# Development of Leadership Self-Efficacy: Comparing Engineers, Other STEM, and Non-STEM Majors

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***Abstract*— The purpose of this work in progress research paper is to examine the differences in leadership self-efficacy among engineering undergraduates and their peers in other fields, and understand how leadership self-concept changes from the first through the fourth year of college. This study conceptualizes engineering formation as a professional identity development process, cultivated through participation in engineering communities of practice. The guiding hypothesis is that experiences that contribute to engineering identity, which focus on the development of technical mastery, conflict with the development of leadership self-concept.**

**This work presents preliminary analysis of the differences between engineering undergraduates and their peers with regard to their leadership experiences during college. Preliminary results reveal a complex picture of the differences between engineering students and their peers in other STEM and non-STEM fields. Engineering students have the highest leadership self-efficacy of all three groups by the end of the fourth year of college, which mirrors differences in self-rated leadership skills at college entry.**

**However, differences in leadership experiences during college vary among these three groups, and not consistently with their leadership self-efficacy. Engineers are least likely to participate in a leadership training during college and to value becoming a leader after college. Among engineering students, students who participate in internships, undergraduate research, and collaborate with peers report higher leadership. Leadership is unrelated to plans to enter engineering as a career.**

***Keywords—student development, leadership development, engineering identity, leadership self-efficacy, quantitative analysis***

## I. Introduction

The purpose of this work in progress research paper is to examine the differences in leadership self-efficacy among engineering undergraduates and their peers in other fields, and understand how self-efficacy changes from the first through the fourth year of college. Recognizing that engineers need solid leadership skills to participate in developing solutions for society's greatest challenges given the need for interdisciplinary solutions, the National Academy of Engineering, among other national voices, have called for leadership as an essential competency taught in undergraduate engineering programs [1]. However, undergraduate engineering programs, as the primary means for the professional formation of practicing engineers, emphasize technical mastery over other skills, like interpersonal skills and the ability to lead in organizational settings [2].

As a result, engineering graduates may lack confidence in their leadership skills because the omission of this outcome in undergraduate programs leads to little treatment of leadership. Further, engineers may not be motivated to lead due to a distaste for assuming leadership roles. [3, 4]. This study examines this hypothesis utilizing longitudinal data collected by the Higher Education Research Institute (HERI). By comparing changes in leadership self-efficacy from the first year to the fourth year of college among undergraduates in engineering, other STEM majors, and non-STEM majors, we examine the impact on leadership confidence of different curriculums across a large national sample.

## II. Leadership in Engineering

Leadership has been a topic of philosophical and scholarly interest since long before modern management programs (dating back thousands of years to antiquity) [5]. This long-standing interest may reflect the multifaceted nature of leadership, which can be viewed differently, depending on the contextual lens through which it is explored. Engineering provides a unique context in which to examine leadership due to the long-standing perception that engineering work can be distinguished as technical or social in nature [6-8]. Additionally, engineering students differ from their peers with higher measures of academic potential and performance [9-11], indicating high potential for leadership. However they also are joining a profession that shows less interest in leadership roles [4] and suffers from the popular idea of being socially inept.

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These contradictions are particularly interesting, as engineering students' technical expertise and critical thinking skills might bring substantive value to the decision-making processes of leadership.

As the technical aspects of engineering work tend to dominate conceptualizations of that work [8], engineers' professional formation process is firmly rooted in technical competence [12, 13]. Technical mastery and professionalism tend to be held as hallmarks in terms of recognition as an "engineer" by others [14], solidifying an aspiring engineer's sense of belonging in the field and resulting engineering identity. Hence, understanding engineering leadership requires a robust view of the full picture of engineering identity. Many institutional approaches to leadership development in engineering fail to appreciate the heterogeneity of engineers when applying a lens that informs the creation of an engineering education curriculum [15]. For example, many engineering leadership programs define leadership in terms of technical expertise, without focusing on other characteristics (such as interpersonal skills) [16] that have been shown to be central to leadership [17].

