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Influences of Engineering Students' College Experiences on Leadership Skill Assurance*

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With a growing interest in developing leadership skills among engineering students comes the need to better understand students' experiences that contribute to leadership abilities. The purpose of this study is to explore the engagement of undergraduate engineering students and learn how it relates to their leadership skill assurance (LSA), the belief in their ability to exhibit leadership skills in their career or studies after graduation. The connection of engagement to leadership development is taken within the context of the College Impact Model. A case study quantitative method was used to gather data from 1,770 graduating engineering students from a large, public university. The study uses generalized linear modeling (GLM) to measure LSA, based on student *classroom, out-of-class*, and *curricular* experiences, as outlined by the College Impact Model. Results showed that activities from each category were significant in their relationship to LSA. The highest rated factors were involvement in Space Grant (an out-of-class activity), quality of peer interactions (a classroom activity), and choosing an engineering management minor (a curricular decision). Identification of activities and level of satisfaction that align with higher LSA help engineering educators to determine where to contribute resources toward the development of leadership in engineering students.

Keywords: leadership; co-curricular; extracurricular; involvement; engagement

1. Introduction

Technical leaders will play an important role in the future. With the integration of so many forms of technology into our daily lives, the future will be built by those who can understand, design, and implement these innovations. Universities play an important role in preparing the tech savvy to also thrive in their abilities to understand other humans and work hand in hand toward a socially responsible future.

Various engineering entities [1] and professional organizations [2–6] have called for colleges of engineering to take on the responsibility of training engineers in topics of leadership. The 2019 student outcome criteria laid out by ABET, the accreditation board for engineering programs in the U.S., includes leadership among the skills necessary for engineering program graduates [7]. Institutions have responded to these calls by creating centers for leadership, leadership degrees, certificates, and minors as well as co-curricular programming centered around engineering leadership [8–10].

These engineering leadership programs have grown in the last 10 years and will continue to grow [8]. However, the leadership education community is still learning the best methodologies to teach and assess this type of learning. Many educators agree on the importance in making engineering leadership education an integrated part of the curriculum [11]. Ultimately, however, substantial cultural change is needed to make real changes within the complex system of higher education. As noted by Rottmann et al. [11], engineering must be seen as a leadership profession.

This study takes a systems perspective to address the state of students studying engineering at a large, public, doctoral, very high research activity institution (LPI), the type of institution that educates a large percentage of engineering graduates in the United States [12]. By understanding the student experience more holistically, the researchers believe they can identify leverage points and provide general insights to the engineering leadership education community as to how to focus resources toward integrating leadership awareness into the engineering curriculum and student experience.

2. Background

Research on engineering leadership development has increased in the past few years with the addition of an engineering leadership development division to the American Society for Engineering Education

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(ASEE) in 2014. Additionally, faculty are increasingly focusing research efforts on engineering leadership development. Other work in this area highlights best practices engineering leadership development programs at different universities [8], leadership expectations at the professional engineering level [11, 13], and studies that take a more holistic perspective on engineering leadership development in higher education [14, 15]. Studies that focus on the broad student experience often source their data from large datasets such as the National Survey of Student Experiences (NSSE) [16–18]. Another recent study of engineering leadership role confidence was done through a large multi-institution survey [19].

We seek to complement these approaches by offering a case study approach to understanding the current state of student confidence in their leadership skills as they graduate from engineering bachelor's degree programs, whether they were part of a formal leadership development program or not. As engineering programs transition to the 2019 ABET student outcome criteria, leadership education will continue to evolve. At many institutions prior to 2019, engineering leadership education was predominantly offered separately from the core curriculum [11]. The addition of leadership to the ABET student outcome criteria will incentivize programs to specifically add leadership training to their curriculum. This study captures the *in-situ* state of student leadership skill assurance (LSA) before this curricular transition happens. Leadership skill assurance is one's belief in their ability to exhibit leadership behaviors in the future. Certain engineering disciplines have a strong historical focus on leadership, such as civil, construction, and engineering management [13] while others have started to include it based on ABET changes in the general student outcomes criteria.

Multiple sources call attention to the level of complexity in leadership [20–23]. Terenzini and Reason's College Impact or Input-Environment-Output (I-E-O) Model [24] includes context areas such as internal organizational characteristics, structures, practices, policies, and faculty culture, all things that influence experiences which then indirectly influence learning [17]. This method of exploring students' experiences through so many different facets of those experiences aligns with a systems way of thinking [25]. The model is shown in Fig. 1.

