Exploring the Relationship Between Students' Engineering Identity and Leadership Self-Efficacy

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Abstract
In order to lead the social process required to solve society's grandest challenges 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. Thankfully, greater numbers of engineering educators are recognizing this need and are consequently establishing engineering leadership certificates, minors, and even full degree programs through centers at universities throughout the country. However, for these programs to reach their full potential, engineering educators must be successful in integrating leadership into the very identity of engineers. This study seeks to better understand the relationship between engineering identity and leadership, so tools can be developed that enable engineering educators to more effectively integrate leadership into an engineering identity.

This paper explores this relationship using a national sample of 918 engineering students who participated in the 2013 College Senior Survey (CSS). The CSS is administered by the Higher Education Research Institute (HERI) at UCLA to college students at the end of their fourth year of college; data from the CSS are then matched to students' prior responses on the 2009 Freshman Survey (TFS), which was administered when they first started college, to create a longitudinal sample. Using a leadership construct developed by HERI as the outcome variable, this work utilizes Hierarchical Linear Modelling (HLM) to examine the impact of engineering identity and a host of other factors shown to be important in college student development on leadership. HLM is especially appropriate since individual student cases are grouped by schools, and predictor variables include both student-level and institution-level variables. The leadership construct, referred to as leadership self-efficacy in this work, includes self-rated growth in leadership ability, self-rating of leadership ability relative to one's peers, participation in a leadership role and/or leadership training, and perceived effectiveness leading an organization.

The primary independent variable of interest was a factor measuring engineering identity comprised of items available on both the TFS and CSS instruments. Including this measure of engineering identity from two different time periods in the model provides the relationship between engineering identity in the fourth year and leadership self-efficacy, controlling for engineering identity in the first year as a pretest. Statistically significant results were found across each of the areas tested, including the fourth-year engineering identity factor as well as several collegiate experiences, pre-college experiences, major, and institutional variables. Taken together, these results present a nuanced picture of what matters to predicting leadership outcomes for undergraduate engineering students. For example, while engineering identity is a significant positive predictor of the leadership construct, computer engineers score lower than mechanical engineers on leadership, while interacting with faculty appears to enhance leadership self-efficacy.

Introduction
For almost two generations, industry and some in academia have been calling for engineering graduates who are better prepared to immediately make a positive impact working on complex engineering problems [e.g. 1, 2-4]. These calls have often taken the form of highlighting the dearth of "professional skills" in engineering graduates, including communication and ability to work in teams . Over the last decade, with the impetus of the National Academy of Engineering (NAE)

Grand Challenges, more are also calling for engineers who are prepared to lead, given the interdisciplinary teams required to solve these problems. These calls have, in turn, led to greater recognition by engineering educators of the need for engineers who can lead. This recognition is evident by the development of an increasing number of engineering leadership development programs [5] and continued expansion of ASEE's Engineering Leadership Development Division.

Our interest is assisting engineering educators who are interested in developing leadership in their students understand how leadership fits into an engineering identity. This work leverages the concept that individuals have numerous identities based on the groups with whom they interact [6]. Specifically, our overall theoretical model is interested in how the concepts of engineering identity and leadership identity might merge to create an engineering leadership identity in undergraduate students in a multi-year ongoing project. The objective of this particular work is to understand the relationship between engineering identity and leadership self-efficacy as a component of a more comprehensive view of leadership identity. This relationship is explored using a national longitudinal data set of engineering students.

Engineering Identity and Its Importance

Historically, identity has been theorized and explored in a vast array of social science thought ranging from different disciplines of psychology to sociology to anthropology [7]. Engineering Identity is a frequent area of interest in the engineering education literature due to its proven benefits in measures of persistence and inclusion [8, 9]. Despite this importance, or perhaps because of it, there is no agreed upon definition of engineering identity, an issue likely driven by the inherent complexity of identity. This complexity is captured well in Tonso's summary of the different schools that approach engineering identity including constructing engineering identity as a collective identity situated in culture, an individual identity conceived from perspectives of developmental psychology, and those conceived from sociocultural perspectives (including professional identity and technical / social dualism) [7].

