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ARE ENGINEERS' LEADERSHIP ATTITUDES AND EXPERIENCES DIFFERENT THAN OTHER STUDENTS?

William J. Schell*, Ph.D., P.E., PEM
Bryce E. Hughes, Ph.D.
Montana State University

***wschell@montana.edu**

Abstract
Only through successful collaborations from multi-disciplinary teams will society be able to solve our most complex engineering challenges. In order to be successful, these collaborations require effective technical leadership, a role that engineers can and should fill. However, most engineering students complete their undergraduate degrees underprepared to begin assuming a leadership role. One reason for this lack of preparation is a conflict between the development of an engineering identity and a leadership identity. This work explores this conflict using data from a national data set of college student leadership experiences compiled by the National Survey of Student Engagement. The data was used to explore the difference between engineering majors and others with regard to their leadership experiences, perceptions of leadership, and leadership development activities. Initial results indicate significant differences between engineering students, other STEM majors and non-STEM majors in their perceptions about how their leadership experiences complement their education and support their future career goals.

Keywords
Leadership development, engineering identity, engineering leadership, undergraduate education

Introduction
Engineers enter college with some of the highest measures of academic potential (Betz & Hackett, 1983; Wang, 2013) and are some of the highest performing college students (Brint, Cantwell, & Saxena, 2012). Given these indicators, one might expect that a high proportion of engineering students would go on lead all types of organizations later in their career. Yet, outside of technical industries, only a small number of leaders of major companies or U.S. political leaders have a background in engineering (Joint Committee On Printing Of The United States, 2016; Stuart, 2006). Perhaps of equal importance to this lack of engineers in formal leadership roles is the fact that engineers often find leadership distasteful (Rottmann, Sacks, & Reeve, 2015). If we are to solve the increasingly complex challenges facing our society and realize the full potential of the increasing numbers of engineers being called for by politicians and industry (National Academy of Engineering, 2013; The White House, 2014), engineering educators must develop and deploy more effective ways to prepare engineering students to assume leadership roles in greater numbers. A key first step in this process may be getting engineering students to see themselves as leaders.

In order to effectively enact this change, engineering educators must first understand how leadership currently fits into the education of engineering students. This begins with the recognition that the formation of engineers is, at its core, an identity development process (Johri, Olds, & O'Connor, 2014; Meyers, 2009). However, the place of leadership within this development process is little understood as most approaches to understanding engineering leadership are grounded in perspectives that privilege the development of leadership skills or dispositions rather than how engineers integrate leadership into their sense of self-concept. The overall project seeks to address this gap through a sequential mixed-methods study of the process of engineering leadership identity development. Our aim is to develop a grounded theory of the process of developing an engineering leadership identity as an aspect of engineering students' professional formation. This paper presents initial findings from the quantitative phase of the project. These findings demonstrate differences in perceptions of gains from leadership experiences between engineering undergraduates and their peers.

Development of an Engineering Leadership Identity
In order to better understand how engineering students might develop an engineering leadership identity within the context of completing their undergraduate degree, we must first understand the individual components hypothesized to create an engineering leadership identity. These components include development of both an engineering identity and a leadership identity.

Engineering Identity

Socialization into a profession does not stop at mastery of practice, but also results in a sense of belonging within the field. This represents a community of practice through the development of professional identity that reflects a transformed self in relation to the field (Lave & Wenger, 1991). As such, engineers can be described as having a sense of engineering identity, which has been demonstrated to predict student retention and persistence in academic programs (Du, 2006; Pierrakos, Beam, Constantz, Johri, & Anderson, 2009). The process of "becoming an engineer," which reflects legitimate peripheral participation as described by Lave and Wenger (1991), consists of three primary activities (R. Stevens, O'Connor, Garrison, Jocuns, & Amos, 2008): 1) mastering disciplinary technical knowledge, 2) navigating both formal and informal pathways into the profession, and 3) identifying oneself and being identified by others as an engineer (Allie et al., 2009; Loui, 2005). Being recognized and legitimated by other engineers has been observed as critical to the development of engineering identity in undergraduates (Tonso, 2006). A strong sense of engineering identity in engineering undergraduates is also marked by a deepening commitment to an engineering career (Meyers, 2009; Meyers, Ohland, & Silliman, 2012; Meyers, Silliman, Ohland, Pawley, & Smith, 2012).