Astin's theory of student involvement, drawn from both psychoanalysis and learning theory, is a foundation for I-E-O models [24]. Student involvement theory asserts that the more involved a student is, the more that student will learn and develop personally [26]. Astin states, "Student involvement refers to the amount of physical and psychological energy devotes to the academic experience [26, p. 518]." The amount of student learning and personal development is directly proportional to the quantity and quality of time the student spends engaged in academic and campus activities. Astin's model is an example of a "college impact model," one that brings in a focus on environment and a student's interactions with others to affect student behavior and change [24, 27].

The I-E-O model outlined here is useful in engineering leadership education today because of

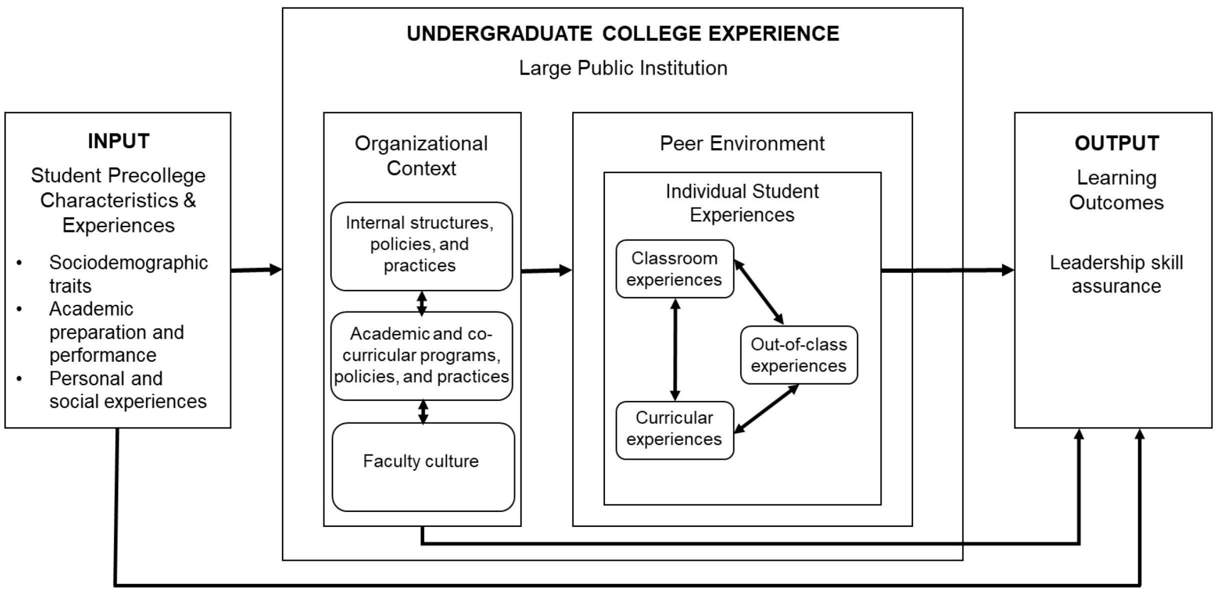

Fig. 1. Adapted Input-Environment-Output College Impact Model from Terenzini & Reason [24].

the holistic focus of modern leadership theories [23]. Research has shown that engineering students are less involved on campus than their non-engineering peers [18]. However, I-E-O models have been used to explore engineering students' college experiences in various areas of focus such as ethics [28], social responsibility [29], and leadership development [17, 18]. The I-E-O model frames the college experience much like systems theory, acknowledging the structure in which the experience occurs and observing the behavior that results [25]. A system is a ''set of things interconnected in such a way that they produce their own pattern of behavior over time'' [25, p. 1)''. Systemic considerations are as important or more important than ever in understanding the social construction of leadership [22].

3. Research Question and Methodology

3.1 Research Question

This study uses a case study methodology to address the following question:

> What student experiences and perceptions are correlated with higher levels of leadership skill assurance among graduating undergraduate engineering students?

3.2 Methodology

In their study on leadership role confidence, Magarian & Olechowski [19] find that leadership role confidence is a within-university effect, highlighting the need for further research that focuses on the environment within a single university. This reasoning led the research team to a case study at one university. The case study methodology of this research leads us to a sample of students that is representative of the full population of undergraduate students in engineering at this one institution. Additionally, this study includes students from majors across the College of Engineering rather than focusing on one specific discipline, addressing another opportunity identified in the previously mentioned article. As highlighted in systems theory, each system has defined boundaries [25]. This study focuses on the Peer Experiences portion of the model shown in Fig. 1. The case study nature of this research supports the exclusion of Organizational Context and previous research on leadership development in an engineering education setting has shown minimal influence of student pre-college characteristics or experiences on leadership development in the final year [16, 17].