Further yet, engineers may differ most from their peers in terms of their willingness to identify with leadership [4], as indicated by their confidence in leading, or leadership self-efficacy. Leadership self-efficacy is a person's judgment that they can successfully carry out leadership [18], which supports a person's sense of agency as a leader and influences their motivation to lead [19]. Leadership self-efficacy stems from a set of beliefs regarding one's confidence to lead [20]. Research suggests that the curricular emphasis on technical mastery may not be the only reason engineering students may lack leadership skills, but also that engineering students themselves express disdain for leadership [21]. That said, previous research has determined that engineers may not differ from their non-engineer peers in terms of leadership self-efficacy [22], although limited by estimating longitudinal effects with cross-sectional data.

## III. Methods

This work presents preliminary analysis of the differences between engineering undergraduates and their peers with regard to their leadership experiences during college. The data for this study come 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 the Higher Education Research Institute at UCLA. 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.

The primary variable of interest in the analysis is the leadership construct developed by CIRP [23]. This variable is used as a measure of leadership self-efficacy because CIRP defines the construct as a measure of students' beliefs about leadership, including leadership development, capacity, and experiences. The construct was developed using Item Response Theory and involved five survey items, including self-rating of change in leadership ability, self-rating of leadership ability relative to peers, extent to which students effectively led in a group setting, participation in a leadership training, and service as leader to an organization [24]. CIRP constructs are computed and then rescaled to a mean of 50 and standard deviation of 10 for interpretation and comparison purposes.

For the first set of analyses, engineering students were compared with their peers in other STEM and non-STEM fields. For the second set of analyses, only the engineering sample was used to compare among the various engineering fields represented in the dataset. The leadership scores among engineering students were also compared on the basis of several experiences that are generally known to promote engineering identity development [25, 26]. These experiences included participation in an internship, undergraduate research, studying with peers, working on projects with peers in and out of the classroom, extent of interactions with faculty, and stated plans to enter engineering as a career.

The comparisons of the leadership construct between two groups, such as whether students participated in undergraduate research, were completed using t-tests. For comparisons of means among multiple groups, including comparisons of the leadership construct among the three major groups (engineering, other STEM, non-STEM), ANOVA tests were used. In the few instances where the data violated Bartlett's test for the equality of variances, robust tests were also run to double-check significant results, as in the instance of testing average self-rating of leadership skills between engineers and their peers. For multiple group comparisons, Scheffe post hoc tests were run to identify which groups significantly differed from others. In one instance, to test the relationship between two categorical variables, a cross-tabulation with a chi-square test was utilized.

Before examining the results, a couple limitations of this dataset must be noted. First, this work represents a secondary analysis on an existing dataset, so the analyses are limited to the available variables. However, the dataset provided a host of variables aligned with the overall research purpose, so this limitation should be of slight concern. Second, even though this dataset is longitudinal, many of the relationships tested were between variables from the same instrument, collected at the same time point. Although causal relationships among variables may be inferred based on theory and literature, this analysis alone cannot fully assure that significant relationships represent experiences that cause changes in leadership self-efficacy.

## IV. Results

The results reveal a complex picture of the differences between engineering students and their peers in other STEM and non-STEM fields. Engineering students score on average the highest of all three groups on the survey's fourth-year leadership construct ($M = 50.8$, $SD = 8.77$). Non-STEM students score second highest (M = 50.6, SD = 8.98), and do not differ significantly from engineering students. Instead, students in other STEM fields score lowest (M = 49.9, SD = 9.03), and differ significantly from both other groups ($P < 0.05$ and $P < 0.001$, respectively). These differences are partially explained by differences in self-rating at college entry: engineering students again score highest (M = 3.84, SD = 0.88), non-STEM students second (M = 3.81, SD = 0.96), and other STEM students third (M = 3.74, SD = 0.95). Other STEM students differ significantly from the other two. Fourth-year self-ratings on leadership ability matched the patterns observed in the first-year data, as well as the fourth-year leadership construct scores: engineers averaged the highest (M = 4.02, SD = 0.81), non-STEM students second (M = 3.98, SD = 0.85), and other STEM students third (M = 3.92, SD = 0.85). Only the differences between other STEM and the two other groups were significant. Dependent samples t-tests comparing the first-year and fourth-year self-ratings of leadership ability did demonstrate significant change in all three groups (all $P < 0.001$).

