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Building Leaders: A National Examination of the Leadership Capacities within Engineering Undergraduate Students*

CLINTON M. STEPHENS
Iowa State University, College of Engineering and Carrie Chapman Catt Center for Women and Politics, 309 Catt Hall, Ames, IA 50011, USA. E-mail: cmsteph@iastate.edu

DAVID M. ROSCH
University of Illinois at Urbana-Champaign, Agricultural Education Program, 905 South Goodwin Ave., Urbana, IL 61801, USA. E-mail: dmrosch@illinois.edu

The demand for leadership capacity in engineering graduates is growing. However, little research has been done to examine the current state of leadership education of engineering students. Using a college experience framework, we tested how engineering students' leadership-oriented experiences and outcomes differ from non-engineering students. This study examined a national representative sample of students (N = 90,444) encompassing 101 higher education institutions. The results suggest that engineering students are less involved in group experiences in high school, but do not differ from comparable peers in self-reported leadership capacity coming to college. The involvement gap continues throughout their higher education. While their self-reported leadership capacity remains similar to comparable non-engineering students, the results suggest their ability to interact on diverse teams remains depressed. This study has significant implications for the processes engineering educators utilize to support their students in building working relationships and successful teams.

Keywords: leadership; SCM; regression; CEM

1. Introduction

An increasing number of colleges of engineering are now striving to educate students on not only the technical skills necessary for professional success, but also the leadership skills required to effectively serve in the modern engineering industry. The mission statements of many engineering schools include commitments to educating future leaders within the profession [1, 2]. Several leading accreditation and association bodies have challenged engineering schools to increase the number of leadership education components within their curriculum [3–5]. A number of institutions have responded to the challenge by developing new curricula. A 2009 study detailed explicit leadership education programs that multiple engineering schools had established [6].

Moreover, in engineering industries there is emerging recognition that leadership skills in employees are not just desirable but necessary [7–9]. The global environment makes technical skills among engineers necessary but insufficient for engineering firms to maintain their competitiveness [7, 10]. Students who possess a combination of leadership skill and technical expertise are well positioned for greater job placement and career advancement as evidenced by the engineering firms' desires for employees with such skills [11]. However, while a clear and documented need for leadership skills exists, little research has been conducted examining the state of leadership development within undergraduate engineering students, especially on a national scale.

1.1 A national framework of college student leadership development

Most modern leadership constructs include "soft skills" such as communication and teamwork listed by accreditation agencies as important to include in engineering education [12]. A recent study of campus-wide leadership programs revealed a prevalence of programs founded upon a "post-industrial" model of leadership practice [13], where emphasis is placed on a leader's ability to create collaborative relationships, align groups around a common purpose, and adhere to community-oriented ethical standards of behavior [14]. In contrast, an "industrial" model emphasizes group control and hierarchical command structures more common to leadership styles that are becoming less relevant in modern organizations [13]. The Social Change Model of Leadership Development (SCM), which we use as the framework for leadership within our study, is the single most popular theoretical model of leadership espoused in higher education [12]. Within the model, leaders are tasked with influencing others toward common goals;

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building strong team members who are motivated to complete tasks; working with other members interdependently; and managing team processes inclusively. Each of these capacities can be productively applied by graduates employed in contemporary engineering organizations, not only in supervision of peers but while working in teams as well.

Despite a wave of recent research on student leadership development in general [23], most efforts collapse student populations with regard to professional career goals or academic majors. Little has been done to examine the state of leadership development among an engineering-specific population. The modern challenges that contemporary engineers are tasked to solve require engineers to not only think in technical terms, but also to build and work in interdependent teams that leverage complementary skills and strengths [1, 3, 12]. Such teambuilding requires leadership capacity among both managers and engineers themselves. Given the demonstrated need for leadership skills in contemporary engineering graduates, its lack of scholarly attention is concerning.

1.2 Student leadership development in engineering

Despite an enduring research gap, in the past decade engineering faculty have begun to focus on the development of engineering students' leadership skills by initiating new curricular programs and embedding it within existing courses. A few have even developed multi-course sequences focused leadership skills in an engineering context [6, 11, 15] These efforts are supported by several articles which call for additional courses focused on teaching ethical leadership in the curriculum, especially in capstone courses and practicum experiences [16–19]. Research has shown that engineering students are lagging behind their peers in engagement experiences [20] that develop these skills, and these engaging experiences contribute to increased persistence in engineering [21]. There is a growing view among engineering faculty that leadership education in engineering is critical. But little research has been done as to how engineering students gain from such programs and whether this differs from their peers outside engineering majors.

