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Understanding the Perceived Impact of Engineers' Leadership Experiences in College

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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. Greater numbers of engineering educators are recognizing this need and establishing engineering leadership certificates and minors through centers at universities throughout the country. While the implementation of these offerings is a step forward, most programs tend to focus on leadership as a set of skills or experiences bolted onto a traditional engineering education with limited formal evidence of the impact these experiences have on student development.

The purpose of this study is to test the effect of experiences engineering students have in leadership roles on their perceived gains in leadership skills, using a national dataset. The framework guiding this study is a model for engineering leadership identity constructed from Lave and Wenger's communities of practice model and Komives et al.'s model for leadership identity development (LID) which recognizes that the engineering formation process is, at its core, an identity development process. Engineering leadership is theorized to develop from peripheral participation in engineering communities of practice in ways that promote students' leadership development. Specifically, undertaking leadership roles in curricular and co-curricular engineering activities develops students' sense of engineering leadership identity, which results in their recognition of gains in different leadership skills.

The data for this study come from the 2015 administration of the National Survey of Student Engagement (NSSE), overseen by the Center for Postsecondary Research at Indiana University. The NSSE is administered to a random sample of first- and fourth-year students, and focuses on curricular and co-curricular student engagement. In 2015, NSSE included a pilot module to assess leadership experiences at 21 participating institutions. The overall sample includes 2607 students who held a leadership role, among whom are 90 engineering students. The dependent variables for this study are a set of eight items prompting students to indicate the extent to which participation in a leadership role contributed to development of different leadership skills. This study employs multiple regression to test the relationships among leadership related experiences and eight leadership skill outcomes for engineering students.

Significant results across the eight regression models paint a complex portrait regarding factors that affect gains in leadership skills for engineering students. For example, receiving formal leadership training is a significant positive predictor of only three of the leadership outcomes explored in this work: thinking critically and analytically, working effectively with others, and continuing leadership after college. These results can be utilized by educators engaged in Engineering Leadership education to tailor their program experiences and better achieve the desired educational outcomes.

Introduction

In a seminal work in the area of engineering design, Bucciarelli [1] revealed that design is a social process that only exists in a collective sense. In order to lead this social process and ensure that the capabilities of an expanded engineering workforce are successfully harnessed, new engineers must be more than just technical experts: they must also be technical leaders [2, 3]. This need provides the impetus for developing greater levels of engineering leadership in undergraduate students.

The need for engineers who can lead is gaining ever greater recognition by engineering educators, as evident by the development of an increasing number of engineering leadership development programs [4] and continued expansion of ASEE's Engineering Leadership Development Division. Given the interest in developing engineers who are prepared to lead, a key question is understanding how effective these programs are in cultivating the desired leadership outcomes.

In this work, we explore this question using a national dataset that provided the opportunity to explore students' self-reported skill development in key areas of leadership. This study utilizes the responses of 90 engineering students to better understand what experiences made the greatest impact. These experiences are also present in the literature on leadership development [5], and are common practice in existing engineering leadership programs [4, 6, 7].

Leadership and Engineering

Leadership has been studied for almost as long as human history, with the ancient works of the Greeks, Romans, and Chinese all exploring the topic [8]. Despite this long history and an ever growing research base [9], there is little evidence of a commonly accepted definition of the topic. This sentiment has led to the conclusion stated in *The Nature of Leadership* that "given the complex nature of leadership, a specific and widely accepted definition of leadership does not exist and might never be found" [10]. What this lack of definability likely means is leadership is multifaceted, needing to be defined and bounded within the context in which the process is being examined. As such, the literature on leadership within particular domains (like engineering) tends to reflect consensus, in spite of a lack of broader consensus across the field of leadership.

While definitions of leadership vary widely, they can largely be placed into one of two groups. The first group, include those definitions that look at leadership as a set of traits that the most successful leaders have, the trait theories [11]. These theories of leadership have largely fallen out of favor in western cultures over the past one – two generations [12]. During this time, behavioral theories have gained prominence. These theories hold that the behaviors of leaders impact their effectiveness and can typically be combined into groups similar to those of Katz and Kahn [13], who categorized behaviors as task oriented, relationship oriented, and participative leadership. Training for behaviors in one or more of these categories is often the focus of engineering leadership programs.

