Integrating Engineering Leadership Throughout an Undergraduate Engineering Degree

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***Abstract*—This innovative practice full paper describes an effort to create a thread of engineering leadership development throughout an undergraduate engineering degree at The University of Texas at El Paso. The first bachelor's degree of its kind in the nation, this new degree is housed in the Department of Engineering Education and Leadership and has a heavy emphasis on integrating fundamental engineering theory and skills with business acumen and leadership development (e-lead.utep.edu). In developing the leadership component of the degree, the faculty understood that one of the most effective methods by which people learn to develop as leaders is through practice. Therefore, rather than place all leadership development in a single course in the Engineering Leadership Program (E-Lead), the degree was designed to have a coordinated thread of leadership development throughout the degree plan, encompassing both curricular and extracurricular opportunities. Focused heavily on practice and application, a framework for leadership development was designed to take a tiered approach. For all students, in-class activities introduce fundamental concepts of engineering leadership in the context of teamwork and engineering project management in the E-Lead courses. For those students interested in more in-depth experience and training, additional extracurricular leadership development opportunities were made available in the form of coaching or attending leadership conferences and workshops. In all of these activities, the focus is on helping students to develop their character, capacity, and competence. Having recently graduated the first cohort of students using this leadership development approach, this paper describes the framework used for leadership development and the key activities dispersed throughout the engineering leadership thread. Further, this paper includes qualitative results from assessing the impact of these activities on our graduating cohort.**

Keywords—Engineering Leadership, Engineering Education, Leadership Development, Professional Development, Curriculum Integration

I. Introduction

The engineering industry has evolved considerably in the 21st century, but advancements in how we educate the engineers joining the industry have lagged [1]. The problems engineers now face are becoming more complex, and therefore require a larger skillset from engineers entering the workforce. In addition to the technical proficiency of graduates of engineering programs, professional engineering organizations, such as ABET and the National Academy of Engineers, call for graduates with professional skills, including leadership, creativity, innovation, critical thinking, problem-solving, communication, and collaboration [1], [2]. This emphasis on professional skills, in addition to the technical, is due to the increased need for engineers to be leaders in their industries. Engineers that can lead teams to solve the world's biggest challenges, such as sustainability, smart infrastructure, and global warming [3].

However, in traditional engineering education, engineers are taught to focus heavily on technical mastery, making it common that employers see recent graduates as technically competent but lacking in professional skills [4]. These professional skills are vital for engineers as it can notably affect the health and vitality of the national economy since engineers and scientist make up four percent of the workforce, but their work provides jobs for a majority of the remaining workforce [4].

Companies and colleges have recognized this growing issue, and engineering leadership (EL) programs are have been developed across the country and world. For instance, Tufts Gordon Institute became the first engineering leadership program in 1987. The program offers a Master's of Science that focuses on developing leadership skills in graduate students through the use of industry-based projects that require teamwork, technical learning, and business acumen [5]. At least thirty-four other institutions have followed the lead of Tufts University by creating engineering leadership programs that adapt to fit the needs and values of their students, faculty, and industry partners. The programs vary from undergraduate and graduate certificates, undergraduate and graduate degrees, to co-curricular experiences [5].

Based on a review of program websites and publicly available material, examples of graduate EL programs include, McMaster University, Northeastern University, Tufts University, Western University, and Ivey School of Business who all offer a certificate or master's degree specifically for students who have been in the engineering field and are returning to complete additional study in engineering leadership. They commonly involve industry-based projects and product development and focus more on innovation, entrepreneurship, and business acumen.

Other schools, such as Penn State University, Cornell University, Iowa State University, University of Florida, National University of Singapore, Rice University, Western University, University of Toronto, Massachusetts Institute of Technology, offer undergraduate minors or certificates that are open to any undergraduate major. These minors heavily emphasize project-based learning and experiences that develop undergraduate students into working professionals. These programs follow their students closely with leadership assessments to determine factors, such as technical skills, leadership, ability to research beyond a textbook, innovation, hands-on learning experiences, interdisciplinary skills, work experience, and reflection [5].

The third type of engineering leadership programs are engineering college-wide initiatives, which include, Northwestern University, Southern Methodist University, and Brigham Young University, and James Madison [5], [6]. These programs focus on interdisciplinary skills that build on technical competencies from the core engineering courses. These programs, therefore, offer individual elective courses that, in some cases, satisfy engineering technical elective credits or certificates in EL. Unlike the other two types of EL programs, these are the most flexible for students, as students can take a few courses or complete the track or certificate, based on the student's interests. These programs also use project-based learning to develop innovation and creativity amongst students.

For many of these programs, "Leadership is a process whereby an individual influences a group of people to achieve a common goal" [7]. However, to bring this definition into the engineering classroom and facilitate engineering leadership development, some programs have crafted frameworks for engineering leadership development [9], [10], [12], [13]. For example, the Gordon Institute of Engineering Leadership at Northeastern University [9] uses a fourteen-point framework for leadership development (Figure 1).