Implicit within the literature on engineering identity and Lave and Wenger's (1991) model is the assumption that as a person moves from the position of novice to master they also become a leader within the field. Existing models of leadership development support this assumption as mentoring, as would happen between master practitioners and novices, have been found to drive the development of leadership skills and behaviors (e.g. Atwater, Dionne, Avolio, Camobreco, & Lau, 1999; Schell, 2010). Engineering work can also be classified into technical and social tasks (Huff, 2014), and leadership would be categorized as a crucial social element of professional practice. As a result, the process of engineering formation should incorporate leadership development in some sense to prepare novice practitioners to become central participants in engineering communities of practice as they replace their master practitioner mentors. However, recent research has illustrated that engineers frequently exhibit a disdain for leadership (Rottmann, Reeve, Sacks, & Klassen, 2016; Rottmann et al., 2015) and other non-technical aspects of engineering (Stevens, Johri, & O'Connor, 2014). This indicates a need to understand the relationship between engineering identity and leadership identity.

Leadership Identity

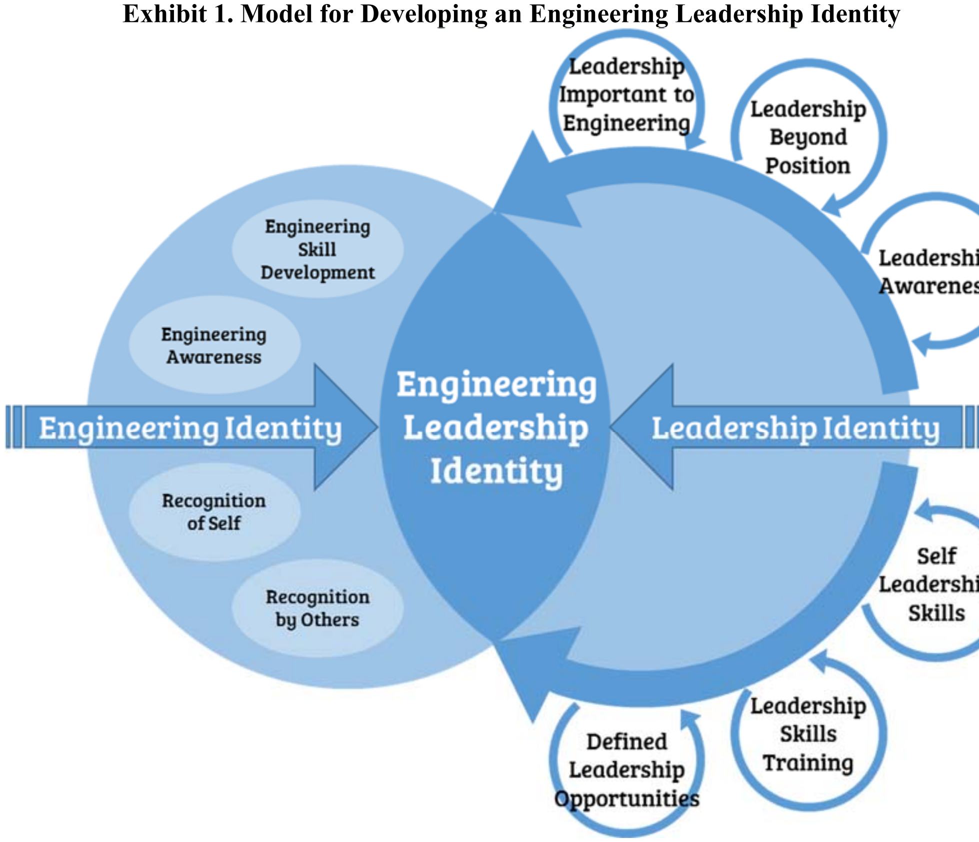
Scholars have increasingly begun to emphasize the role of identity in leadership development (e.g. Hogg, 2001; Lord & Hall, 2005; Munusamy, Ruderman, & Eckert, 2010; Van Knippenberg, Van Knippenberg, De Cremer, & Hogg, 2005). But this body of literature focuses on working professionals, particularly when assuming particular leadership positions or making career transitions (Ibarra, Snook, & Guillen Ramo, 2010). For this study, the development of leadership identity in college students is the central focus, and thus the conceptual model guiding this study leverages the Leadership Identity Development (LID) model to identify experiences that affect college student development (Komives, Owen, Longerbeam, Mainella, & Osteen, 2005). Komives et al. argue that college students assume a leadership identity when they shift from an understanding of leadership as emanating from a role or position within an organization (*positional leadership)*, to one that characterizes leadership as a process of exercising influence any organizational member can employ(*relational leadership)*. For a full discussion of the role of the LID model in developing the Engineering Leadership Identity Model presented in this paper, see (Schell & Hughes, 2016).