Understanding leadership within the engineering context is critical not only for the reasons stated earlier, but also due to the resistance of engineers to leadership, likely a result of perceiving leadership not as engineering knowledge or work (Reeve, Rottmann, & Sacks, 2015). Existing engineering leadership programs tend to define engineering leadership in relation to the technical knowledge needed to enter the field, typically describing engineering leadership as the leverage of technical expertise to influence and inspire colleagues toward solving important problems [14-17]. These programs then employ a variety of trainings and experiential activities to foster leadership development in engineering undergraduates.

Leadership Development

Engineering leadership programs often define leadership learning outcomes in terms of specified leadership skills that will be required of new professionals entering the field, yet often fail to couch programs within the context of a broader leadership theory [4, 18]. The bulk of the leadership development literature focuses on identifying formal practices and informal experiences that contribute to leadership development to evaluate and improve existing programs and to provide guidance for the development of new programs [19-22].

In this work, we are interested in beginning to understand the relationship between identity and leadership in undergraduate students. To do this, we apply Astin's [23] model for assessing the impact of college on student development. Commonly referred to as the I-E-O model (referring to inputs, environments/experiences, and outcomes). The I-E-O framework provides several perceived outcomes of academic and cognitive development that reflect leadership identity. While the focus of leadership outcomes does not entirely align with the I-E-O framework, student cognitive growth (e.g. critical thinking or job-related skill development), is central to leadership identity. In fact, all indicators of leadership quality analyzed in this research may be found in both Astin's [23] *Self-Reported Cognitive Growth* indicators and Lave and Wenger's Communities of Practice model [24].

This focus brings the study to more recent work to examine the role of identity in the development of leadership skills. A wide variety of researchers have examined the role of identity in development of leadership [25-28]. As summarized by Ibarra, et al. [29], work in this area generally focuses on the development of a leadership identity for working professionals, especially as prompted by position or career transitions. This is true even for their proposed extension of work in this area, which posits that leadership development is an identity transition process focused on self-change using a process of separation, transition and incorporation [29]. For the purposes of this work, our interest rests in the identity transition of college students, not working professionals. As such, the model of Engineering Leadership Identity Development in this work leverages the Leadership Identity Development (LID) model [30].

Many of the existing engineering leadership models are tied to educational or training interventions intended to develop students' leadership skills, which is why it is somewhat alarming that authors of two recent meta-analyses, spanning the last 34 years of the leadership development literature, concluded that these experiences are not consistently effective [12, 31]. These findings indicated that, while formal courses were found to be effective at developing specific skills as measured by pre and post intervention testing, it was unclear how effective these skills are when deployed by the subject of the training. This suggests a problem with skill retention and transfer for formal development experiences and the need for a more integrated approach.

As such, our use of the I-E-O model is intended to isolate the effect of specific college experiences on outcomes of interest by organizing and accounting for confounding influences that also can affect those outcomes. Specifically, these influences include experiences prior to college and student demographic characteristics, as well as aspects of the college environment and other experiences during college that also affect development. The review of the literature on factors that affect leadership development, presented next, is organized according to this framework.

Demographics and leadership

Students arrive to college with a variety of characteristics and experiences shown to influence their leadership development before college. Gender in particular has been shown to affect leadership attributes in a number of ways and is a source of extensive research [32], even if findings in this areas are not entirely uniform [33]. For example, male leaders report greater self-efficacy, while female leaders demonstrate higher competency, yet women's performance on conceptual assessments may vary based on the perceived intent of an assessment [34]. And, related to this study, one aspect that seems to more strongly influence women than their male counterparts is classroom and instructor warmth [35].

Race and ethnicity differentially affect students' leadership development as well. For example, like female students, the classroom climate quality may have an especially strong influence on minority students. The consequences of difficult experiences may be amplified for minority students, who typically experience higher attrition rates. Fortunately, support systems are especially valuable and effective for these students [36, 37]. Students of Color are also less likely to know an engineer prior to college [38], and the engineering leaders they will meet as they prepare to become practicing engineers will mostly be White and male. This reality has led to the promotion of increased focus on community engagement for engineers [39].

First generation students, who are disproportionally from underrepresented racial and ethnic minority backgrounds, will be even less likely to know an engineer before college. Fortunately, leadership opportunities for these students can increase their familiarity with academic culture, raising their academic aspirations [40]. Finally, interactions with influential mentors and advisors, which contribute to leadership identity development [30], have demonstrated mixed effects on first-generation students, in terms of significance [40].

