach does little to understand the more complete picture of how leadership fits into the broader picture of the heterogeneous nature of engineering work (Reed Stevens, Johri, & O'Connor, 2014), and the role leadership plays in the formation of an engineering identity. In fact, to date, there is little empirical work in the engineering education body of knowledge that illustrates the role leadership concepts play in the formation of an engineering identity. This project seeks to address that gap through a sequential, mixed-methods study. The overall goal of the project is to construct a grounded theory of engineering leadership as a component of the professional formation of undergraduate engineers, offering implications for the incorporation of leadership development throughout the undergraduate curriculum. This paper presents the approach underway to refine and validate this model, starting with a brief explanation of the theoretical underpinnings of the model, followed by the methods underway and proposed to study engineering leadership identity, concluding with some initial results from the analysis of a national data set of student views on leadership.

Leadership Identity as a Component of the Formation of Engineers

At its core the formation of engineers is an identity development process (Johri, Olds, & O'Connor, 2014; Meyers, 2009). However the place of leadership within this process is little understood. The work presented here seeks to close this gap using a conceptual framework that is built from the literature in leadership identity and engineering identity, and refined by the nascent literature in engineering leadership.

Developing a Leadership Identity

Based on the literature, it appears students need both formal experiences, geared at developing specific leadership skills, and informal experiences, providing opportunities to assume leadership and make meaning of those experiences. Unfortunately, this research also shows that this skill development is often less than effective when put into practice (Collins & Holton, 2004; Day, Fleenor, Atwater, Sturm, & McKee, 2014). What seems to be missing is an understanding of how students make meaning of their exercise of leadership—particularly for engineering students whose leadership experiences occur within the context of their professional preparation. A model that emphasizes the cultivation of one's self-concept as a leader—the process by which people begin to view themselves as leaders—could better explain how a person becomes a leader.

The proposed model for developing an Engineering Leadership identity recognizes that a wide variety of researchers have examined the role of identity in development of leadership (e.g. Hogg, 2001; Lord & Hall, 2005; Munusamy, Ruderman, & Eckert, 2010; Van Knippenberg, Van Knippenberg, De Cremer, & Hogg, 2005). As summarized by Ibarra, Snook, and Guillen Ramo

(2010), work in this area generally focuses on the development of a leadership identity for working professionals, especially as prompted by position or career transitions. This is true even for their proposed extension of work in this area, which posits that leadership development is an identity transition process focused on self change using a process of separation, transition and incorporation (Ibarra et al., 2010). For the purposes of this work, our interest rests in the identity transition of college students, not working professionals. As such, the model of Engineering Leadership Identity Development in this work leverages the Leadership Identity Development (LID) model (Komives et al., 2005), summarized in Figure 1. For a more complete discussion of the LID model and its relationship to Engineering Leadership, see our earlier work describing initial development of the Engineering Leadership Identify model (Schell & Hughes, 2016).

Figure 1 - The Stages of Developing a Leadership Identity (Komives et al., 2005)

A central argument of the LID model is that college students begin to develop a personal sense of identity as a leader when they deepen their understanding of what constitutes leadership (Komives et al., 2005). Specifically, students enter college with a positional view of leadership, where leadership is exercised by a person who holds a specific role in an organization. In order to assume a leader identity, students' understanding of leadership shifts to *relational leadership*, viewing leadership as a process that occurs among people — any person can exercise influence within any role, regardless of formal position. This shift occurs between stages 3 and 4, and is depicted in the figure by the change in color. If engineering students enter college with this perspective, perhaps one reason engineers don't identify with (Bennett & Millam, 2013, p. 4) or even abhor leadership (Rottmann, Sacks, & Reeve, 2015) is the association with "management:" they don't want to manage, they want to innovate. In other words, perhaps leadership identity seems incongruent with engineering identity for undergraduate engineering students. Therefore, before building an engineering leadership identity, we must understand engineering identity.