Engineering Leadership Identity Model

The conceptual framework guiding this study, summarized in Exhibit 1, posits that engineering leadership develops through a process of leadership identity development within the context of engineering formation, or as engineering students assume engineering identities and become practicing engineers. This identity-based approach constitutes an important shift in understanding engineering leadership development as engineering identity can conflict with leadership identity in students (Stevens et al., 2014). Experiences that contribute to engineering identity focus on the development of technical mastery to the exclusion of professional skills (Shuman, Besterfield-Sacre, & McGourty, 2005), like leadership, signaling to students that these skills are less important for their professional development. This project hypothesizes the conflict between engineering and leadership identity can be resolved through approaching leadership identity development as complementary to engineering identity.

The LID model identifies four environmental conditions that affect the development of leadership identity (Komives et al., 2005). The model then uses these to categorize common experiences within engineering programs to determine those with greatest potential to influence engineering leadership identity development. First, students' perceptions of leadership are shaped by adults, mentors, and other influential figures; for engineering students these individuals likely include family members employed as practicing engineers. These precollege encounters with engineers have also been shown to affect engineering identity development as well as students' decisions to enter the field (Lichtenstein et al., 2009; Pierrakos et al., 2009). Students' perceptions then continue to be influenced by engineering faculty and industry mentors as they progress through their undergraduate programs. The second environmental condition that affects leadership identity development is peers, who have been shown to significantly influence the extent to which students develop a sense of engineering identity (Tonso, 2006). Peers are also helpful in developing social networks for navigating the formal and informal pathways into engineering. Meaningful involvement in curricular and co-curricular opportunities is the third environmental influence on leadership development. For engineering students these opportunities constitute their legitimate peripheral participation in engineering communities of practice (Lave & Wenger, 1991). Opportunities for engineering students include student chapters of engineering professional societies, internships and cooperative experiences, and undergraduate research. What appears to be missing then is the fourth environmental condition that supports leadership identity development: opportunities for reflective learning on these leadership experiences. Although engineering students have access to formally structured opportunities for leadership development, these types of opportunities tend to demonstrate mixed results in terms of their effectiveness (Collins & Holton, 2004; Day, Fleenor, Atwater, Sturm, & McKee, 2014), suggesting the need for reflective learning to draw out the personal and professional relevance of leadership, facilitating its incorporation into students' sense of professional identity.

