EXPLORING THE CONFLICT BETWEEN AN ENGINEERING IDENTITY AND LEADERSHIP.

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Abstract – *Through the efforts of government and industry, there is growing recognition among academics of the importance of developing leadership skills in engineering students. Despite this recognition and the increasing level of resource put into engineering leadership programs throughout North America, there is currently little work that illustrates how leadership fits into the broader picture of the heterogeneous nature of engineering work. This work seeks to begin closing that gap by investigating the relationship between models of engineering identity and leadership identity. The investigation is done using quantitative techniques to draw conclusions from two data sets taken from national surveys of undergraduate students in the U.S.. Initial results indicate that while engineering students are engaged in leadership positions more frequently than their peers in other fields (other STEM and non-STEM) they see less of a connection between these roles and their future careers than other students, indicating a potential conflict between an engineering identity and a leadership identity.*

Keywords: engineering identity, leadership identity, leadership development, engineering leadership

1. INTRODUCTION

As evident by continued calls for increasing engineering graduates (e.g. [2, 28, 31]), societies around the world are recognizing the role engineers must play in solving the increasingly complex challenges faced by an interconnected world (e.g. the NAE Grand Challenges [17] and the "Transition to Scale" challenge of Grand Challenges Canada [7]). However, the development of sheer numbers of engineers will, in and of itself, not have the desired effect without a fundamental change in both how engineers are educated and how they see their role in the world. Specifically, to address the core challenges facing society, these new engineers must become part of the interdisciplinary teams needed to solve these problems. These teams must bring together the skills from multiple engineering disciplines, the cognitive and physical sciences, medicine, and others to work in concert. For that work to happen in concert, these teams must harness solid technical leadership. As skilled people trained in complex problem solving methods and systems thinking, engineers should be well-positioned to provide this technical leadership, yet are often ill-prepared in this area. This drives the need for engineering graduates who are prepared to lead – those who possess "engineering leadership" skills – and provides the motivation for this work.

1.1. Literature Review

Recognition of the need for engineers to lead is not new. Articles regularly cite a March 1934 issue of the *Civil Engineering* magazine that stated, in part [26]:

> It is conceded that the engineer must take his proper place in society as a leader and manager rather than as merely a follower of the lawyer, the businessman, and the politician; and when he does so, an important step in the advancement of the engineering profession will have been taken.

This quote illustrates early recognition of the need for engineering leadership, a need that has not traditionally been met by undergraduate engineering programs due to the relative importance placed on technical vs. professional skills. Due to repeated calls from industry and the publication of seminal reports over the past 25 years calling for greater professional skills in engineering graduates [3, 4, 18, 19], this is beginning to change.

When considering leadership development for engineers, the most visible manifestation of this change is the creation of a variety of engineering leadership centers at universities around the world [6, 11]. Despite this increasing level of attention, most current approaches in engineering education to develop leadership skills in engineers do little to understand how leadership fits into the broader picture of the heterogeneous nature of engineering work, or the role leadership plays in the formation of an engineering identity [21, 29]. This is a substantial gap, since the literature tells us that engineers are often not attracted to leadership and even find it distasteful [22].

In order to understand the hypothesized development of an engineering leadership identity shown in Figure 1, first we seek to understand the notion of an engineering identity. For this understanding, we leverage the work of Lave and Wegner [14] and their communities of practice model. This model has been widely used to explain how engineering students develop an engineering identity. This model holds that learning is a social process situated within a specific context of a community of practice where knowledge is co-constructed among members of that community.

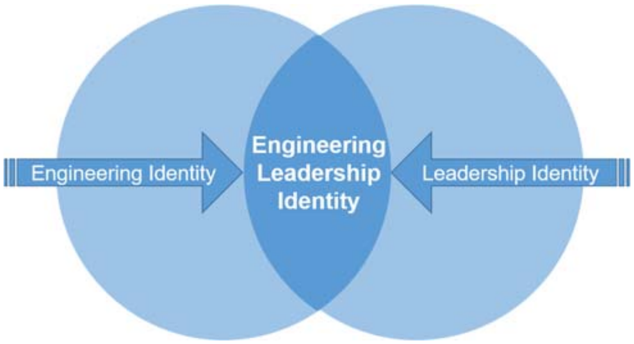

Figure 1. Engineering Leadership Identity Model

Engineering can be considered a community of practice, as can each field of engineering, because a community of practice is generally understood to be a group of people who share a common craft or profession. Learning is then conceptualized as legitimate peripheral participation in that community of practice, meaning novices who have been granted access to the community are invited to perform productive activities that contribute to practice immersed within the community's culture [14]. Legitimate peripheral participation, or the process of "becoming an engineer," is described by Stevens, O'Connor [30] 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. Engineering identity, the third component, is central to the process of becoming an engineer because it fosters commitment to mastering disciplinary knowledge in the field and increases confidence in navigating the various pathways toward becoming a professional engineer.