College experience and leadership

After considering student inputs, the institutional environment and student experiences in college also significantly influence student outcomes, like leadership development. Further, the entire field of engineering education is predicated on the idea that engineering undergraduates have different experiences than their peers during college. Inhibiting engineers' leadership development, however, is the fact that success in an undergraduate engineering program tends to be measured through demonstration of success in a highly technical field, resulting in graduates who highly value technical competence over other areas [41].

In spite of this, Knight and Novoselich [33] found that curricular emphases on engineering thinking, professional skills, and systems thinking were most significant in influencing engineering undergraduates' leadership development. In fact, many classroom experiences have been shown to contribute to leadership development, both for engineers specifically and for college students in general. Effective peer collaboration is an important element in leadership identity development [30, 42], and research has shown collaboration at work to be a core component of leadership in the engineering profession [43]. Collaboration may also be important for broadening participation in engineering; students in Komives et al.'s [30] study who worked closely with peers from different backgrounds developed empathy and more highly valued the involvement of students from marginalized groups. Cooperative class environments are also perceived as "warmer" by students, which contributes to positive outcomes in a host of learning outcomes (like persistence in STEM after graduation), especially for female engineers [35, 39]. Finally, reflective learning can be an important contributor to leadership development as it leads to interdependence with others [39, 42]; connecting leadership experiences to coursework can deliberately engage student in reflective learning on their experiences.

The curriculum is only one of two aspects of students' college experience that influence their devleopment. The co-curriculum, such as participation in Greek life, athletics, internships, on-campus employment, or undergraduate research, also contributes to students' leadership development [44, 45]. Although one study found the co-curriculum to have limited utility in developing leadership [33], much of the literature finds strong relationships between experiences outside of the classroom and leadership development. For example, one study of engineers identified 22 categories of co-curricular activities that promoted leadership development and increased engagement [46]. Knight and Novoselich's [33] findings are also limited in that they did not measure qualities of co-curricular experiences that may increase the efficacy of these experiences in contributing to leadership development: Astin [23] specifically argued that the overall impact of college is comprised of a combination of "time of exposure" (e.g. 1st to 4th year) and "intensity of exposure" (e.g. level of leadership commitment) to the college experience, showing time and intensity of leadership-related experiences during college affect leadership development (pp. 26-28). Further, if experience in leadership roles is thought to be of any value—as Astin's idea of *time of exposure* might suggest—co-curricular activities are an ideal venue for developing leadership qualities. In fact, Haber [47] suggests that co-curricular involvement, holding formal leadership roles, and training are essential to leadership development. The nature of the co-curricular experience is also important, as those with a training and modelling component guide students on good leadership qualities. Astin [23] found that mentor or advisor interactions (often present during co-curricular activities) were central to leadership development, a finding echoed in other research on leadership development [48, 49]. A final contributing factor is "meaningful involvment," where students felt they contributed to the group in a meaningful way, across contexts that vary from athletics to community service [49].

Leadership Outcomes for Engineering Students

As discussed previously, the literature on what defines leadership is vast and often in disagreement. For this work, we examine leadership as a set of behavioral learning outcomes for engineering students. Several of these behaviors are developed as a result of professional preparation in engineering itself. As effective engineering leaders need to demonstrate effectiveness as engineers first, four skills needed to be an effective engineer are technical competence, interpersonal skills, work ethic, and moral standards [41]. One problem, though, is that because successful engineering students demonstrate proficiency in a highly technical field, they consequently also tend to hold a high value for technical competence. Effective engineers, then, may not value the development of skills needed for success as leaders.

The Communities of Practice model then points to other important leadership outcomes that result from participation in, and subsequent mastery of, a particular practice. While research indicates that some successful engineering leaders demonstrate lower levels of technical mastery than the followers surrounding them [41], the model suggests that recognized mastery, not charisma, is the currency through which leaders are validated in many settings [50], including engineering [43]. This mastery requires the ability to think critically and analytically in applied and often very complex scenarios. Success within these communities, as defined by core membership recognition—inherently a leadership role—also requires demonstration of job-related skills, in addition to purely conceptual mastery [51].

In addition to leadership behaviors identified as necessary for success in engineering practice, the literature outlines several behaviors that engineering leaders must also demonstrate to serve as effective leaders in engineering communities of practice. Effective peer collaboration is a core requirement for leaders in Komives et al.'s [30] research on leadership development in college students [42]. And, the benefits of collaborative environment don't stop in college, as studies of leadership in the professions find collaboration to be a core component of effective leadership [17, 52]. Collaborating with people of different backgrounds in particular helped leaders value empathy and "...involv[e] others who may be marginalized in groups", which could be seen as a precursor to interdependence [30].