Understanding Engineering Identity

The ultimate goal of learning in the professions is not solely mastery of the practice, but a feeling of membership within a community of practice, or a sense of identity as master practitioner (Lave & Wenger, 1991). In engineering this would be described as engineering identity, which has been associated with persistence and retention in academic programs (Du, 2006; Pierrakos, Beam, Constantz, Johri, & Anderson, 2009). Learning within a community of practice is referred to as "legitimate peripheral participation," or the productive activities that novices contribute to the practice of their field and support their professional training, while immersed within the community's culture (Lave & Wenger, 1991). Legitimate peripheral participation, or the process of "becoming an engineer," is described by Stevens, O'Connor, Garrison, Jocuns, and Amos (2008) as three primary activities: 1) mastering disciplinary knowledge, 2) navigating the formal and informal pathways into the profession, and 3) being identified by others and oneself as an engineer (Allie et al., 2009; Loui, 2005). Tonso (2006) in particular described the significance of being recognized and legitimated by other engineers as critical to developing an engineering identity among college students. As such, a strong sense of engineering identity is marked by a deepening commitment to pursue a career in engineering (Meyers, Silliman, Ohland, Pawley, &

Smith, 2012). Figure 2 illustrates how engineering identity can be characterized as a psychosocial construct that consists of both psychological (i.e. self-image) and social (i.e. recognition by others) elements (Meyers, 2009). Engineering work can then be classified into technical and social tasks (Huff, 2014), and leadership would be considered one of those crucial social elements of practice.

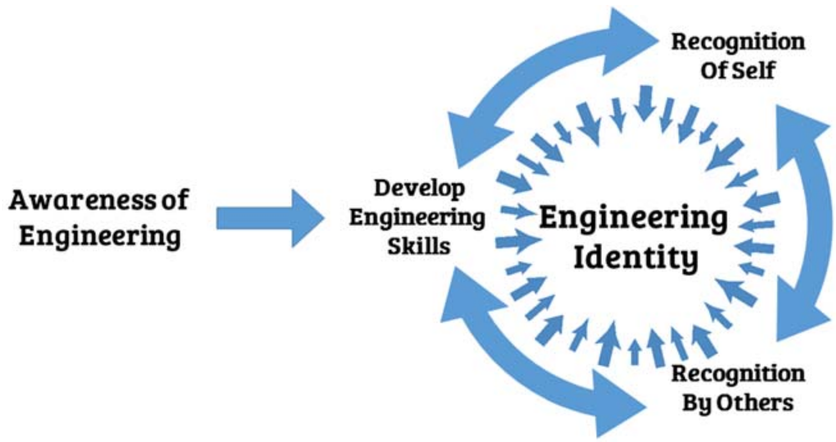

Figure 2 - Components of Developing an Engineering Identity

Implicit within the communities of practice model that underlies much of the engineering identity literature is the development of leadership skills as a person moves from the position of a novice to that of a master (Lave & Wenger, 1991). Existing models of leadership development would suggest that the practice of mentoring a novice practitioner to become a master practitioner is analogous to the mentoring activities found to be a key driver of the development of a variety of leadership skills and behaviors (Atwater, Dionne, Avolio, Camobreco, & Lau, 1999; Schell, 2010). Additionally, apprenticeships into mastery often begin with structured learning approaches designed to achieve basic proficiency in the profession, similar to formal leadership development training (Avolio & Bass, 1994; Van Velsor, McCauley, & Ruderman, 2010). While some aspects of developing an engineering identity necessitate the cultivation of leadership skills, there is little in the typical engineering identity, and even less in the typical engineering curriculum, that includes seeing oneself as an engineering leader. This is an important gap, since if novices are to eventually replace master practitioners within engineering communities of practice, then these novices will need to develop a sense of identity not only as engineers but also as leaders within the community of practice.

Defining Engineering Leadership

In order to develop engineering undergraduates into engineering leaders, several models have been proposed to define a concept of "engineering leadership," or leadership specifically delineated to address the needs of the engineering field. Most existing models can be found within the variety of engineering leadership programs around the country that have developed frameworks to identify the leadership skills that students should learn. While many of the university program models were developed using input from a variety of stakeholders, including those in industry, the models of engineering leadership on which they were built are generally not grounded in empirical evidence of the experience of engineers. This gap is beginning to be addressed in the recent work from the University of Toronto (Reeve, Daniels, Rottmann, Sacks,

& Wray, 2013; Rottmann et al., 2015). In their work, engineering leadership includes sharing good technical problem-solving skills with others through mentoring, building effective teams through learning and leveraging the strengths of others, and bringing technically sound ideas to market. Specifically, this work utilized a large interview data set to empirically identify three orientations to engineering leadership using grounded theory analysis (Glaser & Strauss, 1967a). These orientations are:

1. Technical Mastery – skilled at solving technically challenging problems and supportive of others
2. Collaborative Optimization – a proven ability to build and catalyze high performing teams.
3. Organizational Innovation – Apply entrepreneurial thought to bring technically sound, scientifically based solutions to market.