Further, congruent with previous findings in the project using a separate dataset [27], engineers reported the highest likelihood of having held a leadership role in college (66%), followed by other STEM students (62%), and non-STEM students (61%; $\chi^2 = 10.48$, $P < 0.01$). Seen as an additional reflection of motivation to lead, engineers also reported the second highest concern for finding a career with leadership potential (M = 2.95, SD = 0.82), just behind non-STEM students (M = 2.96, SD = 0.85), and not statistically different. Other STEM students were least concerned (M = 2.86, SD = 0.85), and differed significantly from the other groups ($P < 0.05$ and $P < 0.001$, respectively).

Taken together, these findings may suggest engineering undergraduates have much stronger leadership self-efficacy than hypothesized, and are surprisingly more similar to their non-STEM peers than their peers in other STEM fields. However, their experiences with leadership during college and future leadership intentions vary in a manner inconsistent with these findings. Non-STEM students reported the highest likelihood of having participated in a leadership training (38.7%), followed by other STEM (36.5%), with engineers reporting the lowest likelihood (34.1%; $\chi^2 = 12.24$, $P < 0.01$). When asked about the importance of becoming a community leader after college, non-STEM students reported the highest importance (M = 2.74, SD = 0.95), followed by other STEM students (M = 2.34, SD = 0.92), and engineers third (M = 2.25, SD = 0.91; $P < 0.001$). What appears to be happening is engineering students may be unlikely to seek out opportunities to develop as leaders, and becoming a leader beyond opportunities for career advancement is not viewed as important.

Next, we examined how leadership self-efficacy differed for engineers based on a variety of experiences engineers are likely to have in college that should promote engineering identity. Table 1 provides a breakdown by engineering field the composition of the engineering sample. Unsurprisingly, the highest proportion of engineers in this sample were in mechanical engineering (29%), followed by civil engineering (17%), and electrical engineering (11%). All other groups were less than 10%, with the exception of the "other engineering" category (13%), which captured fields not listed on the survey. Fig. 1 displays, by field, students' average assessment of their leadership ability when they entered college and at the end of the fourth year. In both cases, students in aeronautical and astronomical engineering reported the highest levels of leadership, followed by chemical engineering. Mechanical engineers appear to have grown the most in leadership relative to their peers in other fields, and computer engineers scored lowest on average at both time points. The one-way ANOVAs comparing means among all engineering majors were significant at both time points, but Scheffe post-hoc tests revealed no field-by-field comparisons to be significant. For example, the largest difference was between aeronautical and computer engineering, but the difference was not significant ($P = 0.136$).

*Table 1 - Composition of engineering sample by field*

| Major | n | % |
|---|---|---|
| Aeronautical or Astronautical Engineering | 41 | 4.47 |
| Civil Engineering | 155 | 16.88 |
| Chemical Engineering | 145 | 15.8 |
| Computer Engineering | 83 | 9.04 |
| Electrical or Electronic Engineering | 97 | 10.57 |
| Industrial Engineering | 14 | 1.53 |
| Mechanical Engineering | 268 | 29.19 |
| Other Engineering | 115 | 12.53 |

Several experiences were also significantly related to higher leadership construct scores. Engineering students who participated in internships ($P < 0.05$), participated in undergraduate research programs ($P < 0.01$), studied with other students more frequently ($P < 0.01$), more frequently worked with other students on projects in class ($P < 0.01$) and out of class ($P < 0.001$), and worked on a faculty member's research project more frequently ($P < 0.01$) all reported higher leadership construct scores. Scores on the faculty interaction construct positively and significantly correlated with the leadership construct ($R = 0.25$, $P < 0.001$). The only experience