A skill essential to both peer collaboration and working with diverse others is effective communication. Within the context of the LID model, leadership growth to interdependence that is tied to identity is the most advanced measure of growth. In this stage, a person understands leadership roles as essential to project success and is willing and able to engage with such roles going forward. Some influences on leadership identification and success, hence the negotiation process, are their creative contributions, complex thought, commitment, and ability to empower teammates [53].

Using the combined literature of leadership development and leadership development in college students discussed above, this study utilized the data collected in an existing national survey of college students to identify 30 potential contributors to the development of leadership. Appendix A contains the full list of the predictors explored in this work. To understand the development of leadership, we use eight behaviors drawn from the literature of leadership outcomes.

Methods

The overall goal of this study was to understand the effect of different leadership experiences on engineering students' perceived gains in specific leadership skills. To achieve this purpose, this study employed multiple regression analysis on a national dataset to identify important predictors of leadership outcomes. Multiple models are used, predicting different leadership skill outcomes, to explore patterns among influential experiences in terms of the consistency with which they predict multiple outcomes.

Data Source

Data for this study were taken from the 2015 administration of the National Survey of Student engagement (NSSE) from over 560 colleges and universities nationwide [54]. The NSSE is an annual, national survey of first- and fourth-year college students to measure their engagement in college and their participation in experiences institutionally purposed to foster that engagement. The sample drawn for this study were student responses from a subset of 21 institutions who were selected to participate in a pilot module examining leadership development experiences. Approximately 2607 student leaders from these institutions participated in the survey, with just over one hundred reporting an engineering major. The pilot module was then administered to students who indicated that they had experiences defined by NSSE as a leadership experience. For this study, we restricted our sample to engineering majors who were administered the leadership module. This provided a total of 90 responses, following listwise deletion of incomplete responses. Further analysis comparing these students' experiences with their peers in other majors is examined in forthcoming work. The pilot leadership module explored leadership-related experiences and the leadership skills that students developed during these experiences; these skills are listed in Table 1.

Table 1 - Leadership Outcomes Examined

Leadership Outcome	Abbreviation
Understanding concepts in my major	UCM
Speaking clearly and effectively	SCE
Thinking critically and analytically	TCA
Solving complex, real-world problems	SRP
Acquiring job- or work-related skills	AJS
Working effectively with others	WEO
Understanding people of other backgrounds (economic, racial/ethnic, political, religious, nationality, etc.)	UPB
Becoming a leader in life outside of college	BLO

Analysis Assumptions

Before beginning regression analyses of eight leadership, the key assumptions for regression were checked. Indicators were checked for residual normality and independence, multi-collinearity, power, and model specification adequacy, with all checks passing. In addition, power analysis was run and found power for all models exceeding $\beta = .999$, at $\alpha = .05$. Finally, model specification adequacy was examined by comparing the full regression model with two models that did not include a highly influential independent variable and a minimally influential independent variable. Comparison of the standardized beta for all three models showed that the full regression model was not over-specified [55].

Analysis Techniques

An ordinary least-squares regression model was built to predict each of the eight NSSE leadership outcomes shown in Table 1 using the 31 independent variables shown in Appendix A. Analysis was run with survey weights developed by NSSE to improve the representativeness of the sample to the population from which it was drawn, all students at the NSSE participating institutions. NSSE administers its surveys to a sample of first- and fourth-year students at every participating institution, and then computes a survey weight to ensure generalizability of analyses to the institutional populations from which this sample was drawn.

Independent variables were selected as important contributors to leadership development based on the literature guiding this study, and were organized for building the regression models according to Astin's [23] I-E-O framework. Three variables were included as inputs, 18 were control variables related to the college environment, and 10 variables specifically measured aspects of leadership experiences of interest to this study. The eight outcomes presented in Table 1 were then modeled as separate dependent variables with the same set of predictors used to model each of the eight outcomes.