The Toronto model addresses two substantial problems found in the engineering leadership literature (Rottmann et al., 2015). First, by promoting an empirically grounded model, these orientations provide a framework for educators to move away from the piecemeal manner of educating engineers in leadership (Graham, 2009). Second, this framework begins to model how engineers lead, not how to lead engineers. However, this work only shows how practicing engineers view leadership, not how they developed leadership, nor how students view leadership This project is working to close this gap.

Conceptual Framework for the Development of an Engineering Leadership Identity

While the literature on engineering identity, and its effects, continues to grow, it is missing an examination of how leadership, particularly the development of a leadership identity, could be incorporated into the educational process. The conceptual framework guiding the current study posits that engineering leadership develops in students through a process of leadership identity development within the context of engineering identity formation. This is an important shift in the approach to developing engineering leadership because a traditional engineering identity can conflict with the idea of a leadership identity for students (Reed Stevens et al., 2014). As summarized in Figure 3, most current efforts to add leadership to engineering can be viewed as what Senge (1990) defined as a *fixes that fail* system archetype. In this system, leadership training and development programs are made available to engineering students through various programs. This loop provides an opportunity to develop leadership skills and for students to begin to see themselves as leaders. However, this positive loop is counter-acted by a negative loop of engineering identity with its stereotypical personalities and focus on technical mastery. A negative effect often further reinforced by faculty resistance to professional skills and other "softer" areas (Shuman, Besterfield-Sacre, & McGourty, 2005). The conceptual framework of this project hypothesizes that this resistance can be overcome by approaching engineering leadership as a leadership identity development process that is complementary to, instead of in conflict with, engineering identity.

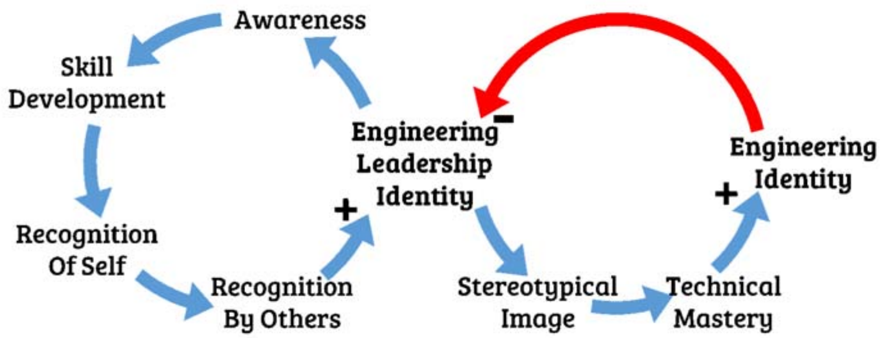

Figure 3 - The System Level Conflict Between Leadership and Engineering Identity

This project adapts the Leadership Identity Development (LID) Model to the engineering education context. Since Komives et al. (2005) argue that students enter college with a positional view of leadership, a key task in supporting students' leader identity development is to move toward a relational view of leadership. The LID model identifies four environmental conditions that influence the development of leadership identity, and experiences that contribute to engineering identity can be categorized into these four conditions.

The first environmental condition is the set of influential individuals who shape a student's perceptions of leadership both before and after college. This includes parents or relatives who work as practicing engineers, and the faculty, industry partners, and other mentors students encounter after entering college. Pre-college encounters with these people raise students' awareness and knowledge of engineering as a potential career field (Lichtenstein et al., 2009; Pierrakos et al., 2009). Peers are the second environmental condition that can influence students' development of an engineering leadership identity. Students develop social networks with peers in their engineering programs that contribute to their sense of belonging in the field as well as shape the informal aspects of students' pathways into the field through sharing information about coursework, involvement, and professional or research opportunities. The third environmental condition that affects leader identity is meaningful involvement in curricular and co-curricular opportunities, including coursework as well as clubs and organizations, undergraduate research, and internships or cooperative learning experiences. Meaningful involvement is likely the source of students' legitimate peripheral participation in the engineering community of practice. What is unclear from the engineering identity research and related literature is if students are provided opportunities for reflective learning regarding their leadership experiences, the fourth environmental condition. As shown through the discussion of engineering identity this reflection is typically left to chance at best or, at worst, actively discouraged through the viewpoint that leadership is a "soft" skill not worthy of consideration in an engineering curriculum. The question of incorporating effective reflective learning is central to the work underway.