1.3 Conceptual framework

Our research is based on Astin's [22] Input-Environment-Output (I-E-O) model of student learning. Students enter college with pre-existing characteristics, attitudes, and skills. While enrolled in higher education, they interact with the college environment—their peers and instructors, course material, and co-curricular programs, for example. Students' input characteristics combine with their experiences and result in certain educational outcomes. This framework was designed to model the varying effects of educational programs and co-curricular experiences on a diverse body of students, controlling for their incoming characteristics. For students in engineering majors, the college environment may be different when compared to students in non-engineering majors and therefore contribute to differing outputs. Outputs measured within this study include skills relevant for practicing post-industrial leadership behaviors, including critical thinking skills, the ability to take the perspective of others, as well as confidence and capacity to practice the style of leadership described within the SCM. These outputs measure many of the leadership skills identified in the literature as important for leading in the engineering industry [3, 10, 12]. Figure 1 shows a complete list of variables included within this study.

1.4 Purpose of the study

The existing literature on leadership education and the importance of leadership education for engineering students points to a need for more research in this area. Using Astin's framework we sought to answer the following research questions:

- RQ1. In what ways do engineering students differ from non-engineering students in their pre-collegiate leadership skills, leadership self efficacy, cognitive flexibility, and involvement in high school activities?
- RQ2. To what extent are there differences in engineering and non-engineering students, comparable on pre-collegiate inputs, in their degree of collegiate involvement, mentoring experiences, and participation in leadership training programs?
- RQ3. To what extent are there differences in engineering and non-engineering students, comparable on pre-collegiate inputs and collegiate experiences, in their leadership skills, leadership self-efficacy, and social-perspective taking?

2. Methods

Our research utilized data collected in spring 2009 and spring 2010 as part of the Multi-Institutional Study of Leadership (MSL), which included 101 colleges and universities selected to serve as a representative sample of undergraduate-serving colleges and universities in the United States [23], diverse in their Carnegie classifications, selectivity, control, size, and geographic location. From the students invited to participate, 115,632 students completed surveys, a 34% response rate, which is considered acceptable for institutional research

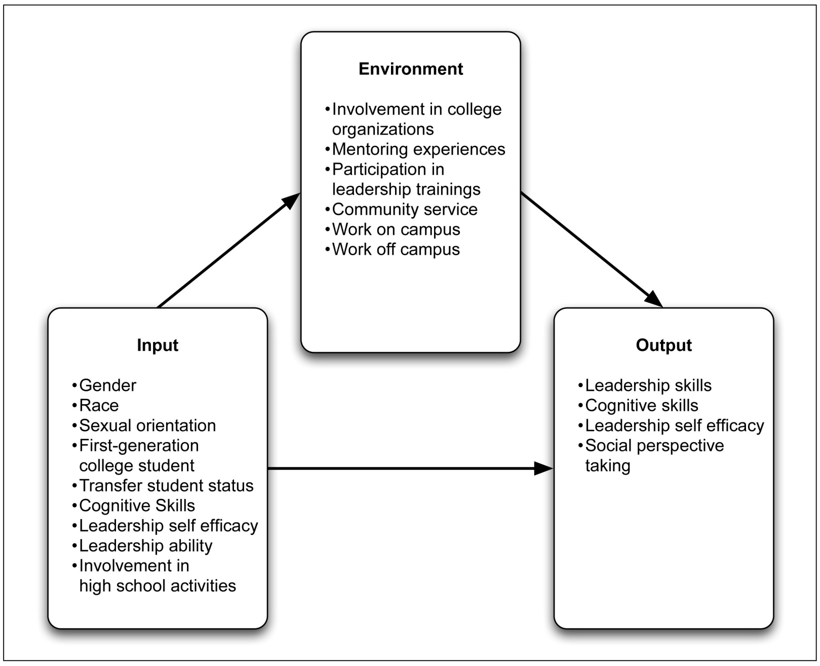

Fig. 1. Study's variables in context of Input-Environment-Output model [22].

using self-reported data [24]. A total of 4,759 students (5%) selected "Engineering" as their primary major. The students who did not select "Engineering" as a major were used as a control group in this study, hereafter referred to as non-engineering students.

2.1 Variable and measures

For demographic and identity variables, we used categorical measures of gender (GEN), race (RAC), and generation status (GenST) in college. Students were asked to report their remembered level of high-school skill and involvement in a variety of measures. Such retrospective measures has been suggested as a valid means of measuring students' perceived growth in higher education when a cross-sectional data collection design is employed [25, 26], especially when asked to assess their current skill and involvement using similar measures and scales [27]. Students' high school leadership skill (LS_{hs}) was assessed using a condensed version of the Socially Responsible Leadership Scale—Revised (SRLS) [28], which assesses leadership defined within the Social Change Model of Leadership Development [29], the most popular of leadership education currently in use within universities in the United States [13]. Scales were also included to measure Leadership Self-Efficacy (LSE_{hs}), cognitive flexibility (CF_{hs}) and social perspective-taking (SPC_{hs}), developed specifically for use within the MSL, these scales and have undergone relevant psychometric examination [23]. High school co-curricular involvement (INV_{hs}) was measured through summing responses from a series of survey items asking students to report their frequency of involvement in a variety of school and community-related organizations and initiatives such as school groups, church organizations, and service initiatives.