Demographics included gender, minority status, and first-generation (to college) status. College-related experiences included major, class level, GPA, Greek system status, armed service status, internship status, cohort community, research with faculty, service learning, co-curricular weekly hours, on-campus job weekly hours, off-campus job weekly hours, service weekly hours, peer teaching, project work, diverse discussion, and reflective learning. Leadership-related experiences included length of time in leadership role, hours per week spent in leadership role, extent to which the leadership experience related to the student's academic program, receiving formal leadership training, size of organization led, interaction with mentor or advisor, receipt of feedback from advisor, inclusion of experiences in coursework, interaction with peers of different backgrounds, and relational vs. positional views of leadership.

Results

All eight models were significant ($\alpha < 0.05$), and 20 of the 30 predictors were significant for one or more of the outcomes. Table 2 provides a summary of these results and each is explored in more detail in the following sections.

Understanding concepts within major (UCM)

A linear combination of the 30 predictors were found to be significantly related to UCM ($p < 0.001$, $R^2_{adj} = 0.693$). Significant regressors (listed in order of decreasing standardized beta) included the extent leadership experience associated with academic program ($p < 0.001$), participation in internship ($p < 0.05$), and duration of leadership activity ($p < 0.05$). The standardized beta for the independent variable that reflected association with academic program (0.598) was substantially higher than all others.

Speaking clearly and effectively (SCE)

A linear combination of the 30 predictors were found to be significantly related to speaking clearly and effectively (SCE) ($p < 0.001$, $R^2_{adj} = 0.528$). Significant regressors included interacting with people from a different backgrounds ($p < 0.05$), interacting with an advisor ($p < 0.05$), and first generation status ($p < 0.05$). The standardized beta for the independent variables reflected interaction with others (an advisor and other backgrounds, 0.301 and 0.310, respectively) was substantially higher than first generation status (0.186).

Thinking critically and analytically (TCA)

A linear combination of the 30 predictors were found to be significantly related to TCA ($p < 0.001$, $R^2_{adj} = 0.698$). Significant regressors included interaction with an advisor during activity ($p < 0.01$), duration of leadership activity ($p < 0.001$), interacting with people from a different background during leadership ($p < 0.01$), participation in a learning community ($p < 0.01$), fraternity or sorority participation ($p < 0.01$), receiving feedback from an advisor during leadership experience ($p < 0.05$), explained course material to students ($p < 0.05$), and received leadership training ($p < 0.05$). The standardized beta for the independent variable that reflected interaction with an advisor (0.332) was substantially higher than other factors.

Table 2 - Summary of Significant Regressors

	UCM	SCE	TCA	SRP	AJS	WEO	UPB	BLO
Demographics								
Institution-reported: Sex	.120	-.055	.071	.137	-.125	-.127	-.038	-.198 *
Recode for 1st gen to college (0) or not (1)	-.108	-.186 *	-.085	-.153	.011	-.006	-.279 **	-.213 **
College Environment								
Are you a member of a social fraternity or sorority?	-.060	.034	-.233 **	-.109	-.059	.011	-.043	.105
Internship, co-op, field experience, student teaching, or clinical placement	.190 *	-.112	-.075	.024	.050	-.047	.091	.007
Learning community or some other formal program where groups of students take two or more classes together	.056	.057	.239 **	.127	-.056	.030	-.016	-.126
About how many of your courses at this institution have included a community-based project (service-learning)?	.065	-.010	-.208 **	-.037	.073	-.217 *	.064	-.081
Hours per week: Participating in co-curricular activities (organizations, campus publications, student government, fraternity or sorority, intercollegiate or intramural sports, etc.)	-.090	.056	.112	.036	-.094	.172	.009	.218 *
Explained course material to one or more students	-.098	-.094	.194 **	.089	.070	.041	-.112	-.134
Worked with other students on course projects or assignments	.045	-.122	-.175	-.093	-.255 *	-.206	-.111	-.130
Discussions with Diverse Others	.001	.078	-.102	.036	.242 *	.026	.113	.261 **
Reflective and Integrative Learning	-.046	.236	.105	.127	.262	.279 *	.099	.115
Leadership Experience								
Length of leadership role	-.188 *	-.071	-.253 ***	-.178	.036	-.165	-.176	-.027
To what extent were the activities of this role associated with your academic program?	.598 ***	-.071	.138	.393 ***	-.056	-.304 *	-.168	-.220 *
Received formal leadership training	-.028	.117	.173 *	.087	.197	.259 *	.111	.232 *
Number of people lead in role	-.060	-.083	-.048	-.072	-.036	-.263 *	-.117	-.227 *
Interact with a staff or faculty advisor for this activity	-.003	.301 *	.332 **	.066	.237	.102	-.038	.321 *
Receive feedback on your performance from an advisor	.045	.026	.211 *	.324 *	-.021	.078	-.036	.080
Include experiences from this role in your coursework or course discussions	.123	.053	.027	.166	.474 **	.452 **	.440 **	.682 ***
Interact with people from a background different than your own (social, racial/ethnic, religious, etc.)	.127	.310 *	.250 **	-.001	-.068	.322 **	.484 ***	-.025
Formal leadership role	-.053	-.156	-.082	-.162	-.014	-.140	-.024	-.298 **