Exhibit 1. Model for Developing an Engineering Leadership Identity



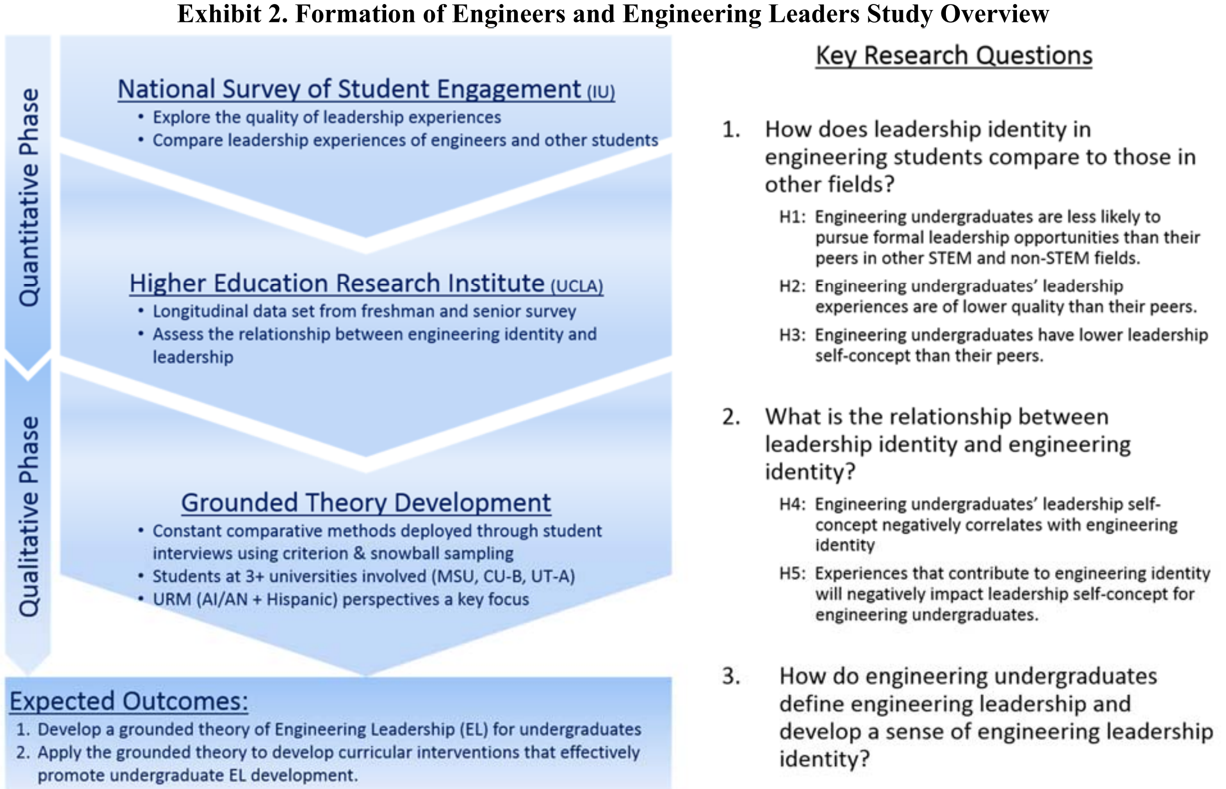
The development of relational leadership in engineering students holds two important benefits with regard to the problem motivating this study. First, understanding leadership as relational should foster in engineering students a more stable sense of leadership identity (Komives et al., 2005). Students who are more likely to see themselves as leaders will then have a greater sense of self-efficacy and confidence to exercise leadership in the workplace following graduation, and, building on their mastery of engineering technical knowledge, develop a stronger sense of belonging in the field. These novice practicing engineers should then be well-positioned to move into the final two stages of the LID model, generativity and synthesis, where they begin carving out a professional legacy through innovative contributions to their organizations and to the field. Second, relational leadership also holds implications for broadening participation of people from groups underrepresented in engineering. For example, the majority of current engineering leaders available to role model and mentor new professionals are White males (Camacho & Lord, 2013), which contributes to the underrepresentation of Latinos/as in engineering. Models of engineering identity development in Latino/a students have identified dimensions of this process that implicate leadership development, such as the role of students' broader network of support beyond the campus as well as the importance of developing community, or even a *familia*, within engineering among Latina and Latino engineers (Revelo Alonso, 2015). Relational leadership implies that the relationships among individuals within the organization, as well as the influence of important individuals external to the organization, are critical to maintain for effective leadership identity development.

A recent study by Knight and Novoselich (2017) helps support the Engineering Leadership Identity Model. In their study, they tested the effect of curricular and co-curricular experiences with a broad, nationally-representative sample of engineering undergraduates. They found classroom and co-curricular experiences both associate significantly with students' self-reported leadership abilities, with curricular emphases influencing leadership ability the most. Although their study did not focus on identity specifically, their results help support the hypotheses posited by our model that environmental influences within the engineering curriculum and co-curriculum can both influence leadership development. In addition, their findings point to the importance of incorporating professional skill development into the engineering classroom, as opposed to sole reliance on co-curricular experiences for engineering students' leadership development. In essence, their findings align with previous research regarding mixed evidence of effectiveness of formally structured programs (co-curricular programs), as well as the LID model's assertion of the need for reflective learning (curricular incorporation).