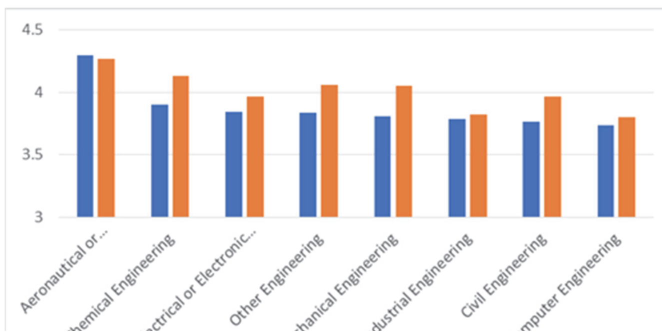


*Figure 1. Leadership Skill Self Assessment by Major for Freshman (TFS) and Senior (CSS) Students*

that did not relate to higher leadership construct scores was students' career plans: engineering seniors who planned a career in engineering (74%) had slightly lower scores than engineering seniors who did not (26%), but the difference was only marginally significant ($M = 50.5$, $SD = 8.72$ and $M = 51.7$, $SD = 8.87$, respectively; $P = 0.0632$). It's encouraging that experiences intended to promote motivation for and commitment to engineering seem to relate to leadership self-efficacy, but leadership self-efficacy does not appear to relate to decision-making among engineering seniors as to whether to enter the engineering field.

## V. Discussion and Implications

This work in progress paper presented the results of initial descriptive statistical analysis examining the differences in leadership self-efficacy between engineering undergraduates and their peers, change in leadership self-concept from the first to the fourth year of college, and how experiences that promote engineering identity relate to leadership self-efficacy. It was hypothesized that engineering students would demonstrate the lowest levels of leadership self-efficacy, but that experiences related to engineering identity may promote leadership development.

The results reflected analysis performed with a separate national dataset [27] which showed engineering students held leadership roles at a higher rate than their peers in other majors. Furthermore, this analysis appears to refute the key hypothesis guiding this study that engineers would score lowest on leadership self-efficacy. Surprisingly, engineers' leadership self-efficacy was not significantly different from their peers in non-STEM fields, which has implications for examining student development in STEM. One might assume engineers' experiences resemble their peers in scientific and technical fields, but perhaps the professional nature of engineering attracts a different kind of student than other STEM fields.

These findings may also be encouraging to people working to promote leadership development in engineering students. The potential for engineers to be motivated to lead appears high, and several experiences relate to higher leadership self-efficacy. Group work with other students, undergraduate research with faculty, and participation in internships are all practices widespread within undergraduate engineering programs and could be leveraged toward leadership development [13, 26]. Another opportunity would be to promote the development of engineering leadership programs across the country; the fact that engineering students were least likely to have participated in leadership trainings may reflect a need for leadership development relevant to their career preparation. Engineering students may also not recognize the social relevance of engineering work [28], which could increase their aspirations to becoming a community leader after college. Programs like Engineers Without Borders thus could help meet previously stated demands for engineering leaders [29].

That said, leadership development is not uniform across engineering fields, though this development does not vary tremendously. While this dataset is somewhat limited in being able to compare across engineering fields given the size of the sub-samples within each field, the results suggest that students in some engineering fields on average remained consistent across four years whereas others changed. The opportunity thus exists to draw out the relevance of leadership across all engineering fields. As all experiences that promote the development of engineering professional identity related to greater levels of leadership self-efficacy. One challenge persists, then—faculty perceptions of the importance of leadership to engineering also varies by engineering fields [30]. If interactions with faculty, both in and out of the classroom, predict higher levels of leadership self-efficacy, a question remains as whether faculty perception of leadership as a learning outcome might affect engineering student leadership development.

Further, plans to enter the field of engineering as a career did not relate to leadership self-efficacy, with those not planning an engineering career reporting a non-significantly higher level of leadership self-efficacy than those planning to enter the field. Future analysis is intended to confirm the relationship between these experiences and plans to enter an engineering career given the need for practicing engineers with strong leadership skills [1]. At this stage it appears leadership is not necessarily a uniform aspect of undergraduates' decision-making regarding commitment to the field of engineering as a career.

## VI. Future Work

This work in progress paper represents the initial findings of the second quantitative phase of a larger project. This quantitative work is being utilized to set the framework for a subsequent qualitative phase. This qualitative phase will utilize the leadership experiences of undergraduate engineering students at three universities to deeply investigate some of the contradictions that appear to be manifesting in the two secondary national data sets. The end result of this phase is the development a grounded theory of engineering leadership identity aligned with undergraduate engineers. This grounded theory will serve as the foundation for the development of curricular interventions designed to promote a more fully complete engineering leadership identity in undergraduates.

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