Solving complex and real-world problems (SRP)
A linear combination of the 30 predictors were found to be significantly related to SRP ($p < 0.001$, $R^2_{adj} = 0.583$) Significant regressors included extent to which leadership experience associated with academic program ($p < 0.001$) and receiving feedback from an advisor during leadership experience ($p < 0.05$). The standardized beta for the independent variables were both high (0.393 and 0.324, respectively).

Job- or work-related skills (AJS)
A linear combination of the 30 predictors were found to be significantly related to AJS ($p < 0.001$, $R^2_{adj} = 0.475$). Significant regressors included including leadership experiences in coursework ($p < 0.01$), working with others on course projects ($p < 0.05$), and discussions with diverse others ($p < 0.05$). The standardized beta magnitude for including experiences in coursework (0.474) was substantially higher than the other significant indicators (-0.255 and 0.242, respectively).

Working effectively with others (WEO)
A linear combination of the 30 predictors were found to be significantly related to WEO ($p < 0.001$, $R^2_{adj} = 0.541$). Significant regressors were include leadership experience in coursework ($p < 0.01$), interact with people from a different background during leadership ($p<.01$), leadership association with program ($p < 0.05$), reflective learning ($p < 0.05$), leadership group size ($p < 0.05$), leadership training ($p<.05$), and service learning ($p < 0.05$). The standardized beta for the independent variables include leadership experience in coursework, interact with people from a different background during leadership, and leadership association with program were higher in magnitude (0.452, 0.322 and -0.304, respectively) than other significant predictors.

Understanding people of different backgrounds (UPB)
A linear combination of the 30 predictors were found to be significantly related to UPB ($p < 0.001$, $R^2_{adj} = 0.565$). Significant regressors included interacting with people from a different background during leadership ($p < 0.001$), include leadership experiences in coursework ($p < 0.01$), and first generation status ($p < 0.01$). The standardized beta for including experiences in coursework (0.440) and interact with people from a different background during leadership (0.484) were substantially higher than first generation to college status (-0.279).

Becoming a leader in life outside of college (BLO)
A linear combination of the 30 predictors were found to be significantly related to BLO ($p < 0.001$, $R^2_{adj} = 0.672$). Significant regressors were include leadership experiences in coursework ($p < 0.001$), leadership interaction with advisor ($p < 0.05$), relational vs. positional leadership ($p < 0.01$), discussions with diverse others ($p < 0.01$), leadership training ($p < 0.05$), quantity of people led ($p < 0.05$), leadership role association with program ($p < 0.05$), weekly hours participating in co-curricular activities ($p < 0.05$), first generation to go to college ($p < 0.01$), and being male ($p < 0.05$). The standardized beta for including experiences in coursework (0.682) was substantially higher than all other significant indicators.

Conclusions and Implications for Engineering Leadership Educators
Overall, several college experiences, including those associated with a leadership role, significantly predicted engineering students' perceptions of their gains in the eight leadership

outcomes measured here. The experiences that made the most substantial positive impact on these outcomes include the inclusion of leadership experiences in coursework or course discussions and interacting with people from a background different than your own. Both of these predictors had a significant positive impact on four of the outcomes measured and did not negatively impact a single outcome in a significant way. The finding regarding the inclusion of leadership experiences in coursework supports Knight and Novoselich's [33] conclusion regarding the central role the curriculum could play in fostering leadership development for engineering undergraduates. In both cases, these findings reflect elements that engineering educators can actively promote in their engineering leadership programs, although neither is likely to be considered an easy action to take. Still, this is particularly encouraging since it shows the type of leadership experiences that seem to motivate students to continue their leadership experiences past college. Integration of leadership into coursework may improve students' appreciation of the value and relevance of leadership experiences within the context of their professional community.