In recent years, two instruments that were developed and validated to define and measure engineering identity were published almost simultaneously. Prybutok, et al. worked to develop a 119 item survey built from previously validated scales in math, physics and general science [10]. The instrument was then tested using a large sample of both lower and upper division students at a large public institution. This instrument found four reliable scales as subsets of engineering identity. These scales are summarized as:

- Engineering Performance / Competence
- Engineering Interest
- Engineering Recognition by Others
- Engineering Recognition by Self

Similarly, Godwin developed her instrument starting from previously validated work from other fields. Development of this instrument included two rounds of study with a large national data set and resulted in an eleven (11) item instrument to measure engineering identity. These items are grouped into three reliable constructs:

- Recognition by Others
- Interest in Engineering
- Performance / Competence in Engineering

By comparing these two lists, the reader can see a high level of overlap, indicating some level of consensus of how engineering identity can be interpreted. This consensus on engineering identity is further supported when considering the situated learning tradition from cultural anthropology [7]. Specifically, the Communities of Practice model, initially conceptualized by Lave and Wenger [11] and furthered by Wenger [12] which noted that learning is a social process, situated within a community, with membership (recognition by others) being the ultimate goal.

As discussed in methods, this work uses secondary analysis of a national dataset that included a subset of questions that can be mapped to a component of engineering identity consistent with the models discussed above.

Leadership Identity

Traditionally, leadership has been thought of in terms of behaviors leaders employ to direct followers, make decisions, and generate positive outcomes. Such thinking explains why leadership development for undergraduate students often takes the form of skill development courses. Unfortunately, a great deal of research has shown that this skill development is often less than effective when put into practice [e.g. 13, 14]. Instead, a more holistic approach may provide greater preparation for developing engineering students who are ready and eager to lead. For this reason, this works looks to understand leadership self-efficacy as a component of identity development within students. Specifically, using identity development considers the processes individuals engage in to develop a sense of who they are, both at an individual level and through making meaning of the groups in which they have membership [15].

While a growing body of work has considered the role of identity in development of leadership [e.g. 16, 17-19], it has been outside the focus of undergraduate students. As summarized by Ibarra, et al. [20], work in this area generally focuses on the development of a leadership identity for working professionals and often focuses on changes prompted by position or career transitions. Therefore, this body of work fails to understand the differences in leadership identity that might be present between working professionals and undergraduate students. Since the interest of our work rests in the identity transition of college students, we focus our consideration on the Leadership Identity Development (LID) model [21]. The LID model considers the meaning that students make of leadership in five developmental areas:

1. Broadening View of Leadership, considering it to be more than positional
2. Developing Self, including leadership skill development
3. Group Influences, particularly how students perceive the value of groups
4. Migration of Self View, from dependence to independence to interdependence
5. Developmental Influences, evolving influence of adults, peers and experiences

Unlike the concepts of engineering identity discussed earlier, the LID model has not yet been operationalized into a survey instrument [22]. However, the national dataset used in this study provided specific questions that investigate portions of this model summarized in bullets 2 – 5 above. Specifics of these measures are discussed in methods.

Methods

This work seeks to better understand the relationship between engineering identity and leadership self-efficacy as a component of leadership identity. This relationship is explored through secondary analysis of a national dataset. While the nature of secondary analysis prevents an explicit exploration of all items of interest in the two identity constructs discussed above, these limitations are outweighed in many ways through the scale of the available data and the consistency of questions with portions of the constructs of interest. Specifically, this data set enabled testing hypotheses related to the impact an engineering identity has on students' leadership self-efficacy, while controlling for the impacts of a large number of other variables. Through this investigation, this work adds to the engineering leadership education communities understanding of the relationship between an engineering identity and the kinds of leadership outcomes many in the community are interested in developing.

Data Source and Sample

The data for this study were taken from the 2013 College Senior Survey (CSS), an annual, national survey of college students administered at the end of their fourth year of college by the Cooperative Institutional Research Program (CIRP) at the Higher Education Research Institute (HERI) at the University of California, Los Angeles. Responses from this survey were then matched to student responses to the Freshman Survey (TFS), administered by CIRP at the very beginning of their first year of college. This matching provides a longitudinal data set to explore changes in college students during the first four years of their experience.