Study Overview

The work to develop a grounded theory for the development of engineering leadership within undergraduate engineering students is a multi-phased project. As illustrated by Exhibit 2, the project begins with quantitative analysis of two national data sets. The first of these is a selection of questions taken from the National Survey of Student Engagement (NSSE) at the University of Indiana. This data set is being utilized to better understand the leadership experiences of undergraduate students, and how these experiences differ for engineering students and others. The subsequent project phases depicted in Exhibit 2 are discussed in future work.

Exhibit 2. Formation of Engineers and Engineering Leaders Study Overview



Data source and sample

The data for this paper came from the 2015 NSSE administration. The NSSE is one of the largest surveys of college students in the nation, and the 2015 administration included more than 315,000 first- and fourth-year students across 585 institutions. The survey collects information on student participation in college and university programs and activities designed to achieve learning and personal development for students. Involvement in these activities is an indicator of higher levels of student engagement in learning.

For this study, NSSE staff pre-selected a group of institutions from the 2015 administration to participate in a pilot study of a new module to measure student leadership experiences, and randomly sampled 6547 students (2.1%) at these 21 different bachelor's-granting institutions. Of these 6547 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% (National Science Board, 2016). This module was provided to students who indicated they held a formal leadership role in a student organization or group. It also included students who indicated they held a role in a student organization or group that may be construed as a leadership position, but did not self-report as such. The questions in the module then prompted students to report various experiences in that leadership role, including the setting, the amount of time invested, the level of support received from advisors, and their perception of what skills or abilities they gained from the experience. Student self-reported gains in leadership abilities were the focus of this study to help respond to our second hypothesis, that engineering students' leadership experiences are of lower quality than those of their peers. The response items are summarized in Exhibit 3.

Exhibit 3. **Questions included in the pilot student leadership module**

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	

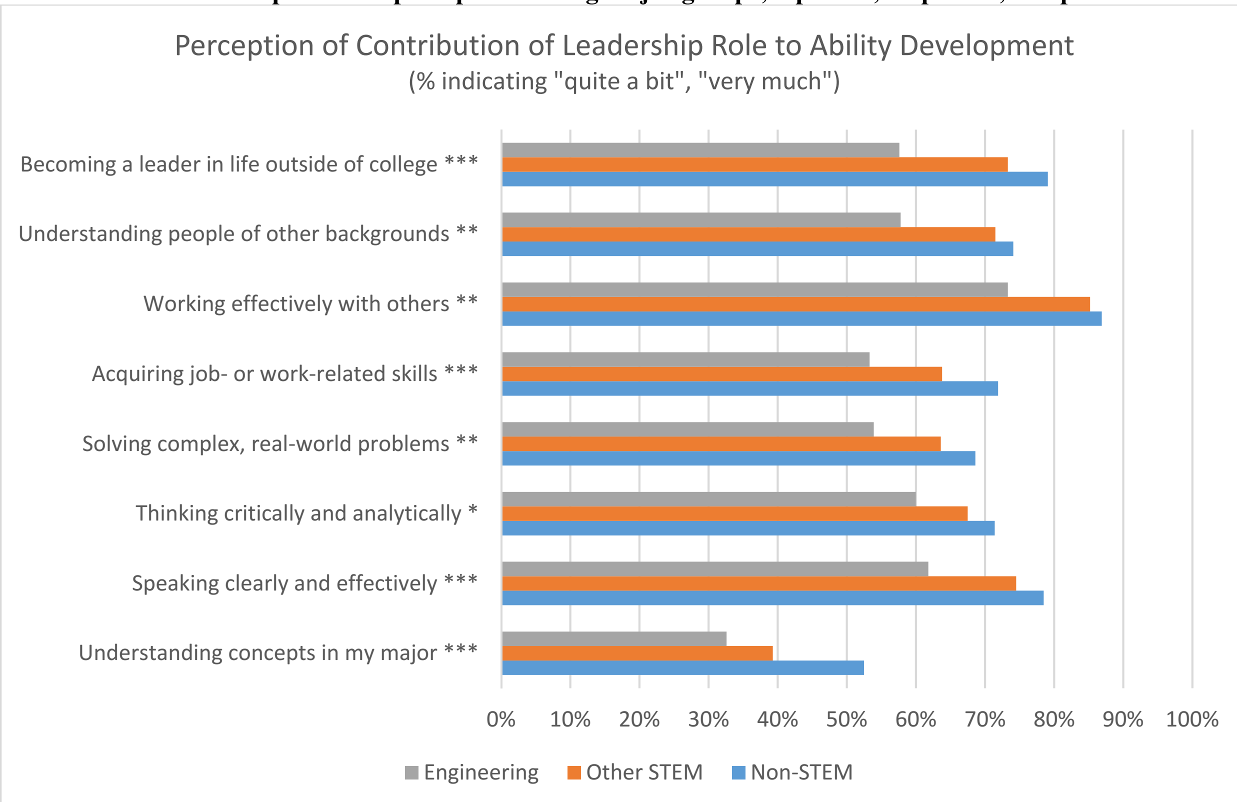
In order to examine differences in leadership experiences between engineering students and their peers, descriptive differences among engineering, other STEM, and non-STEM students were calculated for each of these items. This process began by examining the distributions of each variable to determine the extent to which these variables were skewed. As responses tended to cluster around 3 or 4, the variables were then dichotomized to reflect whether students attributed changes in their leadership abilities to these experiences to a lower extent (very little, some) or a higher extent (quite a bit, very much). Due to the categorical nature of the responses following recoding, group differences were tested using cross-tabulations with chi-square tests for significance (α=0.05) using SPSS v22. Charts are used in the findings to display group differences in proportion of students reporting "quite a bit" or "very much" for each item. Cases missing data on any particular item were removed from the analysis through listwise deletion.