Two other experiences had a similar positive impact on three of the outcome measures investigated. These were receiving formal leadership training and interacting with a faculty or staff advisor in their leadership role. These findings encouragingly reinforce key activities of many engineering leadership programs. Students who reported that their leadership experience involved more interaction with mentors and advisors or people of different backgrounds found that their verbal skills were improved by these interactions. Engineering students are widely characterized as possessing poor social and communication skills, and it may be that increased interactions help develop more effective communication techniques. In addition, these students also reported greater intention to act as a leader after college and higher gains in critical thinking skills. The potency of modelling as a form of guidance may enable students to navigate the world around them with increasingly complex cognition.

After these, as shown in Table 2, and indicated in the results above, there are a number of items that positively influenced one or two of the measured outcomes. Those that have a net positive impact (those that positively influence at least one more outcome than they negatively impact) include receiving feedback from an advisor, engaging in discussions with diverse others, internships or similar experiences, engaging in a learning community, spending more hours engaged in co-curricular activities, explaining course materials to other students, and reflective and integrative learning. Those engaged in designing engineering leadership programs are encouraged to consider utilizing each of these in their programs.

Then there are several experiences that have a significant net negative impact on the outcome measures. This set of experiences surprisingly includes leading larger numbers of people, serving in a leadership position for a greater number of semesters, having more courses with a service learning component, being a member of a Greek organization, and working with other students on course projects. Given the counter-intuitive nature of most of these, they warrant further investigation as discussed in future work below. Granted, as our dependent variable measured perception of growth, rather than actual magnitude of growth, it might be these students simply did not need to grow in their leadership skills as much as their peers. In addition, student demographics of being a first generation student or a female student had a net negative impact. Those involved in engineering leadership are encouraged to consider how to improve the support mechanisms for these students to eliminate these disparities.

Future Work - Implications for Developing an Engineering Leadership Identity
This work represents an important step to forwarding our understanding of the types of experiences that truly impact student's perceptions of their leadership gains. As such, it contributes to the larger effort of this project to understand how engineering students can develop a leadership identity in the context of an engineering program that develops their engineering identity. Our conceptual model for this development is presented in Figure 1.

This study furthers this model is several important ways. First, it indicates that engineering students are gaining many defined leadership opportunities during their undergraduate studies. Next, it highlights the disconnect that engineering students see between leadership roles and engineering. Specifically, this study found that engineering students found less value in their leadership experiences if they were not aligned with their course work. Something that may indicate the often highlighted conflict between the technical and professional skills in engineering education. Finally, this work adds additional credence to the importance of leadership skills training.

As the larger project moves into its next phase, both comparing these results with those of students in other fields, and with a different national data set, we will be able to further investigate constructs of both leadership identity and engineering identity and explore how they interact. In addition, the qualitative phase of the work will enable investigation of some of the counter intuitive findings outlined above.