Moving engineering students from a positional to relational understanding of leadership has two benefits: first, they should have a more stable sense of leadership identity, and, second, they would be more likely to view themselves as a leader (Komives et al., 2005). The assumption then is that the recognition required to view oneself as exercising leadership, regardless of position, requires both self-efficacy and sense of confidence built from developing competence in engineering knowledge and skills, as well as a strong sense of belonging in the community of practice. This sense of self-efficacy around engineering leadership then propels students into the final two stages of leadership identity development—generativity and synthesis—where they have assumed leadership roles and are now concerned with mentoring and preparing new students for entry into the engineering community of practice. At this point, being a leader is part of who they are as a person, and they intend to exercise that capacity in any current and future organization where they become a member.

One particular benefit of this identity-based approach to incorporating leadership into engineering education is its potential for more authentic inclusion of students from groups typically underrepresented in engineering programs. For example, one factor contributing to the underrepresentation of Latinos/as in engineering is the perception of an exclusionary climate within the field—the majority of those considered "engineering leaders" are White males (Camacho & Lord, 2013), and a lack of Latino/a representation among leadership in higher education leads to a lack of opportunity to gain necessary support and credentials (Freeman, 2015). In response, newer work has examined the process of engineering identity development in Latino/a students and identified dimensions of engineering identity that implicate leadership development as well. These dimensions include role modeling of engineering leadership by Latino/a engineers and engineering students, maintaining connections with and making contributions to one's broader community network of support beyond the campus, and nurturing a *familia* within engineering of other Latina and Latino engineers (Revelo Alonso, 2015).

Each of these dimensions relates to the proposed engineering leadership framework for engineering leadership. Role modeling is one of the first stages of the Leadership Identity Development (LID) model (Komives et al., 2005), participating in an engineering community of practice is a core aspect of the engineering identity development process (Lave & Wenger, 1991), recognition that leadership is more than position is a key aspect of the LID model, while both sides of the model focus on recognition of self – both as an engineer and a leader. The proposed model also relates to Carlone and Johnson’s (2007) model of science identity (with its three dimensions of competence, recognition, and performance), which was built from the experiences of women of color and has been previously adapted to engineering education (Chang, Eagan, Lin, & Hurtado, 2011; Hughes & Hurtado, 2013). These alternative notions of engineering leadership draw attention to the experience of marginalization in the field and how the development of engineering leadership identity could play a role in reversing these barriers when considered within the specific context of the experiences of underrepresented racial/ethnic minority students. The study team expects that conceptualizing engineering as a community of practice and leadership as a relational process will provide the basis for a model of engineering leadership that is more inclusive than existing practices, attention to specific individual differences will allow this study to confirm the inclusivity of this model and point the researchers toward important distinctions within engineering leadership that will result in broader participation. Figure 4 illustrates the proposed model for engineering leadership identity development.