Results

Initial analysis, presented in greater detail in (Schell & Hughes, 2017), demonstrated that, among college seniors, engineering students were most likely to report having held a leadership role in a student organization (39.7%), followed by students in other STEM fields (38.1%) and then non-STEM students (29.4%). This difference was significant ($\chi^2(2) = 18.928$, $p<0.001$). Engineering students who held formal leadership roles were most likely to characterize these as president or chairperson (26%), other executive role like secretary or treasurer (16%), and manager or coordinator (12%). Among those engineering students who held a formal position but did not consider themselves as having held a leadership role, the position held tended to be manager or coordinator (25%), instructor or teaching assistant (21%), or tutor (17%).

Exhibit 4 displays the results of the cross-tabulation comparing student perceptions of how their leadership role contributed to the development of the specific outcomes detailed in Exhibit 3. The bars in Exhibit 4 display the proportion within each student group who indicated either "quite a bit" or "very much" in response to the item. The asterisks indicate the level of significance of each difference. All comparisons were significant at a level of $\alpha = 0.05$ or lower. Perhaps the most striking aspect of these charts is the consistent pattern across all dimensions that shows engineering students perceive their leadership roles contributing the least to each outcome, followed by students in other STEM fields, with non-STEM students attributing the highest perceived gains from their leadership role(s).

Exhibit 4. **Comparison of perception among major groups; * p<0.05; ** p<0.01; *** p<0.001**