Armed with an understanding of engineering identity and the goal of building a construct of an engineering leadership identity, we now seek to understand the foundations of a leadership identity, so the two can be combined. Our model for developing an Engineering Leadership Identity recognizes that a wide variety of researchers have examined the role of identity in development of leadership [9, 15, 16, 32]. As summarized by Ibarra, Snook [10], work in this area generally focuses on the development of a leadership identity for working professionals, especially as prompted by position or career transitions. For the purposes of this work, our interest rests in the identity transition of college students, not working professionals. Therefore, the model of Engineering Leadership Identity development in this work uses the Leadership Identity Development (LID) model [12] for its direct application to undergraduate students. This development of leadership identity is described as occurring over six developmental stages: 1) Awareness 2) Exploration and Engagement 3) Leader Identified 4) Leadership Differentiated 5) Generativity 6) Integration and Synthesis. A more complete discussion of these stages can be found in our prior work describing the development of the engineering leadership identity model [23].

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 [12]. 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. If students enter college understanding leadership as positional, perhaps one reason engineers gravitate away from leadership is the association with "management:" they don't want to manage, they want to innovate.

1.2. Problem Definition

This brings us to the seemingly inherent conflict between an engineering identity and a leadership identity. Figure 2 presents a summary of this hypothesized conflict. This diagram leverages Senge's concept of a *fixes that fail* archetype [27]. In this archetype, a problem is solved with a fix that is effective in the short-term but has unintended consequences in the long-term. For this application, the problem is a need to train future engineers in complex topics and problem solving approaches. The traditional engineering education emphasizes these technical areas and requires a great level of student commitment and effort. This effort detracts from most students' ability to participate in many activities outside their academic work, which further promotes the stereotypical image of engineers and the focus on technical mastery in engineering education depicted in the bottom of the right hand loop. This focus results in an engineering identity. In the left hand loop, leadership training and development programs are made available to students (depicted as the phases of the LID model) and have a positive influence on development of an engineering leadership identity, the desired outcome of this work. The *fixes that fail* component comes from the hypothesized negative influence of an engineering identity on the engineering leadership identity, depicted by the red arrow on the top of the right hand loop. In other words, the fix of engineering training is hypothesized to systematically reduce engineers' identity

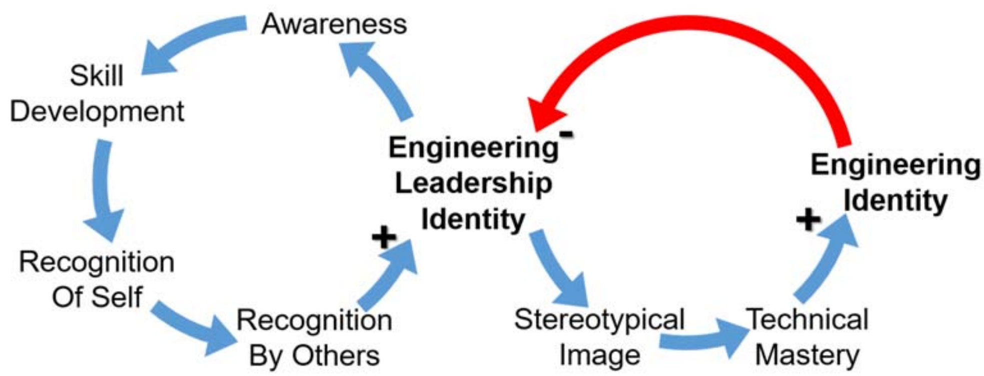

Figure 2. Hypothesized conflict between an engineering identity and a leadership identity

as leaders. This is the hypothesis that this paper investigates using data from two national surveys of undergraduate students in the United States.

2. METHODS AND ANALYSIS

This paper is drawn from work completed as part of a larger research program investigating engineering leadership. The overall program is employing a sequential, mixed-methods study to develop a grounded theory of engineering leadership for undergraduate engineering students. In the first phase of this program, discussed here, quantitative techniques are used with two national surveys to explore student activities and the relationship of these experiences to the constructs of engineering identity and leadership identity.

2.1. Data Sets and Applications

The data for this work comes from two national surveys of U.S. college students, one survey is administered by the National Survey of Student Engagement (NSSE) at Indiana University and the second by the Higher Education Research Institute (HERI) at UCLA.