Collegiate experiences were collected using involvement (INV_{col}), similarly to INV_{HS}, student class year (ClassYr), transfer status (TRAN), mentoring by university faculty and staff (MENT), and participation in collegiate training programs (LeadTR). Students' leadership outcomes were measured by students' current levels of leadership skill (LS_{col}), leadership self-efficacy (LSE_{col}), and social perspective-taking (SPT_{col}). See Table 1 for a detailed list and Fig. 1 for a graphic summary of the variables included within this study.

2.2 Analytic design

2.2.1 Matching

Perhaps the biggest challenge in studying the leadership development experiences of students majoring in engineering is that the students self-select into their major and their participation in leadership development opportunities, and likely do so for unobserved factors that affect their decision. This creates a likely endogeneity with their collegiate experiences, which are the focus of this study. We controlled for endogeneity by using coarsened exact matching (CEM), a relatively new pre-processing technique [30].

In the context of this study, we utilized CEM in

Table 1. Vectors of Variables used in Empirical Analyses

Abbr.	Full name	Brief description
Demographics Vector (four variables)		
GEN	Gender†‡	Female, Male, Transgender
RAC	Race†‡	White/Caucasian, Middle Eastern, African American / Black, American Indian / Alaska Native, Asian American / Asian, Latino / Hispanic, Multi-racial, Race/ Ethnicity not included above
SexO	Sexual orientation‡	Heterosexual, bisexual/gay/lesbian/questioning, rather not say
GenST	First-generation†	First generation college student
Pre-Collegiate Vector (six variables)		
LS_{hs}	Leadership skills†	Condensed eight-question Socially Responsible Leadership scale
LSE_{hs}	Leadership self-efficacy†	Construct of four self-efficacy questions (e.g. "Organizing a group's tasks to accomplish a goal.")
CF_{hs}	Cognitive flexibility†	Construct of five cognitive flexibility questions (e.g. "Analyzing new ideas and concepts")
SPC_{hs}	Social perspective-taking†	Construct of three perspective-taking questions (e.g. "I attempted to carefully consider the perspectives of those with whom I disagreed.")
INV_{hs}	Involvement level†	Five questions on level of high school activities participation
TRAN	Transfer status†	1=Started college at current institution
Collegiate Vector (seven variables)		
ClassYr	Class year†	First-year, sophomore, junior, senior, graduate student, unclassified
INV_{col}	Involvement level†	Four questions on level of college activities participation
MENT	Mentor experiences†	Six questions on quantity and quality of mentoring experiences
LeadTR	Leadership training	Twelve questions on curricular and co-curricular training frequency
WorkOff	Work off campus	Employed at an off-campus job
WorkOn	Work on campus	Employed at an on-campus job
MCS	Monthly community service	Engage in regularly community service
Outcomes Vector (three variables)		
LS_{col}	Leadership skills	Full 71-question Socially Responsible Leadership Scale
LSE_{col}	Leadership self-efficacy	Construct of four self-efficacy questions
SPT_{col}	Social perspective-taking	Construct of eight perspective-taking questions (e.g. "Before criticizing somebody, I try to imagine how I would feel if I were in their place.")

† = Used in coarsened exact matching procedure, ‡ = Used with effects coding in regression estimation.

answering RQ2 by first matching Engineering and non-engineering participants on pre-collegiate demographic information and relevant measures. For RQ3 we matched participants using both pre-collegiate measures and college experiences. Participants' were coarsen matched by responses that scored into the top half or the bottom half of the sample's scores on each question comprising the scales. Matches were done in the pre-processing step and the resulting subset of matched observations used for further analysis with the original values from before matching occurred. See Table 1 for a complete list of variables included within each phase of our analysis. See Table 2 for a summary of our research questions and corresponding samples utilized to examine each question.

Effects coding was used in the multivariate regression analysis. We included three categorical variables, race, gender, and sexual orientation, as independent variables to control for these demographic characteristics. Traditional practices involve either reducing a categorical variable down to an indicator variable or choosing a reference group to exclude, privileging one group for analytical and non-theoretical reasons. To avoid this false dichotomy we employed effects coding [31] to eliminate the need for a reference group with categorical variables. All groups are reported in the regression results and their coefficients are interpreted as a comparison to the sample's mean. See Table 1 for a complete list of included categories for each variable.