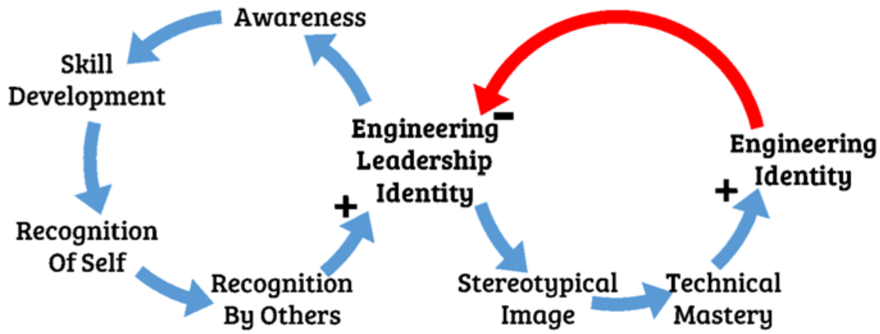


Students across the board felt their leadership role provided the greatest benefit in their ability to work effectively with others, with only a slight difference between non-STEM and other STEM students (1.7%) and a much larger difference between non-STEM and engineering students (13.3%). Students felt their leadership roles contributed to understanding concepts in their majors the least, ranging from less than one-third among engineering students to slightly more than half of non-STEM students. One of the starkest differences was with regard to becoming a leader outside of college. While more than three-quarters (79.1%) of non-STEM students and slightly less than three-quarters (73.3%) of other STEM students felt their leadership roles contributed to this outcome, only 57.6% of engineering students felt the same way.

Implications, Conclusions, and Future Work

An initial hypothesis of this study is that engineering students were less likely to see themselves as leaders than their peers. These results offer support for that assertion. Perhaps even more importantly, if we combine the outcomes of acquiring skills, solving problems, thinking critically, and understanding concepts from my major, to be the most representative of what is typically considered to be engineering work, we see an very stark contrast between the average response from engineers (50.0%) and others (Other STEM 58.6%, Non-STEM 66.1%) . This may indicate further support for the hypothesized negative effect that an engineering identity has on a leadership identity, as illustrated by the red line in Exhibit 5, adapted from a fixes that fail system archetype (Senge, 1990).

Exhibit 5. The System Level Conflict Between Leadership and Engineering Identity



Considering all of these results together, it appears engineering students are less likely than their peers to perceive gains from their experiences in leadership roles which may also suggest a lower sense of leadership self-concept. These results align with the assertion made in Exhibit 5 illustrating how the experience of developing engineering identity conflicts with the development of leadership identity within the undergraduate engineering formation process. While these results do not show causation, they add another level of insight into the results of the leadership skill prediction models for engineers built by Knight and Novoselich (2017). Their results indicated that almost all significant predictors from an engineering program of study had a negative impact on a student's self-reported leadership skills.

The project summarized in Exhibit 2 is only recently underway and the results presented here are preliminary. Over the course of the coming years we expect to deliver a better understanding of what truly constitutes an engineering leadership identity. This understanding will be developed in two phases as depicted in Exhibit 2. The initial quantitative phase includes the NSSE data discussed here and an additional data set from the Higher Education Research Institute at UCLA. When combined, these data will enable a deeper understanding of the relationship between leadership identity and engineering identity. This understanding will provide the foundation for a qualitative phase to develop a grounded theory construct of engineering leadership identity. This construct will provide the foundation upon which to design curricular interventions that are effective in allowing students to see the role of leadership in engineering and themselves as leaders.

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About the Authors

William J. Schell holds a Ph.D. in Industrial & Systems Engineering - Engineering Management from the University of Alabama in Huntsville and M.S. and B.S. degrees in Industrial & Management Engineering from Montana State University (MSU). He is an Assistant Professor in Industrial & Management Systems Engineering and Associate Director of the Montana Engineering Education Research Center at MSU. Prior to his academic career, he spent 14 years in industry where he held leadership positions focused on process improvement and organizational development with Fortune 50 and Inc. 500 companies. He is a registered Professional Engineer, certified Professional Engineering Manager and serves ASEM as the Director of Student Membership. Prior research work on leadership received recognition with the Eschenbach Award for 2014 from the Engineering Management Journal (with Kuntz) and ASEE's Engineering Leadership Development Division 2016 Best Paper Award (with Kauffmann).

Bryce E. Hughes holds a Ph.D. in Higher Education and Organizational Change from the University of California, Los Angeles, as well as an M.A. in Student Development Administration from Seattle University and a B.S. in General Engineering from Gonzaga University. He is an Assistant Professor in Adult and Higher Education MSU. His research interests include college student development, teaching and learning in engineering, and STEM education policy. His professional experience includes five years as a student affairs practitioner training and supervising student leaders, including members of student government and peer mentors to first-generation and low-income students. He is also an affiliate faculty member with the Montana Engineering Education Research Center at MSU.