The case study methodology addresses this research question by focusing on better understanding the current status quo of a ''typical'' engineering program on the cusp of ABET outcome changes related to engineering leadership development. The university in this study has a relatively small number of students involved in a formal leadership development program (6.3 percent), and its various departments address leadership in various ways through coursework and other programming. Learning about this individual large public university's experiences will help identify leverage points for other institutions to direct resources strategically as they strive to address the ABET outcome related to engineering leadership development.

3.3 Methods

A survey administered to all fall 2017 to spring 2019 graduating seniors in the College of Engineering at a large public research-intensive institution. These data were supplemented by document analysis in which the researchers inspected university, college, and department websites and public curricular information such as course descriptions and syllabi. Research was conducted in accordance with approved expedited protocol (17-0424) from the researchers' Institutional Review Board (IRB).

Survey data for this study were collected from the engineering college-wide Senior Survey. This omnibus survey consists of many questions shown to all the graduating students as well as major-specific questions. Questions cover topics such as satisfaction with the university experience, ABET outcomes, participation in internships and other work experiences, co-curricular activities, and post-graduation plans.

The specific item related to leadership self-assurance asked, ''How well prepared do you feel to display leadership skills in your career or studies after graduation?'' Students responded using a 5-point Likert-type scale ranging from (1) ''Not at all prepared'' to (5) ''Highly prepared. The question was in the first quarter of the survey. The survey was emailed to all graduating seniors over the month preceding their graduation, in fall, spring, and summer semesters. The survey was long with a median response time of around 40 minutes, and students sometimes skipped survey items. Analyses were completed using the number of responses for each relevant question or set of questions. Prepopulated institutional data was provided to the research team that included the demographic information of first-generation status, ethnicity, and gender. The data collected by the survey administrators were identifiable, but the data shared with the research team were anonymous.

The survey had 1662 responses out of 1770 surveys sent (a 94 percent response rate), which includes students from all College of Engineering departments. Many departments require their students to take the graduating senior survey. Three

Table 1. Characterization of Study Sample

n = 1770	*LSA Mean (SD)*	*n*	*Percentage*	*Response Rate (%)*
Total Survey Responses		1662	100	93.9
Variable of Interest:				
Leadership skill assurance	3.96 (0.89)	1545	92.9	90.9
Student rates self above midpoint		1148	69.1	
Students by Major:				
Aerospace Eng	4.07 (0.87)	213	12.8	93.4
Architectural Eng	3.93 (0.86)	68	4.1	98.1
Chemical; Chemical and Bio Eng	3.96 (0.85)	274	16.4	91.2
Computer Science	3.77 (0.98)	244	14.7	90.4
Civil Eng	4.12 (0.85)	122	7.3	97.6
Electrical; Electrical and Comp Eng	3.69 (0.98)	165	9.9	87.3
Environmental Eng	4.06 (0.86)	84	5.1	100
General Eng	4.20 (0.67)	52	3.1	91.2
Mechanical Eng	4.03 (0.83)	440	26.5	98.2

Table 2. Example of Peer Experience Categories, Terenzini & Reason's I-E-O Model (2005)

Classroom experiences	**Out-of-class experiences**	**Curricular experiences**
Pedagogies Instructor pedagogical skills Student interaction	Living situation Job Co-curricular activities	Major Relevant internships Socialization to the field

programs not accredited by ABET, each with a relatively small number of students, were excluded from this study. Two sets of engineering majors in the same department were found to have very similar course requirements and were therefore combined for analysis: Electrical Engineering and Electrical & Computer Engineering; Chemical Engineering and Chemical & Biological Engineering. There were 1545 students who answered the LSA question representing 91 percent of the undergraduates graduating from LPI in the ABET-accredited majors. The response rate for each major is based on the number of graduates per major. See a full characterization of the study sample in Table 1. The largest major at the institution was mechanical engineering, with these students comprising 28.5 percent of the data set. Throughout the analyses, various n values were realized based on the number of students who answered a given question on the survey.

To explore this data, the researchers identified the boundaries for the "system" under analysis to be the "Peer Environment" section of the I-E-O model from Terenzini and Reason [24] shown in Fig. 1. The categories included in the *peer environment* are the *classroom experiences, out-of-class experiences*, and the *curricular experiences*. The researchers identified factors within the survey that fit into each of these categories and were hypothesized to influence student leadership skill assurance based on previous research as well as the I-E-O model. Table 2 highlights example factors that fit into each of the three categories of the model. One set of experiences, internships and co-ops, is placed in the *curricular experiences* category per Terenzini & Reason [24] because of the experience's relevance to the student's major field of study.