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 measure student leadership experiences and the effect of students' college experiences on eight different leadership outcomes. Table 1 summarizes each of these outcomes and how they were measured in the survey. NSSE staff pre-selected a group of institutions from the 2015 administration to participate in the pilot study and randomly sampled 6,547 students (2.1%) at these 21 different institutions. Of these 6,547 students, 250 (3.8%) indicated an engineering major and another 935 (14.3%) indicated a major in another STEM field. This distribution compares favorably with national data, where engineering degrees constituting 4.7% of all bachelor's degrees conferred and other STEM fields representing 12.5% [20]. This data set included both freshman and senior respondents. For this analysis we utilized only senior respondents (n = 3,336). This data was first utilized to compare the level of engagement in leadership roles for engineering students and those in other majors (other STEM, and non-STEM) and second to examine differences in perceived leadership gains between these groups.

The third part of the investigation used the same parent data set but limited the analysis to just first and fourth year engineering students (n = 250) who completed the full survey (n = 90), using listwise deletion to remove incomplete responses. This data set was utilized to predict the leadership outcomes shown in Table 1 using a range of student demographics and college experiences as predicted.

The final part of this investigation, examined perceived leadership ability and views on the importance of leadership to future positions using the HERI data set. This data came from the 2013 administration of the College Senior Survey (CSS), a national survey of fourth-year students conducted by the Cooperative Institutional Research Program (CIRP) within HERI. These data are matched to students' responses to the CIRP Freshman Survey to produce a longitudinal dataset to help capture the impact of college over four years. The overall sample includes approximately 17,000 fourth-year students, including 918 engineering students and 4600 students in other STEM fields.

2.2. Student Engagement in Leadership Roles

The first area of investigation utilized the senior NSSE data set described above. This data was utilized to examine any differences between majors in the percent of students engaging in leadership roles. This examination found a

Table 1. Measured Leadership Outcomes

To what extent did your leadership role contribute to your abilities in the following areas?

Item	Coding
Understanding concepts in my major	4 = Very much 3 = Quite a bit 2 = Some 1 = Very little
Speaking clearly and effectively	
Thinking critically and analytically	
Solving complex, real-world problems	
Acquiring job- or work-related skills	
Working effectively with others	
Understanding people of other backgrounds (economic, racial/ethnic, political, religious, nationality, etc.)	
Becoming a leader in life outside of college	

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 roles ($p < 0.05$ and $p < 0.001$ respectively) than other majors (39.7%, 38.1%, and 29.4% respectively).

Further investigation of roles held by major found that engineers were most likely to hold the top position in their organization (president or chair, 26%), other executive (16%), manager / coordinator (12%), and other (20%). Perhaps most insightful when considering the construct of engineering leadership identity was a subsequent investigation of how students defined leadership roles. In this thread, the NSSE survey asked questions to reframe “leadership role” for those students who performed leadership tasks but stated they did not hold a leadership role. This investigation found that 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 could be construed as leadership positions more focused on helping and supporting others and not positional leadership roles. This finding appears to support the elements of the LID model noting that students generally view leadership as positional, a problem since they must move beyond this view in order to develop a leadership identity.

2.3. Perceived Gains in Leadership Outcomes

Using the same data set described in Section 2.2, the next analysis investigated differences in perceived gains by major in the leadership abilities defined in Table 1. As previously reported in [24], these comparisons were performed using cross-tabulation and, as shown in Figure 3, significant differences by major were found across all eight dimensions. Of particular interest for this investigation of a conflict between engineering identity and leadership identity is the measure of understanding concepts within my major (UCM) and the outcomes of skills traditionally associated with engineering. These skills include thinking critically and analytically (TCA), solving complex real-world problems (SRP), and acquiring job related skills (AJS). Not only are engineers significantly lower than other majors in each of these dimensions, the average across the four is below 50%. This indicates that engineers may find the effort needed to engage in leadership roles a fairly low returning investment.

2.4. Predicting Gains in Leadership Outcomes

The subset of the NSSE data using just engineering students was then utilized to examine which activities and demographics were significant predictors of the leadership outcomes listed in Table 1 for engineering students. This examination utilized eight ordinary least-squares regression models to predict the eight outcomes using a range of independent variables available through the NSSE survey. A significant ($p < 0.05$) regression equation was found for each of these outcomes. A complete discussion of this analysis can be found in the in press paper, Schell, Hughes, and Tallman [25].

Examining the four outcomes of particular interest to an engineering identity construct finds a number of significant regressors. The two most important of these are: 1) the extent to which the leadership role was associated with the student’s academic program, which was a significant positive predictor of UCM and SRP; and 2) receiving feedback on leadership performance from an advisor, which was a significant and positive predictor for TCA and SRP. A number of other predictors were significant for only a single outcome.