2.2.2 T-tests

For addressing RQ1, four two-tail t-tests were constructed to compare students in engineering majors and non-engineering majors on four pre-collegiate measurements [32, 33]. The dataset had unequal sample sizes of engineering students and non-engineering students and unequal variances in each sample, violating an assumption of the student's t-test [33]. Therefore, we employed coarsened

Table 2. Summary of Research Questions

	Variables used for CEM	Matched Students: Engineering Students	Matched Students: Non-Engineering Students	Dependent Variables	Independent Variables
RQ1: Pre-Collegiate leadership-oriented attributes	Demographics Vector	4,761	4,761	LS_{hs} LSE_{hs} CF_{hs} INV_{hs}	
RQ2: Collegiate leadership experiences	Demographics Vector Pre-Collegiate Vector	4,600	62,253	INV_{col} MENT LeadTR	Engineering Major (1/0) Demographics Vector Pre-Collegiate Vector (10 total variables)
RQ3: Collegiate leadership outcomes	Demographics Vector Pre-Collegiate Vector Collegiate Vector	2,322	7,565	LS_{col} LSE_{col} SPT_{col}	Engineering Major (1/0) Demographics Vector Pre-Collegiate Vector Collegiate Vector (17 total variables)

exact matching to identify an equal-size sub-sample of the non-engineering students who were highly similar to the engineering students based on the demographic variables. Testing showed these matched samples of equal counts to have equal variances for applying the student's t-test [33].

2.2.3 Regression analyses with college experiences

In addressing RQ2, nine multivariate regressions were estimated on key collegiate experiences after pre-processing the data using coarsened exact matching. First, engineering and non-engineering students were matched using CEM on the nine variables. CEM supports one-to-many matches [34] and therefore, this matching resulted in a sub-sample of 66,853 highly similar students, 4,600 engineering majors and 62,253 non-engineering majors. Using this matched sample, we estimated regressions for three different dependent variables of their collegiate experiences: involvement level, mentoring experiences, and leadership training. For each dependent variable we built three block regressions starting with the engineering-major indicator variable, adding the demographic vector, and finally adding the pre-collegiate vector. Each regression was estimated with list-wise deletion of observations with any missing values on the included variables, dropping no more than 0.3% of the sample in all the regressions estimated. Plots of fitted residuals yielded no visual evidence of heteroskedasticity. For clarity, only variables with statistical significant coefficients are reported in Tables 4, 5, and 6. The full results of the estimated regressions and diagnostics are available upon request with the authors.

2.2.4 Regression analyses with college outcomes

To address RQ3, multivariate regressions were estimated on key outcome variables after pre-processing the data using a more extensive coarsened exact matching than RQ2. First, engineering and non-engineering students were matched using CEM on 12 variables. This extensive matching resulted in a sub-sample of 9,887 highly similar students, 2,322 engineering majors and 7,565 non-engineering majors. With this matched sample, we estimated two sets of regression models. The first set used the combined sample of all 9,887 students and the engineering-major indicator variable in each block regression. A second set of regression models used two subsetted samples, the first subset with the 2,322 engineering majors and the second subset with the 7,565 non-engineering majors. Collectively, these sets of regression models enabled a more nuanced analysis of both the direct effect of an engineering major in the first set of models and in the second set

Table 3. Pre-collegiate comparisons of engineering and non-engineering student for RQ1

	LS_{hs} ENG	LS_{hs} Non-ENG	LSE_{hs} ENG	LSE_{hs} Non-ENG	CF_{hs} ENG	CF_{hs} Non-ENG	INV_{hs} ENG	INV_{hs} Non-ENG
N	4,761	4,761	4,761	4,761	4,761	4,761	4,758	4,757
μ	3.89	3.88	2.88	2.86	3.04	3.05	10.61	10.78
SD	0.49	0.52	0.69	0.71	0.57	0.58	3.53	3.61
t	0.59		1.42		–0.72		–2.31*	
p	0.56		0.15		0.47		0.02	
ES	0.06		0.06		0.06		0.06	

Notes: * p<.05.

Table 4. Significant Predictors of Collegiate Co-curricular Involvement (INV_{col}) for RQ2

	Block 0 β	**Block 1** β	**Block 2** β
ENG Major	–0.40***	–0.28***	–0.24***
RAC–White/Caucasian		–0.57*	–0.47*
RAC–Latino/Hispanic		–0.70**	–0.76**
RAC–Multi-racial		–0.48*	–0.51*
GenST		0.62***	0.49***
TRAN			–0.31***
LS_{hs}			0.25***
LSE_{hs}			0.73***
CF_{hs}			–0.23***
INV_{hs}			0.24***
R^2	0.001	0.006	0.100
Adjusted R^2	0.001	0.006	0.100
F^2 effect size	0.001	0.006	0.107

Notes: * $p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 5. Significant Predictors of Mentoring Experiences (MENT) for RQ2

	Block 0 β	**Block 1** β	**Block 2** β
ENG Major	–0.78***	–0.36***	–0.32***
GenST		0.44***	0.34***
TRAN			–0.51***
LS_{hs}			0.79***
LSE_{hs}			0.41***
CF_{hs}			–0.28***
INV_{hs}			0.17***
R^2	0.002	0.020	0.069
Adjusted R^2	0.002	0.020	0.069
F^2 effect size	0.002	0.020	0.074

Notes: * $p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

of models an analysis of the contrasting collegiate experiences and outcomes between engineering students and non-engineering students.