The TFS is the longest-running, and one of the largest, national surveys of college students, administered to provide a nationally-representative glimpse into the population of first-time, full-time college students at four-year institutions across the United States. The data set in this study also included institution-level data from the Integrated Postsecondary Education Data System (IPEDS). For this study, all fourth-year engineering students were included, meaning students who indicated engineering as their major on the CSS, which totaled 918 students at 49 universities.

Variables

The dependent variable in this study is the leadership construct developed by CIRP in the CSS instrument. The leadership construct measures students' beliefs or experiences on five items:

- Growth in their leadership abilities
- Comparison of their leadership abilities to those of their peers of the same age
- How effectively they have led a group
- Participating in leadership training
- Serving as leader of a group

Detailed information about items that comprise the construct and construct development can be found in Cooperative Institutional Research Program [23], and Sharkness, et al. [24]. CIRP constructs are developed using item response theory; construct scores are then rescaled for interpretability to have a mean score of 50 points and a standard deviation of 10 points. As shown in Figure A, these items can be mapped to four of the developmental areas defined in the LID model. This work makes no claim that these five items provide a comprehensive view of leadership identity, instead viewing the CIRP leadership construct as an indicator of leadership experiences and self-efficacy that will contribute to a leadership identity and are therefore of interest.

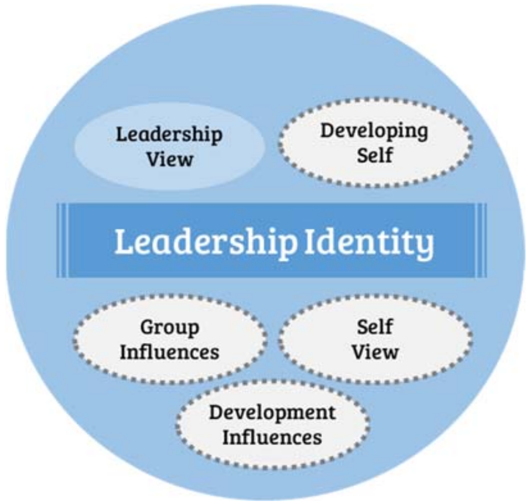

Figure A - The Development Components of the LID Model

The primary independent variable of interest in this study is engineering identity. Engineering identity was computed using exploratory factor analysis with three items from the CSS indicating the importance to students of becoming an authority in their chosen field, being recognized for contributions to their field, and making theoretical contributions to science. These items are well aligned with the engineering identity components discussed earlier and have been used in previous studies using CIRP data to measure science and STEM identity [25]. Furthermore, they are theoretically grounded in Carlone and Johnson's model of science identity (competence, recognition, and performance) [26], which also undergirds models of engineering identity in the field discussed previously. Factor scores were calculated through a summation of these variables (Authority in their field = 0.6799, Recognition for contributions = 0.7114, Theoretical contributions = 0.4808, weighted by factor loading. Eigenvalues revealed a single factor structure, and all three items loaded onto the factor at 0.40 or higher, with a Chronbach's alpha of 0.6888.

Other independent variables of interest were a set of college experiences hypothesized to predict either leadership or engineering identity. These included:

- Three dichotomous variables indicating whether students participated in internship programs, clubs and organizations, and undergraduate research programs.
- Two variables capturing the frequency by which students studied with other students and worked on professors' research projects, on a three-point scale from "not at all" to "frequently".
- A CIRP construct score for student-faculty interaction that considers the level and type of interaction and students' satisfaction with these interactions.

Several other variables were included in the model to control for confounding factors and help parse out the unique variance shared between the primary independent variable and the dependent variable. These included:

- The CIRP social self-concept score as a proxy pre-test of the leadership construct.
- A pre-test of engineering identity computed from items on the TFS that matched those from the CSS used to compute engineering identity. Inclusion of a pre-test allows the

results for engineering identity to be interpreted as change in engineering identity over four years of college.
- Demographics including students' sex, status as an underrepresented racial or ethnic minority (URM; African American, Latinx, or American Indian), family income, and first-generation.
- A variable that indicated whether either of a student's parents were employed as an engineer.