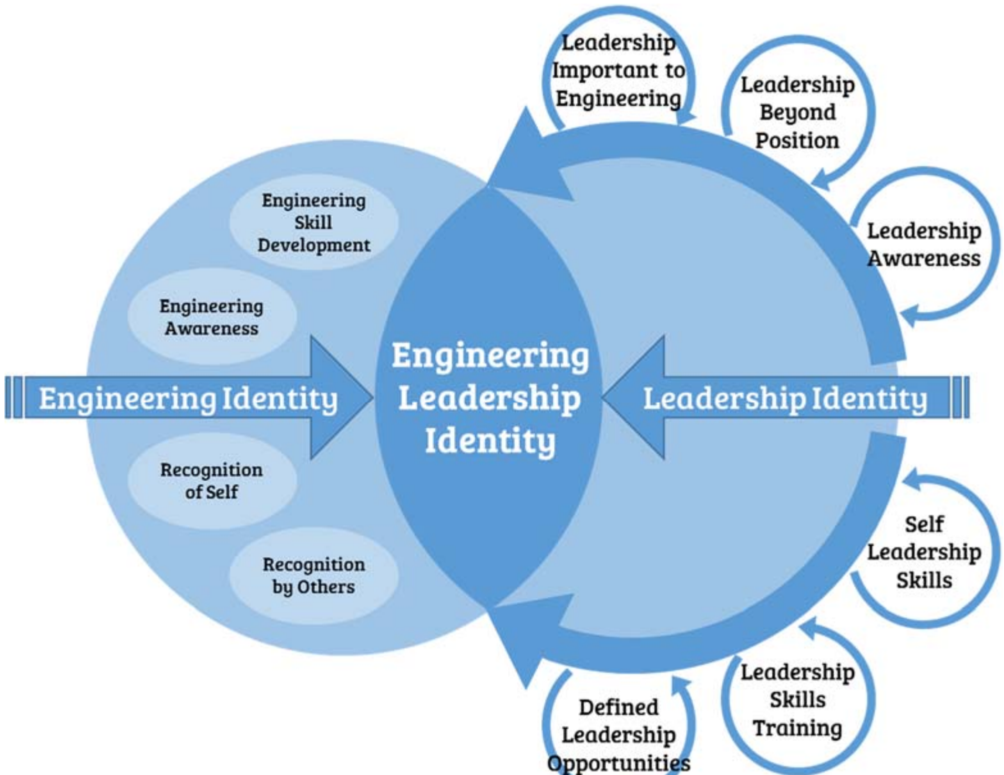

Figure 4 - Model for Developing an Engineering Leadership Identity

Overall Project Approach

This project employs a sequential, mixed-methods approach (Creswell & Plano Clark, 2011) to test and refine a model of engineering leadership identity development. Specifically, this work utilizes an explanatory mixed-methods design to respond to the following research questions:

1. How do leadership experience and leadership identity in engineering students compare to those in other fields?
2. What is the relationship between leadership identity and engineering identity?
3. How do engineering undergraduates define engineering leadership and develop a sense of engineering leadership identity?

The methods and initial analysis used to answer the experience component and some identity components of Question 1 are shared in this paper. The approach being deployed to answer Questions 2 and 3 including both quantitative and qualitative phases are discussed in the future work section.

Comparing the Leadership Experience of Engineering Students to Other Fields

The first component of the quantitative phase of this research seeks to understand how engineering majors, differ in their experiences with leadership from students in other fields. Experiences investigated include participation in and setting of leadership roles, time invested in leadership, and training and development associated with this role. Leadership self-concept is also compared.

Data Source and Sample

The data for the quantitative phase of this project come from national surveys of college students administered by the Higher Education Research Institute (HERI) at UCLA and the National Survey of Student Engagement (NSSE) at Indiana University. Research Question 1 is addressed using the NSSE dataset and discussed here. Research Question 2, as well as leadership self-concept, will be addressed using the HERI dataset as discussed in the future work section.

The NSSE source is a cross-sectional dataset using variables from a pilot module tested in 2015 as part of their larger national survey. The pilot module was designed to explore the quality of students' leadership experiences, and this project features the first analysis of this data for research purposes. The NSSE survey is one of the largest national surveys of college students—over 320,000 students at more than 560 institutions participated in 2015—and examines students' perceptions of the contributions of institutional practices to their engagement in college (National Survey of Student Engagement, 2016). For this analysis, the dataset includes 3336 students, including 131 engineering students.

Variables

The NSSE pilot module includes items that examine the types of leadership experiences students have, the skills developed as a result of leadership experiences, and the activities performed and feedback received during leadership experiences. Examples of these items include "To what extent were the activities of this [leadership] role associated with your academic program?" and "About how many people did you represent and/or serve in this role?" NSSE data is being used to descriptively identify significant differences between engineering students' experiences with leadership and their peers in other STEM as well as non-STEM fields. These particular items were selected because they provide examples of skill development and recognition as a leader by self and others, presented in both the LID model and our fixes-as-failures system archetype.

Analysis

To respond to Research Question 1, cross-tabulations with chi-square tests of independence were used to determine if the proportion of engineering students who reported involvement in leadership experiences differs significantly from their peers in other fields. For continuous measures, like the frequency by which a student leader interacted with an advisor on a leadership activity, ANOVA and ANCOVA analyses are used to compare the average score on the variable among the three comparison groups (engineering students, other STEM students, non-STEM students).

Validity

The National Survey of Student Engagement (NSSE) takes several steps to ensure the rigor of their data collection and that, indeed, the items included on the survey closely measure the underlying constructs they purport to measure. With respect to the NSSE pilot module, the content of these items were developed by experts in the field of college student engagement, and went through two iterations before reaching the point at which they were administered to participants. In addition, they were found to demonstrate high inter-item reliability with leadership items on the main NSSE instrument, demonstrating consistency with other measures. The analysis in this project will help demonstrate their reliability across different groups of students.