For each of the factors in the peer experience category, an independent test for impact on LSA was completed followed by a linear regression model for the peer experience category that included the independently significant factors [30]). The goal of this method of analysis was to identify factors that were more likely to be significant when included in the generalized linear model (GLM), thereby limiting the number of factors in the model. Because the data were not assumed to be normally distributed and ordinal (for the LSA rating), non-parametric Kruskal-Wallis or Mann Whitney-U tests were conducted, using the leadership skill assurance question as the dependent variable, akin to the method used by Magarian & Olechowski [19] in their research on leadership role confidence. Then, taking the significant factors from each category ($p < 0.05$), the researchers ran three initial GLMs, one aligning with each category highlighted in Fig. 1. Finally, the researchers ran a fourth, combined GLM which included the significant items from each of the GLMs from each

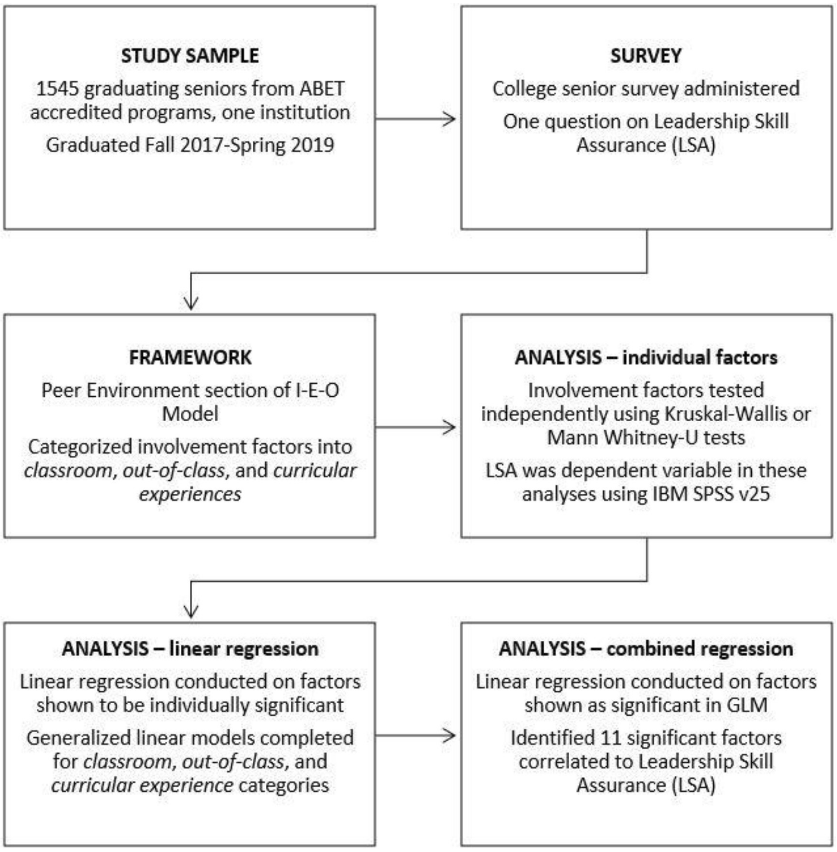

Fig. 2. Flow Chart Summarizing Research Methods.

category. For each GLM, reported results include the slope of the linear predictor (*B*), the standard error of *B*, and the level of statistical significance of B. Higher B values show more impact on the LSA. All statistical tests were run in IBM SPSS v25. A summary of the methods used is found in Fig. 2.

4. Results

The results of the *Peer Experience* analyses are reported first by each individual category's (*Classroom*, *Out-of-Class*, and *Curricular*) independent comparisons and GLMs followed by the omnibus GLM of significant factors from each category.

4.1 Classroom Experiences

Terenzini and Reason [24] describe classroom experiences as those that define students' time in the physical classroom. These experiences are heavily influenced by the people who contribute to classroom experiences: faculty, teaching assistants, and other students. The six survey questions relating to the quality of the classroom experience were Likert-style, with ratings from one to five. The analyses summarized in Table 3 compare the differences in leadership skill assurance among students based on their perceived quality of classroom experiences and classroom climate around diversity. The factors shown in Table 3 are those included in the *Classroom Experiences* GLM because they were found individually to be statistically significant in the Kruskal-Wallis tests. Leadership Skill Assurance was taken as the dependent variable with the classroom experience factors as the independent variables. The three classroom experiences that were predictive of LSA in the GLM at a statistically significant level were overall student quality in one-on-one interaction, overall quality of faculty instruction, and overall opportunities for faculty interaction/accessibility.