A set of variables measuring pre-college academic preparation were also included. These were:
- High school grade point average and standardized test scores (SAT score or ACT equivalent).
- Students' academic self-concept construct score

Indicators of their future career or academic plans at college entry, including:
- Whether students planned to pursue engineering as a career after college.
- How likely they were to change major during college (on a four-point scale from very unlikely to very likely).
- The highest degree to which students aspired during their lives.
- Students' intended major, included to test differences among engineering fields.
- The importance of getting a better job as a reason for them to attend college (measured on a three-point scale from not important to very important), assuming this reason might explain why they were motivated to select engineering.

A set of institution-level variables collected by both CIRP and IPEDS were included to test for potential institutional differences affecting retention in engineering programs. From CIRP:
- The type of institution attended (research university or four-year college)
- Institutional control (public or private)
- Institutional selectivity (average SAT scores among first-year class)

From IPEDS:
- The percentages of women and URM students among engineering students
- The overall full-time enrollment at each institution
- The proportion of students at each institution in engineering

Analysis and Findings

Before analysis, the dataset was inspected for potential assumption violations and to determine the extent to which missing data might be a problem. Several variables were transformed to improve normality or for better interpretability. As examples, income was recoded to reduce the number of categories and simplify the analysis. Percentage of women among engineering students was scaled so an increase of one unit represented an increase of 10 percentage points. Enrollment was transformed using a natural logarithm due to a skewed distribution.

In terms of missing data, most variables were missing data on 5% or fewer of cases and did not present concerns. However, some variables, like standardized test scores, were missing for a much higher percentage. Additionally, in terms of the proportion of cases with complete data, only about 61% of cases were complete. To combat these concerns and use the full information available to efficiently estimate model parameters, missing values were imputed using a multiple imputation process. Multiple imputation is a method for estimating missing values that overcomes the limitations of many other widely used imputation procedures [27]. Foremost among these limitations, the use of single imputation procedures increases the likelihood of a Type 1 statistical error by estimating standard errors too low. Two steps in the process thus offer multiple imputation an advantage over other techniques to better impute missing values: MI takes random draws from the distribution of variable residuals and adds that error to estimated values and then creates several datasets by producing multiple estimates of missing values. These datasets are analyzed separately, and results are pooled into a single model.

The analysis technique used to address the purpose of this study was hierarchical linear modeling (HLM) with robust standard errors, and the model is provided in Table 1. HLM was most appropriate for this analysis because the data that are "nested" in structure—in this case, student-level data is nested within institutions [28]. Nested data violate the assumption of independence for ordinary least-squares regression because of intraclass correlation among cases within groups.

The mean score for students in this sample was just about at the population mean (50) for the College Senior Survey (CSS) leadership construct score. Other descriptive statistics, reported in the appendix, offer a profile of the sample for this study. Women are overrepresented in this sample, at 27%, and a high proportion of students in this sample attend private colleges and universities (85%), as well as attend four-year colleges (versus research universities, 51%). Nearly 100% of students in the sample aspire to a bachelor's degree or higher, the required credential for entry into the field, and more than 80% aspire to a degree beyond the bachelors. Slightly more than half plan to pursue a master's degree, and 23% aspire to a doctoral degree.

Results and Limitations

The primary research question of interest to this work is whether engineering identity predicts leadership outcomes that present a subset of a hypothesized leadership identity construct. Based on the measures used in this study, it appears that students with a higher sense of engineering identity also have a higher belief of their leadership self-efficacy. While part of this finding may be driven by engineering students' confidence in their own abilities, an outcome seen in some of our prior work [29], it also presents a partial refute of one key hypothesis motivating the overall project of which this analysis is part. Specifically, a key hypothesis undergirding the start of this project is that an engineering identity detracts from development of an engineering leadership identity [30]. It was expected that this hypothesis might explain why engineers do not assume leadership roles commensurate with many of their capabilities.

Table 1 presents the full results of the regression analysis. In this analysis, engineering identity factor scores appear to positively predict leadership construct scores, controlling for the influence of several other factors included in the model, especially first-year engineering identity factor scores. Only one pre-college experience is significantly associated with the leadership construct score, first-year social self-concept. This measure serves as a proxy for a leadership pretest and is not only significantly related to leadership, but has the highest t-value (17.69) of any variable included in the model. (For reference, the second-highest t-value is 4.62) No other pre-college experiences or student characteristics were significant.