Regressions were all estimated on four different dependent variables of key outcomes: collegiate leadership skills, leadership self-efficacy, and social perspective-taking. For each dependent variable and each set of regression models we built three block regressions starting with the demographic vector, adding the pre-collegiate vector, and finally adding the collegiate vector. Plots of fitted residuals yielded no visual evidence of heteroskedasticity. Again for clarity, only the full block regressions and the variables with statistical significant coefficients are reported in Tables 7, 8, and 9. The full results of the estimated regressions and diagnostic are available upon request with the authors.

3. Results

3.1 Pre-collegiate differences

First we addressed RQ1. Using comparison samples of engineering and non-engineering students matched by GEN, RAC, and GenST, we examined how these groups might differ regarding four levels of high-school skill and involvement. We conducted four respective student's t-tests; the results of these can be found in Table 3. Controlling for gender, race, and first-generation status, the only significant difference ($p < 0.05$) that emerged was in high school involvement (INV_{hs}): engineering students report being less involved than their non-engineering peers to a small but measurable extent. The matched samples of students did not differ in their degree of leadership skill, leadership confidence, nor their amount of cognitive flexibility in integrating new ideas to their way of thinking.

3.2 Differences in collegiate leadership experiences

Next we focused on RQ2. To assess differences in collegiate leadership experiences between engineering and non-engineering students, we conducted a series of multiple regression analyses using our respective criterion variables of interest as dependent variables: college co-curricular involvement (INV_{col}), mentoring experiences on campus (MENT), and curricular and co-curricular leadership training experiences (LeadTR).

Table 6. Significant Predictors of Leadership Training Participation (LeadTR) for RQ2

	Block 0 β	**Block 1** β	**Block 2** β
ENG major	–0.17***	–0.18***	–0.18***
RAC–White / Caucasian		–0.24***	–0.23***
RAC–Middle Eastern		0.23**	0.13
RAC–African American/Black		0.28***	0.16**
RAC–American Indian/Alaska Native		0.49***	0.16
RAC–Multi-racial		–0.14*	–0.16**
RAC–Race/Ethnicity not included above		0.15*	–0.05
RAC–No response		–0.88*	–0.09
GenST		0.10***	0.05***
TRAN			0.20***
LS_{hs}			–0.03***
LSE_{hs}			0.40***
CF_{hs}			–0.18***
INV_{hs}			0.09***
R^2	0.000	0.005	0.063

Notes: * $p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 7. Significant Predictors of Students' Current Leadership Skill (LS_{col}) for RQ3

		Subsetted Samples	
	Combined Sample β	**ENG** β	**Non-ENG** β
ENG Major	–0.01*		
GEN–Female	0.01**	<0.01	0.01***
GEN–Male	–0.01**	<0.01	–0.01***
RAC–Middle Eastern	–0.55**	–0.74**	–0.37
RAC–Latino / Hispanic	0.04	0.45*	–0.38
RAC–Multi-racial	0.02	0.38*	–0.35
TRAN	0.04***	0.08***	0.04**
LS_{hs}	0.40***	0.40***	0.40***
LSE_{hs}	0.05***	0.05***	0.06***
CF_{hs}	0.08***	0.08***	0.09***
INV_{hs}	<–0.01*	<0.00	<0.00
INV_{col}	0.01***	0.01***	0.01***
LeadTR	<0.01**	<0.01	<0.01*
MENT	0.02***	0.02***	0.01***
WorkOff	0.02**	0.01	0.02**
MCS	0.05***	0.05***	0.05***
R^2	0.443	0.460	0.440
Adjusted R^2	0.442	0.455	0.438
F^2 effect size	0.796	0.850	0.786

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 8. Significant Predictors of Current Leadership Self-Efficacy (LSE_{col}) for RQ3

		Subsetted Samples	
	Combined Sample β	**ENG** β	**Non-ENG** β
ENG major	0.02		
GEN–Female	–0.03***	–0.02	–0.04***
GEN–Male	0.03***	0.02	0.04***
TRAN	0.12***	0.13***	0.11***
LSE_{hs}	0.42***	0.37**	0.43***
LS_{hs}	0.24***	0.25***	0.24***
INV_{hs}	<–0.01	–0.01*	<–0.01
INV_{col}	0.03***	0.03***	0.03***
MENT	0.02***	0.02***	0.01***
LeadTR	0.01***	0.01***	0.01***
WorkOff	0.08***	0.01	0.10***
WorkOn	0.03*	0.03	0.03*
R^2	0.376	0.350	0.387
Adjusted R^2	0.375	0.343	0.386
F^2 effect size	0.603	0.537	0.632