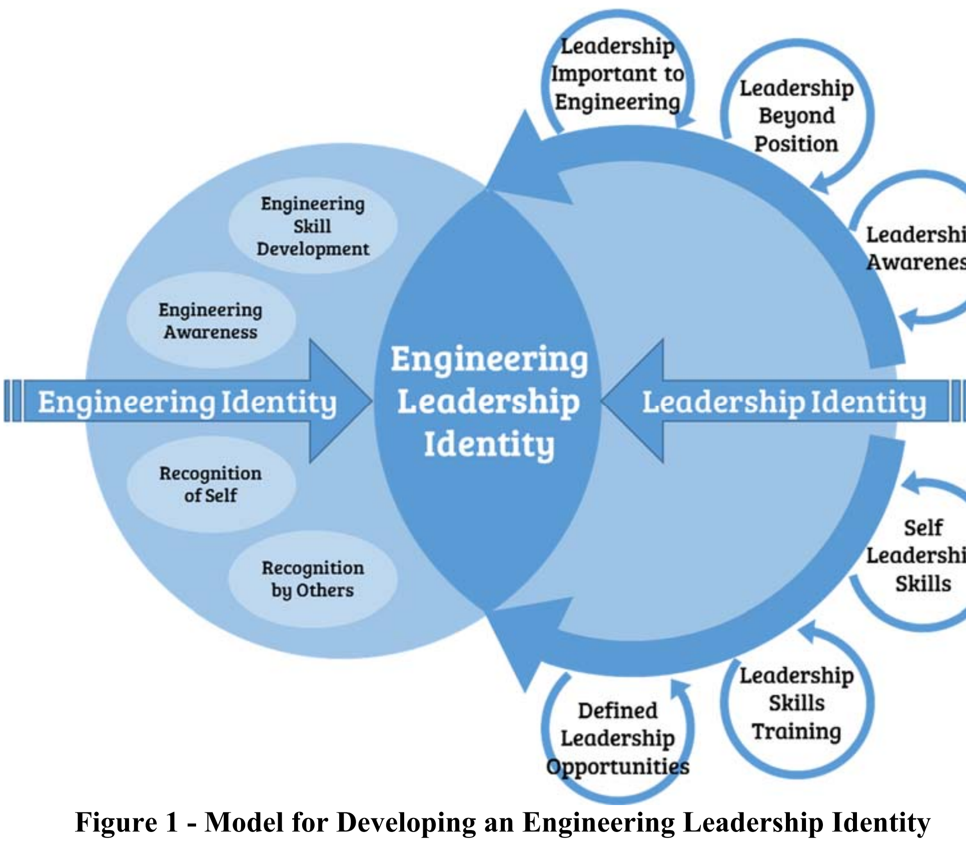

Figure 1 - Model for Developing an Engineering Leadership Identity

Concerns and Limitations

When interpreting this work, several limitations need to be highlighted with regard to the generalizability of these findings to engineering undergraduates as a whole. First, this analysis is a secondary analysis of an existing dataset; the NSSE is designed to quantify student engagement and high-impact practices during the college experience, and the pilot was intended to examine the contributions of leadership experiences to student engagement. However, secondary data sources are often powerful resources in conducting educational research, especially when considering the level of resources necessary to collect data of this scope, and that this dataset provided many items of interest to our purpose. That said, additional items not included on the survey may also help explain change in leadership skills, though our review of the literature demonstrated the set of variables we used was robust and widely supported. Second, the dependent variable was a self-reported measure of perceived gains in leadership skills as opposed to a more direct pre/post-test longitudinal measure of gains in skills. Although self-reported gains are not generally reliable as an absolute measure, our analysis was not concerned with the magnitude of these gains but rather the relationship between variance in perceived gains and variance in the other predictors. Finally, causal relationships among the variables can only be inferred from this analysis as informed by theory and research—the independent and dependent variables were captured on the same instrument, and the relationships between them can only be assumed to be correlational.

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Appendix A – Complete List of Regressors Considered

Variable Name	Code	Description
Demographics		
Gender	0 1	Female Male
Minority	0 1	Majority Minority
First-generation status	0 1	First Generation Continuing Generation
Environment		
Class	0 1	First-Year Fourth-Year
GPA		Continuous gpa scale, range 0-4
Fraternity or sorority participation Athlete Veteran	0 1	No Yes
Participation in internship Participation in a learning community Research	1 2 3 4	Have not decided Do not plan to do Plan to do Done or in progress
About how many of your courses at this institution have included a community-based project (service-learning)?		Continuous, number of courses
Hours per week: Participating in co-curricular activities (organizations, campus publications, student government, fraternity or sorority, intercollegiate or intramural sports, etc.)		Continuous, hours per week
Hours per week: Working for pay ON CAMPUS		Continuous, hours per week
Hours per week: Working for pay OFF CAMPUS		Continuous, hours per week
Service learning	1 2 3 4	None Some Most All
Explained course material to students Working with others on course project	1 2 3 4	Never Sometimes Often Very often
Discussions with Diverse Others		Continuous, summary variable
Reflective learning		Continuous, summary variable

Variable Name	Code	Description
Leadership Experience		
Duration of leadership activity		Continuous, number of semesters served in leadership
Hours per week: Leadership		Continuous, hours per week
Extent leadership experience associated with academic program	1 2 3 4	Very little Some Quite a bit Very much
Leadership training	0 1	No Yes
Leadership group size		Continuous
Interacting with an advisor during activity	1 2 3 4	Never Sometimes Often Very often
Receiving feedback from an advisor during leadership experience		
Include experiences from this role in your coursework or course discussions		
Interacting with people from a different background during activity		
Relational vs positional leadership	1 2	Positional leader Relational leader
Leadership Qualities		
Understand concepts in major	1 2 3 4	Very little Some Quite a bit Very much
Speaking clearly and effectively		
Thinking critically and analytically		
Solve complex and real-world problems		
Acquiring job- or work-relatecd skills		
Work effectively with others		
Understand people of different backgrounds		
Post-college leadership intent		