Initial Results

At this time, high level analysis is underway using the data from senior participants in the 2015 National Survey of Student Engagement's formal leadership experiences pilot module. The data from this component of the survey enables an initial understanding of differences in leadership experiences within one cohort of the data. This section provides early results from the model validation process currently underway. Figure 5 displays the percentage of college seniors in the NSSE dataset who held a formal leadership role in a student organization, compared by major group (engineering major, other STEM major, non-STEM major). This comparison found a significant difference between groups ($\chi^2(2) = 18.928$, $p<0.001$) with two-proportions testing showing both engineering and other STEM majors having significantly higher proportions holding leadership role ($p = 0.018$ and < 0.001 respectively) than other majors. Surprisingly, engineering students were the most likely to report holding a leadership role in an organization (nearly 40%), with other STEM students very close behind (slightly more than 38%).

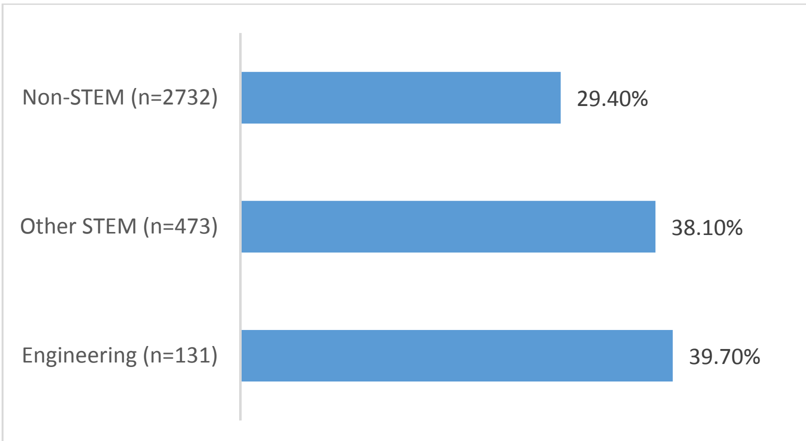

Figure 5 - Percentage of students who held leadership role in student organization, by major group

The next level of analysis further investigated those who indicated having held a formal leadership role, summarized in Figure 6. This analysis found engineering students were most likely to hold the position of President or Chairperson (26%), other executive role (16%), manager or coordinator (12%), or a role not listed (20%).

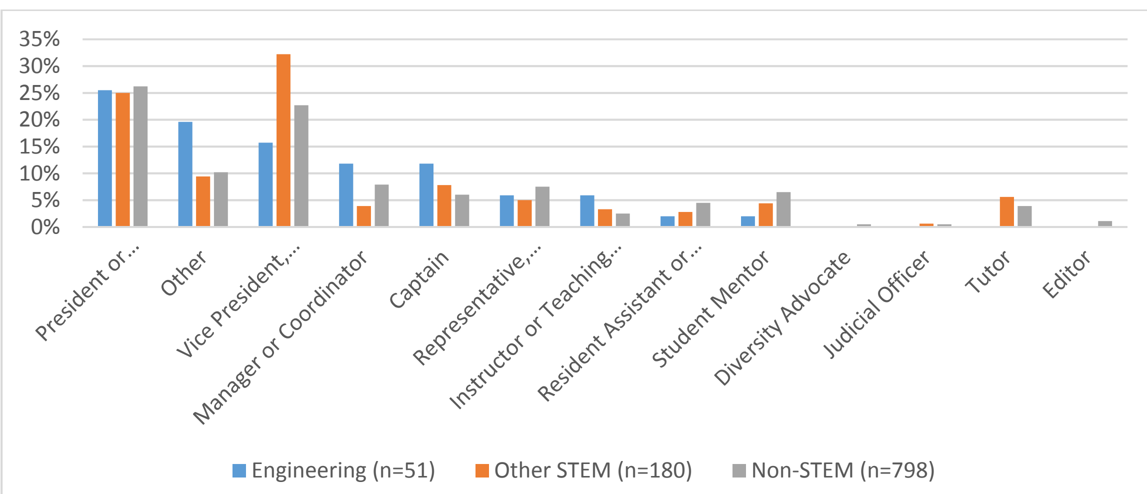

Figure 6 - Formal leadership role held by students, by major group

The survey also reframed the concept of "leadership role" for students who indicated not holding a leadership position, in case students held a position that performed leadership tasks but they did not perceive their role as one of leadership. Figure 7 displays the types of roles these students held, disaggregated by engineering majors, other STEM majors, and non-STEM majors. Engineering majors who felt they had not held a formal leadership role were most likely to act as a manager or coordinator (25%), instructor or teaching assistant (21%), tutor (17%), student mentor (13%), or a role not listed (21%). These roles tend to be more focused on helping and supporting their peers, as compared to the positional leadership roles identified in the previous figure. By comparing these two figures, one might infer that engineering participants still view leadership as positional, and that these peer mentoring roles are not perceived to be "leadership" by many engineering students.