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 9. Significant Predictors of Current Social Perspective-taking for RQ3

		Subsetted Samples	
	Combined Sample β	**ENG** β	**Non-ENG** β
ENG Major	–0.12***		
GEN–Female	0.11***	0.12***	0.10***
GEN–Male	–0.11***	–0.12***	–0.10***
SexOrient–Hetero	–0.07*	–0.03	–0.09*
TRAN	0.13***	0.14*	0.12*
LS_{hs}	0.39***	0.49***	0.35***
LSE_{hs}	–0.06***	–0.05	–0.07**
CF_{hs}	0.10***	0.03	0.12***
INV_{hs}	0.01*	<0.01	0.01
MENT	0.02***	0.01*	0.02***
MCS	0.05*	<–0.01	0.07**
R^2	0.184	0.206	0.167
Adjusted R^2	0.180	0.190	0.161
F^2 effect size	0.226	0.260	0.200

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

3.2.1 *Co-curricular involvement*

The significant results of our regression analysis can be found in Table 4. Even controlling for a variety of demographic factors and high school experiences, engineering students are measurably less involved than their non-engineering peers, while the difference in involvement attributed to students' major choice emerged as approximately as large as differences attributed to their levels of high-school skill and involvement. Within this analysis, high-school leadership self-efficacy, transfer status, generation status, and racial identification also emerged as significant predictors of collegiate involvement. Each demographic factor remained a significant predictor even after controlling for high school experiences.

3.2.2 *Mentoring experiences*

The results of this regression analysis can be found in Table 5. Our analysis showed that students in engineering majors experience fewer experiences of mentoring on their campuses than non-engineering students, even after controlling for a variety of demographic and high school experience factors. Generation and transfer status also emerged as significant predictors, as well as reported levels of high-school leadership skill, leadership self-efficacy, cognitive flexibility, and co-curricular involvement. Each remained significant ($p < 0.001$) while controlling for other factors.

3.2.3 *Participation in leadership training*

To assess significant predictors of participation in curricular and co-curricular leadership training programs, we conducted a Poisson regression analysis due to the construction of the leadership training (LeadTR) variable. Summing up the number of students' leadership training experiences created a count variable. The data followed a Poisson distribution—rather than a normal Gaussian distribution—and therefore we estimated the coefficients using a Poisson regression [32, 35, 36]. With a Poisson regression, estimated coefficients are odds ratios, which can be converted to probabilities for easier interpretation [32, 33]. The results of the analysis can be found in Table 6. Similar to other analyses, engineering students are less likely to participate in leadership training initiatives relative to their non-engineering peers, even when controlling for demographic variation and high school experiences. White and multi-racial students participate more than their peers, especially African-American students, while generation and transfer status also emerged as significant predictors. Again, high school leadership skills, self-efficacy, cognitive flexibility, and involvement also emerged as predictors. The only variables that contributed more to the prediction of leadership training participation than the engineering major were students' leadership self-efficacy, whether they started college at their current institution, and their identification as White/Caucasian.

3.3 *Differences in collegiate leadership outcomes*

Finally, we analyzed the data to answer RQ3. Our variables of interest were students' current levels of leadership skill, leadership self-efficacy, and social perspective-taking. To examine outcome differences between engineering and non-engineering students we employed two analytical models, the first model with major choice as an independent variable within the model, and the second model with two separate samples of engineering and non-engineering students to conduct parallel analyses. As a benefit of the statistical power gained from our large sample size, we conducted both analyses in examining factors predictive of each outcome. For clarity, only the final block of each analysis is shown.

3.3.1 *Leadership skill*

When both samples are collapsed, the Engineering major retains a small but measurable predictive power on students' current level of leadership skill, even when controlling for a wide variety of demographic, high-school experience, and collegiate experience factors. However, an examination of beta weights shows that the strength of its prediction is tiny compared to a student's leadership-related experiences. When each sample is separated, differences emerge between the samples in the ability of demographic variables to predict current leadership skill. Gender predicts skill for non-engineers, but not for engineering students. Three racial identifications (Middle Eastern, Latino/Hispanic, multiracial) predict skill for engineers, but not non-engineers. Within both samples, high-school involvement shows no predictive ability when controlling for other relevant factors. The list of statistically significant results in the analysis can be found in Table 7.

3.3.2 *Leadership self-efficacy*

The decision to major in engineering does not significantly predict students' current level of confidence in leading others. The only demographic variable to emerge as a predictor when both samples are collapsed is GEN (men outscore women). When separating engineering students from their non-engineering peers, however, GEN serves as a predictor only for non-engineers. When controlling for other factors among engineering students, gender plays no significant role in predicting leadership self-efficacy. A listing of significant findings from the analysis is found in Table 8.