4.2 Out-of-Class Experiences

The next category, *Peer Experience*, includes activities in which students participate that are outside of the classroom and includes factors that account for the time students spend away from organized class time. This includes factors such as where students live and whether they have a job on or off campus. Terenzini and Reason [24] highlight that these experiences, historically overlooked, are integral in studying any learning outcome. Table 4 summarizes the differences in leadership skill assurance based on student participation in various activities. Response data were bivariate, with study partici-

Table 3. GLM Results for Classroom Experiences

Factor (n = 1441)	*B*	*Std. Error*	*Sig.*
Overall student quality in one-on-one interactions	0.466	0.086	0.000
Overall quality of faculty instruction	0.370	0.089	0.000
Overall opportunities for faculty interaction/accessibility	0.259	0.089	0.004
Respectful climate for diversity	0.100	0.071	0.163
Overall quality of teaching assistants (TAs)	0.051	0.069	0.454
Overall student quality in team experiences	–0.067	0.069	0.331

Model Deviance Value/df = 0.734; Pearson Chi-Square Value/df = 1.262.

Table 4. Summary of Out-of-Class Activities

Factor (n = 1545)	*% participated*	*p-value*	*Mean LSA participants (SD)*	*Mean LSA non-participants (SD)*
Student Clubs				
Leadership role, *engineering club*	35.1	0.002	4.06 (0.85)	3.91 (0.90)
Leadership role, *non-engineering club*	25.2	0.004	4.06 (0.86)	3.93 (0.89)
Engineering student club, *non-leader role*	23.0	0.147	4.01 (0.90)	3.95 (0.88)
Work				
Off-campus, *non-internship/co-op*	32.8	0.013	4.08 (0.84)	3.90 (0.90)
On-campus, *non-research*	47.0	0.101	4.00 (0.87)	3.92 (0.90)
Research	29.0	0.287	3.99 (0.89)	3.95 (0.89)
Space Grant	7.9	0.011	4.16 (0.80)	3.96 (0.89)
Other				
Volunteer, *Over 50 hours/semester*	19.1	0.026	4.07 (0.82)	3.93 (0.90)
Engineering Honors	7.6	0.061	4.11 (0.81)	3.95 (0.89)
Diversity Scholarship Program, *URM, women, low SES*	26.8	0.068	4.04 (0.82)	3.93 (0.91)
Residential Academic Program	37.3	0.208	4.00 (0.86)	3.94 (0.90)
Engineering Peer Mentor	1.9	0.908	3.92 (0.98)	3.96 (0.88)
Campus Leadership Program, *co-curricular*	1.9	0.934	3.97 (0.98)	3.96 (0.88)

Table 5. GLM Results of Significant Out-of-class Experiences

Factor (n=1545)	*B*	*Std. Error*	*Sig.*
Space Grant	0.424	0.176	0.016
Off-campus work non-internship or co-op	0.344	0.102	0.001
Leadership role in non-engineering group	0.225	0.111	0.043
Leadership role in engineering club	0.196	0.107	0.066
Volunteer 50 or more hours	0.129	0.128	0.316

Model Deviance Value/df = 0.913; Pearson Chi-Square Value/df = 0.820.

pants indicating whether they participated in these activities. Thirteen involvement factors were explored. The five factors found to be significant at a 0.05 level when tested independently were subsequently analyzed using a generalized linear model. Those results are shown in Table 5. Only three of the factors remained significant at the 0.05 level: participation in Space Grant, off-campus work (non-internship or co-op) and having a leadership role in a non-engineering group.

4.3 Curricular Experiences

Curricular Experiences, as defined by Terenzini and Reason [24], include factors as innate to college life such as choice of major and coursework requirements such as a capstone design course. Additionally, the official support students receive from faculty and staff advisors aligns with their curricular experiences. Six nominal factors with bivariate responses to optional curricular involvement were analyzed (Table 6) along with six factors that included major, satisfaction and career preparation measures (Table 7). The satisfaction and career preparation measures were on a Likert scale from 1–5. The nine significant factors from each individual factor test were analyzed again using a generalized linear model as shown in Table 8; seven factors remained significant predictors for LSA.