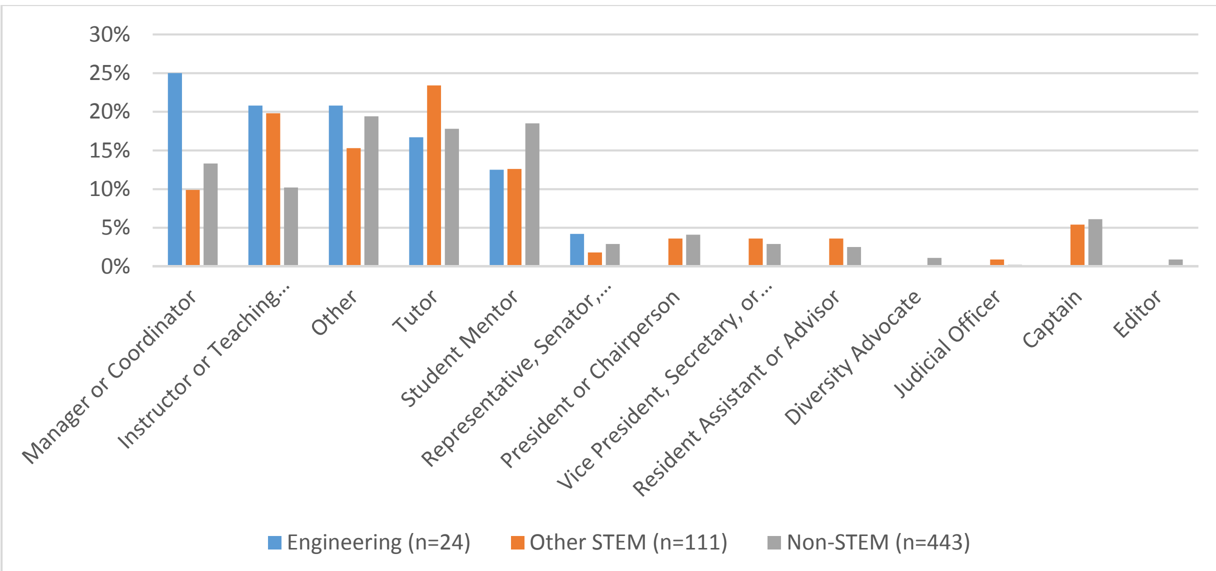

Figure 7 - Leadership role held by students who indicated not holding formal role, by major group

The third decomposition of the data investigated the setting in which students exercised these roles, summarized in Figure 8. This item was completed by students who responded to either of the previous items about their leadership role, and thus reflects both groups combined. The chart is similarly disaggregated by engineering majors, other STEM majors, and non-STEM majors, although similar to the previous two charts, very few differences are observed among the groups. Engineering seniors were most likely to exercise leadership in a student organization (28%), academic setting (17%), on-campus job (15%), or a setting not listed (14%). These settings correspond with the leadership roles indicated in the previous two figures and add context to the type of leadership most typically exercised by engineering students.