3.3.3 Social perspective-taking

The social perspective-taking measure was where engineers differ from non-engineer peers to a considerable degree. Within the analysis that included the collapsed sample, gender and a variety of high school experiences and skills emerged as significant predictors of this capacity, but only collegiate mentoring experiences contributed from within the university environment. When separating engineers and non-engineers, high school cognitive flexibility and leadership self-efficacy emerged as predictive for non-engineers, but not for students with engineering majors. Moreover, the only collegiate experience for engineers predictive of their ability to take the perspectives of others—their mentoring experiences—retained significance only at the $p < 0.05$ level. A list of all significant results can be found in Table 9.

4. Discussion

In line with a growing concern and research about the leadership skills of aspiring engineers [6, 8, 37–40], this study consisted of a national examination of the leadership capacities of undergraduate students matriculated at colleges and universities in the United States. Our research questions focused on the differences between comparable engineering and non-engineering students in their high school leadership and involvement experiences, collegiate leadership and involvement experiences, and outcomes necessary for leadership and team-building success in a professional environment.

4.1 Summary of findings

4.1.1 Pre-collegiate experiences

Our results suggest that engineering students did not differ from their non-engineering peers on retrospectively measured scales of leadership capacity; their remembered high-school leadership skills and confidence were of a level achieved by non-engineers as well. However, engineering students report significant differences in their intensity of involvement in co-curricular group experiences while in high school. Even when matched demographically by gender, race, and first-generation status, engineering students participated in fewer co-curricular student clubs and organizations to a small degree. In essence, this suggests engineering students come to their university experience not lacking in leadership-oriented confidence and skill, but potentially lacking in practical teamwork experience vis-à-vis their peers.

4.1.2 Collegiate experiences

Our results further demonstrate that once in college, engineering students are to a small-to-moderate extent less involved in co-curricular student clubs and service organizations, report fewer relationships with faculty and staff mentors, and participate less often in curricular and co-curricular leadership training programs than their non-engineering peers, even when controlling for demographic variables and high school involvement experiences. Moreover, engineers differ with their non-engineer peers to the greatest extent in the degree to which they can identify mentors—defined in the study instrument as a campus affiliated faculty or staff member who helps them learn leadership skills or otherwise achieve professional success in either formal or informal ways.

4.1.3 Collegiate leadership and teamwork outcomes

The results of our study suggest that engineering students do not significantly differ from non-engineers in leadership-oriented confidence. However, they do differ slightly in leadership skill and considerably in their ability to take the perspective of others while interacting with these others. Differences persist even when controlling for demographics, high school experiences, and most significantly, collegiate mentoring, co-curricular involvement and leadership experiences. For engineering students, mentoring experiences played a much more significant role in predicting leadership and teamwork capacity than for non-engineers, and served as a significant predictor of the skill to take the perspective of others in interactions. Moreover, both high school and collegiate involvement experiences predicted engineering students' confidence in their leadership practices. Somewhat surprisingly, the amount of curricular and co-curricular leadership training engineering students' reported did not significantly predict scores in each of the relevant leadership and teamwork outcomes examined within the study.

5. Implications

Several implications emerge as a result of this research study. Related to our examination of the incoming high school experiences of engineering students, engineering educators should recognize that their students tend to arrive at their university with less practical experience in co-curricular student organizations than might be expected of a typical university student. Moreover, these differences not only persist once immersed within the university environment, they are present even when comparing engineering and non-engineering students who were similarly involved in high school. Our findings suggest that what might separate engineering students from non-engineering students is their degree of skill in navigating interpersonal interactions.

Engineering curricula are densely packed with academic requirements, and suggesting students become more involved in team and leadership experiences outside of academic coursework may be simplistic. However, great potential exists to modify team-based training and assignments in these courses. Short training sessions in collaboration and conflict management targeted at assigned teams, augmented with online resources that detail the roles and skill of effective team members and effective team communication behaviors may serve to provide a foundation for suitable growth. Still, a potential key in augmenting these skills might be found in the practical knowledge and skills gained from interactions within co-curricular experiences—a finding supported in past research in a non-engineering environment as well [20]. Educators might benefit their students by creating more efficient pathways to these types of involvements for busy or professionally-motivated engineering students who feel that success in coursework may be the only relevant route to later success—through providing nominal credit within courses or instituting a co-curricular transcript to supplement the traditional academic one.

The results also imply the significance of mentoring to engineering students' education in leadership and team-oriented skill development. The degree to which engineering students experienced significant mentoring on campus served as a significant predictor in every outcome measured, even after controlling for a host of other demographic, high school, and collegiate variables. Somewhat distressingly, however, engineering students report fewer of these relationships than their non-engineering peers, even controlling for demographic and precollegiate factors.