Table 6. Summary of student curricular experiences

Factor (n = 1545)	*% participated*	*p-value*	*Mean LSA Participants (SD)*	*Mean LSA Non-participants (SD)*
Co-op/Internship	45.3	0.000	4.07 (0.88)	3.87 (0.88)
Engineering Management minor/certificate	12.9	0.000	4.19 (0.79)	3.93 (0.89)
Leadership+ Program Leadership + other topics	30.9	0.002	4.07 (0.81)	3.91 (0.91)
Leadership Program specific to leadership	6.3	0.006	4.21 (0.76)	3.94 (0.89)
Diversity Program - bridge Underrepresented minority	2.1	0.175	3.79 (0.86)	3.96 (0.89)
ROTC	2.5	0.593	3.92 (0.85)	3.96 (0.89)

Table 7. GLM results for curricular experiences: major, satisfaction, and career

Factor (N = 1196)	*N*	*B*	*Std. Error*	*Sig.*
Belief that senior design prepared student for career		0.263	0.058	0.000
Satisfaction: major curriculum sequencing		0.252	0.082	0.002
Satisfaction: major curriculum		0.234	0.090	0.010
Satisfaction: faculty advising and mentoring		0.233	0.067	0.001
Satisfaction: staff advisor		0.161	0.061	0.008
*Major**		–	–	0.459
Architectural	55	–0.065	0.275	0.814
Aerospace	153	0.299	0.189	0.114
Chemical; Chemical & Biological	194	0.020	0.172	0.907
Computer Science	167	–0.127	0.189	0.502
Civil	98	0.244	0.225	0.279
Electrical; Electrical & Computer	103	–0.200	0.218	0.359
Environmental	66	0.024	0.256	0.927
Multidisciplinary	34	0.352	0.329	0.285
Mechanical	326	–		Ref factor

* Engineering unless otherwise noted.
Model Deviance Value/df = 0.657; Pearson Chi-Square Value/df = 0.9410.

Table 8. Summary GLM results for curricular experiences

Factor (N = 1196)	*B*	*Std. Error*	*Sig.*
Internship/Co-op	0.425	0.111	0.000
Engineering Management	0.368	0.159	0.021
Belief that senior design prepared student for career	0.294	0.056	0.000
Leadership Program specific to leadership	0.276	0.235	0.239
Satisfaction: major curriculum	0.270	0.090	0.003
Satisfaction: major curriculum sequencing	0.251	0.082	0.002
Satisfaction: faculty advising and mentoring	0.245	0.066	0.000
Satisfaction: staff advisor	0.144	0.058	0.014
Leadership + Programs with additional topics	0.143	0.126	0.257

Model Deviance/df = 0.641; Pearson Chi-Square Value/df = 0.956.

To further narrow down the factors that show significant differences in leadership skill assurance, a final omnibus GLM was run comparing only the significant factors from each of the three sets of analyses that aligned with the three *Peer Experience* categories. Table 9 summarized these results and shows that 11 of 13 predictors is shown to be significant with a positive B value (slope).

5. Discussion

Based on the result summary in Fig. 3, factors from across categories of student experience align with the leadership skill assurance of engineering and computer science students near the end of their undergraduate college careers. Of the 11 significant factors, two align with *Classroom Experiences*,

Table 9. Omnibus GLM results: classroom, out-of-class, curricular

Factor (n = 1159)	*Type of Peer Experience*	*B*	*Std. Error*	*Sig.*
Space Grant	*out-of-class*	0.582	0.224	0.009
Overall student quality in one-on-one interactions	*classroom*	0.541	0.085	0.000
Engineering Management minor or certificate	*curricular*	0.476	0.162	0.003
Internship/Co-op	*curricular*	0.402	0.115	0.000
Off-campus work, non-internship/co-op	*out-of-class*	0.391	0.122	0.001
Leadership role, non-engineering group	*out-of-class*	0.329	0.129	0.011
Belief that senior design prepared student for career	*curricular*	0.257	0.059	0.000
Overall quality of faculty instruction	*classroom*	0.248	0.103	0.017
Satisfaction: major course sequencing	*curricular*	0.188	0.084	0.025
Satisfaction: faculty advising and mentoring	*curricular*	0.157	0.072	0.029
Satisfaction: staff advising	*curricular*	0.146	0.061	0.016
Overall opportunities for faculty interaction/accessibility	*classroom*	0.099	0.101	0.325
Satisfaction: major curriculum	*curricular*	0.036	0.097	0.707

Model Deviance Value/df = 0.567; Pearson Chi-Square Value/df = 0.909.