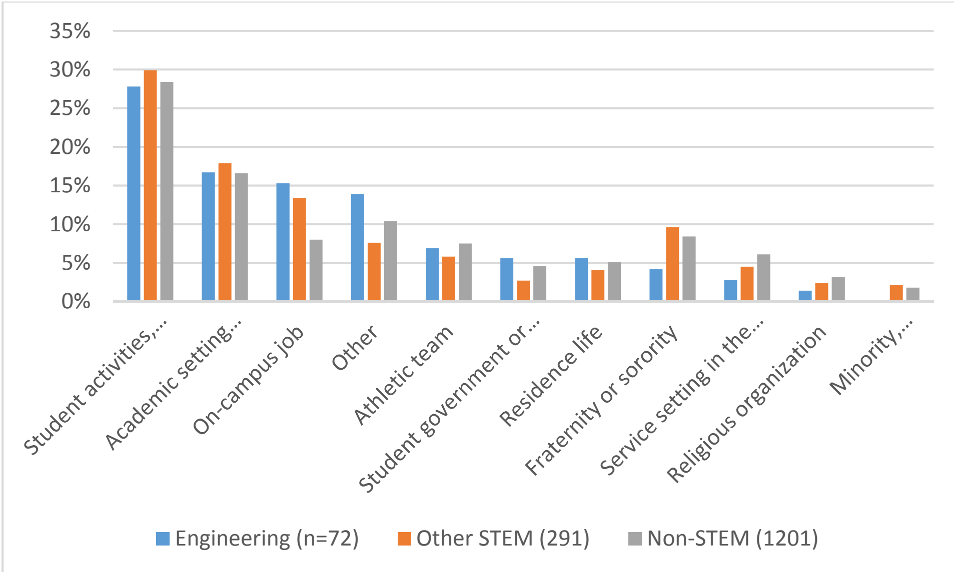

Figure 8 - Leadership setting, by major group

Implications and Conclusions

The challenges facing society in the 21st Century will require technological innovations and visionary leadership; thus, colleges and universities need to train engineers who can serve as engineering leaders. However, the process of professional formation in engineering tends to lead to engineers who dislike leadership, with a perception that engineers solve problems for *others*, not identify problems to solve *themselves*. This paper presents an identity-based model for incorporating leadership into engineering and the work underway to refine and validate this model. The initial analyses offer preliminary insight into the data used to validate and refine the proposed engineering leadership identity development model. While these results indicate a greater proportion of engineering students involved in leadership activities than expected, a considerable amount of work, including more complex statistical testing currently underway, remains to understand the impact of these roles and how engineering educators might better prepare engineers who are ready to lead. The following section outlines key aspects of the project planned for the next several years.

Future Work

The complete research plan outlined in this work will be executed over the next three years with the support of the National Science Foundation (EEC Award # 1664231). In order to answer Research Question 2, which seeks to better understand the relationship between engineering identity, and leadership identity a second national dataset is being studied. This dataset is a longitudinal dataset from HERI taken from their Freshman Survey (TFS) and College Senior Survey (CSS). The TFS is the longest running national survey of incoming college students, consisting of hundreds of thousands of students from hundreds of colleges and universities across the nation (Higher Education Research Institute, 2016). The CSS is a follow-up survey administered by HERI to students at the end of their fourth year. Student responses on the CSS are linked to their initial responses on the TFS to provide a longitudinal dataset for analysis of the effects various college experiences have on academic and social outcomes.

The HERI datasets include a set of items measuring social self-concept, including self-reported leadership skills, providing insight into the extent students perceive themselves to be leaders. These questions are asked at both survey time points to allow for analysis of change in social self-concept and leadership from college entry through the end of the fourth year. These datasets also include items that have been used to measure both STEM identity and engineering identity in previous research (Chang et al., 2011; Hughes & Hurtado, 2013), as well as a number of covariates for use as control variables to isolate the unique predictive relationship between engineering and leadership identity.

To respond to Research Question 2 in particular, two hierarchical linear models (HLM) will be developed to identify how experiences in college, such as participating a major-related student organization or internship experience, contribute to engineering and leadership identity. These outcome variables, engineering identity and leadership self-concept, are included on both surveys, allowing the researchers to control for initial levels of these measures when determining the contributions experiences make to these outcomes in the fourth year. Multilevel regression modeling (HLM) is used to account for dependencies or correlations among students grouped within the same schools, providing more robust estimates of test statistics than ordinary least squares regression.

Informed by the results of the national analyses performed in the quantitative phase of the project, the central component of this work is the qualitative phase, responding to Research Question 3, using a grounded theory approach. This phase will build an explanatory model of engineering leadership identity development. Grounded theory is especially appropriate for the proposed examination of engineering leadership because it aims to develop a unified theory or explanation of a process as a framework to guide practice and future research (Creswell, 2013; Glaser & Strauss, 1967b).

The data for the grounded theory will consist primarily of interviews with undergraduate engineering students enrolled at three different universities in the United States. These three universities include two minority-serving institutions: one Hispanic-serving institution in the American Southwest, and a university in the Rocky Mountain region with an institutional focus on American Indian student success. Faculty and staff within the engineering programs on these campuses will be interviewed as well, and documents pertaining to engineering leadership opportunities will be gathered for review and triangulation. Participants will be primarily identified through criterion sampling, that they meet the criteria of experience with engineering leadership, but additional participants may be identified through snowball sampling techniques during campus site visits (Patton, 2015).

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