Table 1 – Summary of Regression Results Modeling Leadership Self-Efficacy Construct

Regressor	Coefficient	Standard Error	
Constant	11.176	6.534	
Student-level variables			
Experiences in college			
CSS engineering identity factor score	0.662	0.213	**
Participated in an internship program	-0.011	0.515	
Participated in student clubs/groups	2.849	0.643	***
Participated in an undergraduate research program	0.123	0.625	
Frequency, studied with other students	0.861	0.426	*
Frequency, worked on professor's research project	0.016	0.412	
CSS faculty interaction construct score	1.400	0.303	***
Student characteristics			
Female	0.956	0.544	
Underrepresented racial/ethnic minority student	-1.067	0.739	
Either parent employed in engineering	-0.048	0.573	
First-generation student	0.351	0.689	
Family income			
Low income (ref: middle income)	-1.604	1.085	
Low-middle income	-0.953	0.912	
Middle-high income	0.162	0.603	
High income	0.796	0.729	
Pre-college items			
TFS engineering identity factor score	0.163	0.224	
High school GPA	0.044	0.301	
SAT score or ACT equivalent (scaled by 100)	0.045	0.242	
TFS academic self-concept construct score	0.487	0.390	
TFS social self-concept construct score	5.491	0.310	***
Likelihood, change major field	0.065	0.306	
Planned engineering career at college entry	-0.872	0.597	
Importance, reason attended: to be able to get a better job	-0.042	0.634	
Initial intended major (ref: Mechanical Engineering)			
Aeronautical or Astronautical Engineering	-0.428	1.161	
Civil Engineering	0.231	0.682	
Chemical Engineering	-0.524	0.717	
Computer Engineering	-1.995	0.877	*
Electrical or Electronics Engineering	-1.672	0.798	*
Industrial Engineering	0.404	2.087	
Other Engineering	-0.221	0.821	
Highest degree aspired at college entry			
Less than bachelor's degree (ref: bachelors)	-4.787	3.357	
Master's degree	-1.171	0.671	
Doctoral degree	-0.233	0.767	
Medical degree	0.781	1.201	
Law degree	-1.524	2.023	
Institutional characteristics			
Percent women in engineering (per 10%)	1.259	0.533	*
Percent URM students in engineering (log, 10%)	0.134	0.452	
Full time equivalent enrollment (log)	-0.159	0.514	
Average SAT score of first-year class (scaled by 100)	-0.398	0.304	
Four-year college (ref: four-year university)	0.253	0.627	
Control: private (ref: public)	-1.940	1.129	

* = significant at $\alpha = 0.05$, ** at $\alpha = 0.01$, *** $\alpha = 0.001$ n = 918

Three college experiences that were previously shown to predict engineering identity [31] also significantly predicted leadership scores. The frequency students reported studying with their peers, scores on the student-faculty interaction construct, and participation in an internship or cooperative education program all significantly and positively predicted leadership scores. As the model accounts for engineering identity, these results show these three experiences also share unique variance with the leadership construct, meaning students likely experience both leadership development and a stronger commitment to engineering as outcomes of these experiences. These findings lead to interesting questions about the relationship among these three experiences, engineering identity, and leadership identity that could be further tested using structural equation modeling.

Significant results were also observed among engineering fields and institutional characteristics. Students in computer engineering and electrical/electronics engineering scored significantly lower on the leadership construct than mechanical engineering students. Students who attended institutions where women comprise a higher percentage of engineering students scored higher on the leadership construct. It does make sense that some differences among engineering fields might be observed, reflecting cultural differences among engineering fields. In terms of the latter finding, it's encouraging that attending a program with higher gender diversity might indirectly affect leadership development.

Of course, much more information is needed regarding the ways institutions differ; one cannot conclude from these results alone that leadership outcomes were directly a result of engaging in a more diverse program. However, programs that offer more opportunities to develop leadership may also enroll higher numbers of women engineering students, especially if those opportunities include clubs and organizations like chapters of the Society for Women Engineers or Engineers Without Borders. It may also be worth testing for mediation effects through structural equation modeling to determine if the gender composition of engineering programs affects outcomes specifically for women in engineering. However, previous analyses have shown that students' interactions with those of diverse backgrounds do relate to better leadership outcomes for engineering students [32]; it would not be surprising to continue observing this effect.