	Classroom Experiences	***Out-of-Class Activities***	***Curricular Experiences***
Significant Impact	Overall student quality 1 on 1 Overall quality of faculty instruction	Space Grant Off-campus work, non-internship Leadership role, non-engineering group	Engineering Management Internship/Co-op Senior design = career preparation Satisfaction: course sequencing, faculty advising and mentoring, staff advising
No Significant Impact	Opportunities for faculty Interaction Respectful climate for diversity Quality of TAs Student quality in teams	Leadership role engineering club Campus leadership program Club involvement, non-leader On-campus work – non research Engineering Honors Research	Major Engineering leadership program ROTC Satisfaction: major curriculum Diversity program

Fig. 3. Summary of All Factors Highlighting Those Shown to be Significantly Correlated with LSA.

three align with *Out-of-Class Experiences*, and seven align with *Curricular Experiences.* As posited by the I-E-O model, each of these areas of experience contribute to students' level of leadership skill assurance. The benefit of the GLM was to compare the relative importance among these multiple factors.

As shown in Table 9, the activity that showed the largest influence (B = 0.582) on leadership development was participation in Space Grant activities. The Space Grant program offers mostly extracurricular volunteer or paid project positions to students via a competitive application process. The projects are various, but all align with space-related topics. Listed time commitment for positions range from 6–12 hours/week per project [31] and have a significant amount of faculty, administrative, and professional support. Students who were involved in Space Grant were self-motivated to seek out the opportunity and excelled through an interview process. Over 43 percent of students involved in Space Grant were aerospace engineering students, and mechanical engineering students made up almost 19 percent. As shown in Table 1, these two majors' leadership assurance score was in the top half of the majors.

Among the results in Table 9, belief in the high quality of peers in a one-on-one setting was one of the factors most associated with a high level of LSA. As engineering students work toward their degree, the value of building a community of peers around an academic topic, a community of practice, has shown to be beneficial to student learning [32]. The results of our study, that a high rating of one-on-one interactions with peers relates to higher LSA, also align with the work of Komives et al. [33] who pinpoint four factors that facilitate leadership identity development, one of which is peer influences. Alternatively, however, the rating of peers in a team setting did not have a significant correlation to LSA. Communities of practice provide practitioners with a set of resources and best practices focused on a given topic, while practitioners may still do the work independently [32]. Educators who strive to intentionally develop leadership in their engineering students can take this information to plan simple classroom activities that promote regular student interaction around classroom topics. Long-term, team-based projects are not needed to encourage leadership development in the classroom. As highlighted by Terenzini and Pascarella [34], significant student learning is based on personal interactions. This theory holds true for peer interaction, as well as for faculty interaction.

Satisfaction with faculty advising, mentoring, instruction was shown to be correlated with higher levels of leadership skill assurance. Other research has determined that faculty play a significant role in helping engineering students develop leadership skills [35] through their planning of course activities, content, and opportunities for students to access resources such as guest lecturers. Nearly 75 percent of faculty members agree that engineering educators are in a strong position to teach undergraduate students the importance of leadership skills for their future careers. Interestingly, in practice, 55 percent of faculty who do scholarly work in the topic of engineering leadership development have work experience outside of academia and 38 percent are in non-tenure track or non-academic positions [36]. The influence of faculty on leadership development of engineering students is evident in this study and past research, highlighting the importance of integrating leadership topics into the standard engineering curriculum [11]. However, evidence shows that only 18 percent of engineering educators feel qualified to teach leadership topics [36], yet it is not enough to rely on experiences in student groups or other co-curricular activities for leadership development without concerted integration into curriculum as well [17]. The results of this study show that participation in a formalized leadership program did not correlate with a higher LSA value, instead highlighting the association of higher LSA with the faculty influence on classroom and curricular experiences. This is informative to educators who strive for the inclusion of leadership education in their curriculum – resources should be leveraged to train faculty how to confidently teach leadership topics.

Students who had internships and other off-campus work reported higher levels of leadership skill assurance than their peers. These factors highlight that work, in the engineering area of focus or not, may contribute to leadership development. Internships provide an authentic technical experience for students, allowing them to engage in engineering alongside professionals. Internships have been shown to help students build their engineering leadership identity [16]. Even work off-campus (non-internship) was shown to be correlated to higher LSA values among students, aligning with at least two of the four factors Komives et al. [33] identified that facilitate leadership identity development: adult influences, peer influences, meaningful involvement, and reflective learning. Conversely, on-campus work did not show the same correlation to LSA, implying that the opportunity for leadership development is stronger when students are applying their skills in authentic experiences in an off-campus setting. Given that the internship and other work experiences are off-campus, university educators may find it difficult to have impact on students in these settings, other than promoting internship opportunities. Educators have the potential opportunity to help students make the most of these experiences through pre-internship training and post-internship reflection, as critical reflection is important for leadership development and general learning [37, 38]. For students working off-campus in a non-internship role, educators can create trainings on how to leverage that experience, no matter the field or role in an organization, to gain leadership skills.