Lastly, the findings related to the social perspective-taking capacity of engineering students were noteworthy. Even when controlling for important variables such as gender, race, transfer status, and high school and collegiate involvement, engineering students lag behind non-engineering peers in their ability to take the perspectives of others. The engineering major played a larger role in predicting scores than a student's first-generation status or transfer history, suggesting that engineering educators are not currently doing enough to provide their students skills in creating collaborative relationships that require conflict management and consensus-building, especially in academic environments where finding the "correct" solution to problems is repeatedly reinforced. Several steps could positively contribute to social-perspective taking skills. Orientation programs might be augmented by providing explicit training in conflict management, decision-making, and group dynamics. Academic courses could include short sessions before group projects on best practices in creating team behavior norms. Students' motivation to develop their skills in this area might be enhanced once they understand that a productive group dynamic often results in more efficient and successful problem-solving in complex environments. Our research found that engineering students are not attending curricular and co-curricular leadership trainings at the same rate as their peers, so targeted trainings focused on interpersonal skill development specific for problem-solving environments could be in order.

Overall, a stereotype exists that engineering students lack interpersonal skills [10, 41]. Our research study, unfortunately, provides empirical evidence suggesting that there might be truth to such beliefs. Even when matching engineering students with their peers on a total of 17 input and environmental variables, engineering students lag behind their non-engineering peers on measures of leadership capacity and social perspective-taking.

6. Limitations and future directions

As with many similarly-structured national studies, our examination consisted of a cross-sectional design, not a rigorous longitudinal analysis. Measurable growth derived from high school and collegiate experiences within this study emerged only through retrospective measures and matched-sample analysis, not through following individual students over time. A longitudinal design, while likely sacrificing such a large sample, would provide more rigorous findings related to student growth. In addition, while our study included efforts to match students on a variety of variables known to be significant to the relevant outcomes, unobserved variables influencing the outcomes may still be present. For example, while our findings suggest the roles that schools of engineering could contribute to desirable leadership outcomes, we did not examine engineering sub-disciplines.

Lastly, our analysis relied wholly on student self-reported data. While self-reported data has been supported over a generation of social science research [24], measuring complex and diffuse phenomena like leadership and teamwork capacity through self-report data has occasionally been proven problematic [42]. Additional studies that include observer-assessment or behavioral measures might add additional rigor to the examination of issues like engineering students' leadership and teamwork capacities.

Beyond future research study, several programmatic interventions may be suggested from our findings. University faculty and student affairs professionals working with engineering students can glean from this study's implications substantial insights in how to improve the learning of leadership by engineering students. This study showed that intentional teamwork experiences, leadership trainings, and co-curricular involvement can and do contribute to engineering students' learning. Students need to be encouraged and supported to participate in co-curricular activities and trainings. Further, educators might engage students in more and deeper mentoring opportunities and encourage them to seek out informal mentoring relationships, which past research suggest is often a more effective form of mentoring [43, 44]. Finally, of all the subpopulations examined in this study, transfer student status stood out as a substantial contributor to lower outcomes. Many schools of engineering already have programs for transfer students and these would make ideal venues for promoting what we know works: co-curricular opportunities, leadership trainings, and mentoring experiences.

7. Conclusions

A national sample of undergraduate engineering students and a rigorous comparison sample of non-engineering peers were examined to determine differences between these two groups in leadership and teamwork-oriented outcome measures. A significant gap emerged between the two groups in ability to take the perspective of others in interpersonal interactions, while a narrower gap emerged in regards to leadership skill. These gaps persisted even when rigorously controlling for a variety of student demographic and experiential factors, such as gender, race, student high school involvement, collegiate involvement, mentoring experiences, and participation in leadership programs. Moreover, our results show that engineering students' collegiate co-curricular involvement lags behind non-engineering peers in the degree to which they join student organizations, participate in leadership development opportunities, and interact with faculty in a mentoring relationship. This study possesses significant implications for engineering educators in the way they help students develop leadership and teamwork capacity; particularly in the role that faculty mentoring and transfer student services can play.

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Clinton M. Stephens is a lecturer for leadership education with the Carrie Chapman Catt Center for Women and Politics at Iowa State University. Currently, Stephens coordinates the Catt Center's leadership program and teaches classes in leadership development. Stephens studies student leadership development, specifically assessing the effectiveness of courses and workshops to develop participants' leadership skills. Stephens completed a B.S. in Business Administration at Kansas State University in 2002, a M.S. in College Student Development at Oklahoma State University in 2005 and a Ph.D. in Higher Education Administration in 2012 at Iowa State University.

David M. Rosch serves as an Assistant Professor in the College of Agriculture, Consumer, and Environmental Sciences at the University of Illinois at Urbana-Champaign. His particular areas of interest include programmatic training in leadership development and the accurate assessment of leadership effectiveness in student and professional organizations. He earned a Ph.D. in Higher Postsecondary Education from Syracuse University, a M.S. in Student Affairs in Higher Education from Colorado State University, and a B.A. in Psychology from Binghamton University (NY).