Conclusions and Implications

This analysis indicates that increases in an engineering identity positively impact a number of leadership dimensions included in our leadership self-efficacy construct. Perhaps most importantly in these dimensions are students' perceived growth in their leadership ability. We can construe this as a measure of confidence and confidence has been shown to predict a leader's motivation to succeed, persistence, and willingness to accept a challenge [33, 34]. Improvement in outcomes like persistence are very similar to the benefits seen from increases in engineering identity elsewhere in the engineering education literature.

These findings have further implications for engineering educators interested in further developing leadership in engineering students. Especially those interested in identifying ways that leadership can be more fully integrated with general engineering education. Specifically, by knowing that engineering identity is a potential driver for components of leadership identity, engineering educators can identify ways that leadership capabilities can be more closely tied to core topics and practices that drive engineering identity. In other words, by incorporating work known to improve engineering identity, and considered core to a traditional engineering education, leadership focused educators can likely gain benefits in leadership outcomes.

Future Work

The work presented here represents analysis of one component of one of two national data sets used in a larger multi-year project. The analysis of the national data set has shown a conflict with one hypothesis guiding much of this larger project – that an engineering identity conflicts with development of leadership outcomes consistent with a leadership identity. Through the efforts of our ongoing qualitative work, this relationship is being explored further to understand the deeper relationship between engineering identity and leadership identity.

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APPENDIX

Summary Statistics for the Data Set

Table 2 - Descriptive Statistics for Continuous Variables

	Mean	Std. Dev.	Min	Max
Student-level variables				
CSS leadership construct score	50.836	8.777	23.97	65.05
CSS engineering identity factor score	4.761	1.265	1.82	7.28
Frequency, studied with other students	2.656	0.537	1.00	3.00
Frequency, worked on professor's research project	1.632	0.752	1.00	3.00
CSS faculty interaction construct score	4.979	0.837	2.73	6.70
TFS engineering identity factor score	4.595	1.192	1.80	7.19
High school GPA	7.318	0.890	3.00	8.00
SAT score or ACT equivalent (scaled by 100)	13.293	1.484	8.80	16.00
TFS academic self-concept construct score	5.585	0.799	3.25	7.00
TFS social self-concept construct score	5.035	0.855	2.43	7.04
Likelihood, change major field	2.445	0.790	1.00	4.00
Importance, reason attended: to be able to get a better job	2.860	0.422	1.00	3.00
Institution-level variables				
Percent women in engineering (per 10%)	2.456	0.570	0.00	4.10
Percent URM students in engineering (log, 10%)	-0.273	0.621	-1.93	2.24
Full time equivalent enrollment (log)	8.763	0.678	6.66	10.36
Average SAT score of first-year class (scaled by 100)	12.915	1.333	8.70	15.00

Table 3 - Descriptive Statistics for Categorical Variables

	Proportion
Student-level variables	
Participated in an internship program	71.35%
Participated in student clubs/groups	84.84%
Participated in an undergraduate research program	39.72%
Female	27.34%
Underrepresented racial/ethnic minority student	13.25%
Either parent employed in engineering	20.31%
First-generation student	16.56%
Planned engineering career at college entry	76.57%
Family income	
Low income (<$25,000)	6.24%
Middle-low income ($25,000-$49,999)	9.17%
Middle income ($50,000-$99,999)	30.83%
Middle-high income ($100,000-$199,999)	34.77%
High income ($200,000 or higher)	18.98%
Initial major	
Aeronautical or Astronautical Engineering	4.47%
Civil Engineering	16.88%
Chemical Engineering	15.80%
Computer Engineering	9.04%
Electrical or Electronic Engineering	10.57%
Industrial Engineering	1.53%
Mechanical Engineering	29.19%
Other Engineering	12.53%
Highest degree aspired at college entry	
Less than a bachelor's	0.47%
Bachelor's degree	16.86%
Master's degree	51.87%
Doctoral degree	23.19%
Medical degree	6.24%
Law degree	1.38%
Institution-level variables	
Four-year college (ref: research university)	50.65%
Control: private (ref: public)	85.08%