Beyond working off-campus, students who chose to incorporate professional skill building into their curriculum and activities had a higher level of LSA. Students who took engineering management courses, considered senior design to be beneficial to their future careers, and students who served in leadership roles in their non-engineering student groups were identified as having higher values of LSA than their peers who did not. The choice to study engineering management shows that students have the foresight or interest to explore topics beyond their technical engineering coursework. At this institution, the engineering management minor has a "Leadership & Professional Skills" course as an elective, with required courses that include introduction to engineering management, project management, and engineering economics. The students who believed senior design prepared them for their future careers also reported higher levels of LSA, showing their willingness to look ahead to the future, with some intentionality while involved in coursework. The majority of the senior design courses at this institution require the students to work with an industry or community partner, highlighting the fact that senior design outcomes typically involve providing the students an authentic, professional-like experience [39–41]. Knight and Novoselich [17] state that students report higher leadership skill when they had more student-centered teaching and group learning in a course, as is the case in senior design courses. Additionally, many senior design courses include various professional skills (such as communication, teamwork, self-awareness) as learning outcomes [39, 42, 43], factors that are part of being a skilled leader [44]. Studies show leadership skills are valued and achieved by students in senior design courses [45].

Finally, a separate study showed that students who held leadership titles in student clubs and organizations had higher levels of leadership self-efficacy, especially women [15]. One point of note in this study is that students who reported having a leadership role in an engineering club were not shown to have significantly higher LSA, though the p-value for that comparison was 0.066, just above the standard cut-off for significance of 0.05. Future research could be done to explore the LSA levels by gender within this population. This finding aligns with one study which found engineering students who are varsity athletes or in Greek life have significantly higher levels of Leadership Role Confidence than their peers [19]. This difference in engineering and non-engineering leadership roles may be influenced by the tendency of engineers not to see engineering as a leadership profession [11], therefore students interested in gaining leadership skills identify their formation with experiences outside of engineering. These factors show that students are interested in learning about topics beyond the technical necessities of engineering.

Educators can continue to encourage participation in activities in which they can gain and practice leadership skills by allowing students more flexibility in scheduling to take courses such as those in engineering management. When provided with the intentional opportunity to practice leadership skills, such as in senior design, students seem to value the chance and take advantage of it, leveraging their classroom circumstances to practice communication, teamwork, and leadership more broadly. Again, this highlights the role faculty can play in providing leadership development topics and opportunities in their courses. Educator and administrative support of intentional leadership development for both engineering and non-engineering student groups helps to bridge the creation of a strong engineering leadership identity [16] in which students do not think of technical and professional skills as mutually exclusive, but rather consider both sets of skills to be necessary and complementary.

6. Limitations

The limitations of this study include its dependence on single-item ratings. It would benefit from the creation of an expanded survey instrument to more thoroughly address leadership self-assurance [46–47]. This study employs self-reported data which can lead to bias [48]. The study is unable to determine causality since it is unclear whether the students with a higher LSA sought out experiences such as Space Grant, the Engineering Management minor, and leadership roles in student groups. Causality would need to be studied using pre- and post-assessments and additional methods, such as longitudinal interviews that range in time from when students enter college through when they graduate with a bachelor's degree.

As was previously mentioned, a very low number (6.3%) of students were involved in leadership programs, making this important group of students difficult to study in comparison to the much larger remainder of the student population. The distributed survey was done so by the College of Engineering administration leaving the researchers only a small opportunity to guide the questions. The survey was lengthy, with the median duration of completion being about 40 minutes, likely negatively affecting the n value for individual questions. Finally, it is impossible to identify everything in a students' life that may have affected their leadership development, and this study includes only their undergraduate experiences, a limited period in a student's development.

7. Conclusions

This study explores student-reported levels of leadership skill assurance (LSA) and correlates those attitudes to the experiences and activities in which engineering students partake during their college years. Based on the results, educators (departments, faculty, and staff) can foster leadership in the classroom setting, through curricular requirements and through out-of-class learning opportunities. Classroom opportunities for leadership development included even brief peer-to-peer interaction around classroom topics and more generally, inclusion of leadership skill building opportunities into the core curriculum. Faculty instruction and interaction positively correlate with LSA, creating the opportunity to better train faculty members in integrating leadership topics into their courses and curriculum. Out of the classroom activities such as work off-campus, internship experience, and student group leadership are positively correlated with LSA as well, providing the chance for faculty and staff to promote more independent, informal learning among students.

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