Of particular interest are those items which were significant negative predictors of one or more of these outcomes. This included three negative predictors of TCA: member of a Greek organization, number of service learning courses, and length of leadership role. The last of which was also a significant negative predictor of UCM. The other significant negative predictor was working with other students on course projects, which impacts AJS.

2.5. Leadership Ability Gains and Importance

The HERI data described previously was utilized to investigate student perceptions of their leadership abilities, as measured by the HERI leadership construct, and the importance students place on becoming a leader after college. In both of these dimensions, engineering students respond significantly differently than their peers.

Engineering students score highest among the three groups in the leadership construct and significantly higher than their non-STEM peers. This measure may be construed as the student’s confidence in their leadership ability. However, engineering students place the least importance on becoming a leader after college, with non-STEM students scoring highest. This finding echoes

*Figure 3. Comparison of perceived leadership gains by major; * p<0.05; ** p<0.01; *** p<0.001 (Source: NSSE)*

previous findings of engineers' reluctance to assume leadership roles or see themselves as leaders [22].

3. IMPLICATIONS FOR AN UNDERGRADUATE ENGINEERING LEADERSHIP IDENTITY

These results provide a complex picture of the forces at play between elements associated with an engineering identity and those of a leadership identity. A notable element that runs counter to the hypothesized negative influence of an engineering identity is the significantly higher participation rates of engineering students in leadership roles. While this finding initially surprised the authors, it has received strong anecdotal support from engineering faculty and administrators at large engineering schools. These colleagues support the authors' subsequent realization that the sheer number of engineering related clubs and activities provides so many leadership opportunities that engineers almost have to hold higher percentages of leadership positions. One might expect that the increased engagement in leadership roles would drive engineers to associate with leadership, and therefore fully negate the hypothesized negative relationship. However, many other measures run counter to this participation and appear to support the hypothesized negative impact depicted in Figure 2. This conflict may indicate that the quantifiable metrics investigated here capture the quantity of the involvement, but not the quality of the experiences.

The first of these points are the low scores that engineering students place on the leadership outcomes most closely tied to elements of engineering identity. Closely related to this concern is recognition that engineering students place consistently lower scores on all leadership outcomes in the NSSE data than their peers in other majors. This is despite the fact that a similarly representative group of engineering seniors in the HERI data score themselves higher than their peers score themselves on leadership ability. Perhaps this indicates a seemingly common misconception among engineering undergraduates that professional skills are the easy part of engineering work after graduation and substantially less important than the technical prowess they possess.

The elements of prediction present items that are simultaneously concerning and hopeful. On the concerning side we see a number of educational practices that educators often utilize to improve educational outcomes negatively impacting leadership outcomes. This includes the number of service learning courses and time spent working with teams of other students. In addition, the length of a student's leadership position is a significant negative predictor of two of the leadership outcomes most closely associated with traditional engineering skills. This impact is surprising and demands greater investigation during the qualitative phase of future work on this project. Again, this may be an indicator of the quality of these experiences, rather than the quantity measures present here. On the hopeful side are the outcomes showing that the closer leadership experiences are tied to coursework, the more beneficial it is to an engineer's leadership outcomes. This provides empirical support for the very core of engineering leadership programs.

Finally, we see a number of signs that undergraduate engineering students do not view leadership as important to their future work. This includes not just the consistently lower scores in the NSSE data, but also the relative lack of interest in serving in leadership roles after graduation.

4. CONCLUSION AND FUTURE WORK

While the field of engineering in general and engineering leadership in particular is gaining increased attention in North American universities, there appear to be structural limitations to building greater levels of engineering leadership, such as the typical time commitment required by academic work in engineering [5], and limited movement by engineering faculty to promote the importance of professional skills [1, 8, 13]. Specifically, based on the data from two national surveys, while engineering students engage in leadership roles at a higher level than their peers in other disciplines, they place less importance on these roles. In other words, they do not believe they will gain much in their future careers from these experiences. This belief supports the hypothesized conflict between an engineering identity and a leadership identity depicted in Figure 2.

This view that leadership is relatively unimportant to an engineering degree or future role as a working engineer is concerning for those who believe the world would be improved with more engineers in leadership positions across all sectors of society. In order to better understand this conflict, its origins, and ways to overcome it, future phases of this work will engage undergraduate engineering students from a number of campuses to investigate their perceptions of engineering identity, leadership identity, and the intersection of the two. Through these future qualitative phases, we expect to better understand this conflict and design curricular and co-curricular interventions to overcome it.

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