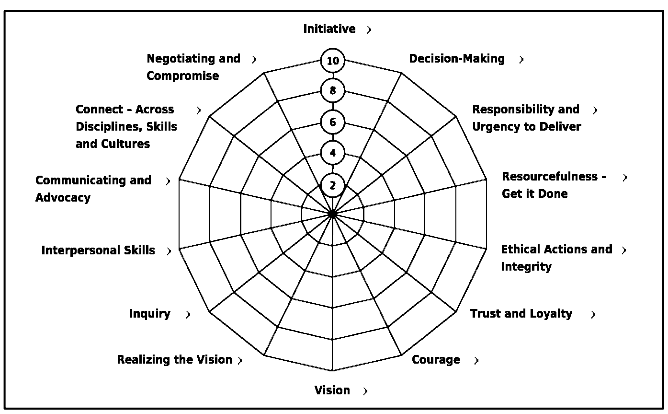

Fig. 1. Northeastern University's fourteen-point framework for leadership development [9]

Similarly, Iowa State University's Engineering Leadership Program developed a Leadership Model via a collaboration between engineering faculty, staff, and students [10]. It includes eight learning outcomes:

1. An ability to function on interdisciplinary teams
2. An understanding of professional and ethical responsibility
3. An ability to communicate effectively
4. The broad education necessary to understand the impact of engineering solutions in a global and societal context
5. A recognition of the need for, and the ability to engage in, life-long learning
6. An ability to create a vision, articulate it, and inspire others to share and implement it
7. An ability to effectively influence and innovate to deliver results
8. Recognition of the need for actively encouraging diversity and creating an inclusive environment

Note that the first five outcomes are familiar to many American engineering educators, as they mirror the ABET accreditation requirements for engineering degrees [11].

At Penn State University, they developed an engineering leadership framework that includes three distinct categories: core leadership, business basics, and strategic planning (Figure 2). When taken together, these categories lead to the development of global competencies, project management, and innovation management and are applied to projects in developing nations [12].

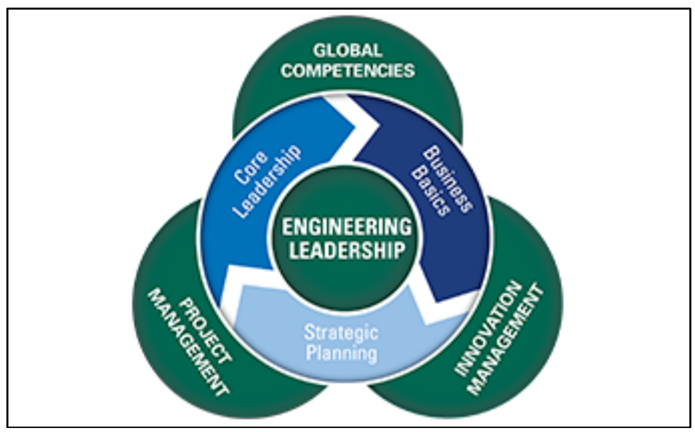

Fig. 2. Penn State University's Engineering Leadership Framework [12]

Each of the development categories are highlighted within both their undergraduate certificate and their graduate certificate. Penn State designs their courses and certificates to ensure students gain competency in these areas.

Northwestern University's framework defines an effective leader based on nine concepts [13]:

1. Start with questions, not answers
2. Learn what motivates those around you
3. Play to your strengths
4. Enable the excellence of others first
5. Select a few challenging experiences
6. Experiment, observe, learn, apply…repeat
7. How you lead→ why you lead
8. Build resilience through risk and failure

9. Build a network of trusted advisors

Northwestern's program is designed to help students become proficient in these nine areas, and thereby develop as engineering leaders. Like many other programs, they highlight hands-on learning as well as reflection. One unique element of the Northwestern framework is their emphasis on helping students learn to build their network of colleagues, mentors, and advisors.

However, none of the described programs include an entire undergraduate degree dedicated to engineering leadership development alongside technical engineering. Therefore, in this paper, we describe the framework for engineering leadership development currently being implemented in the first undergraduate bachelor's degree focused on engineering leadership. Further, we explore how this framework is implemented in the E-Lead program, and the specific feedback students have on the leadership development activities in this degree.

II. Engineering Leadership at The University of Texas at El Paso

At the University of Texas at El Paso (UTEP) was have an undergraduate Bachelor of Science in Engineering Leadership (BSEL, also known as E-Lead) that was established in the fall of 2014. The initial vision came from our then Dean, based on Duderstadt's report "Engineering for a Changing World" [3]. The Dean's vision for the E-Lead program was to have a medical school model for engineering education with an emphasis on leadership due to the high demand for engineers with professional skills [1]. As of fall 2017, we had 77 students in the major with ~15-20 in each cohort. As an engineering degree, we will be pursuing ABET accreditation in 2019-2020.

The first degree of its kind in the nation, this new degree is housed in the Engineering Education and Leadership Department and has a heavy emphasis on integrating fundamental engineering theory and skills with business acumen and leadership development (e-lead.utep.edu). In developing the leadership component of the degree, the faculty understood that one of the most effective methods by which people learn to develop as leaders is through practice. Therefore, rather than place all leadership development in a single course, the degree was designed to have a coordinated thread of leadership development throughout the degree plan, encompassing both curricular and extracurricular opportunities.

One of the unique features of this degree is that leadership development is integrated throughout what is essentially a general engineering degree that also incorporates design thinking, business acumen, and technical engineering. As such, the technical team-based projects serve as the main mode of engineering leadership practice [14], [15]. Two required professional practices help to further expand this experience. As a result, our students pursue a variety of traditional and non-traditional engineering career paths, from becoming entrepreneurs to working for large engineering firms (see Results section for additional details on where students in the first graduating cohort are now employed).

A. *UTEP Engineering Leadership Framework*

Based on a similar model used at West Point, we think of leadership development from the perspective of the 3 C's: Character (who you are), Capacity (what you can do), and Competence (what you know) [16]. We believe that an effective leader has a deep understanding of who they are, what they are doing, why they are doing it, and have the necessary skill sets needed to bring the right group of people together to carry out their shared vision. This is all couched in the context of engineering (Figure 3). However, for us, the distinction of leader vs. engineering leader is not explicit. All teaching of leadership is done in the context of engineering projects. Further, we do not believe that we are producing ready-made leaders. Rather, we are accelerating the potential for our students to lead in a variety of environments based on their interests, values, and passions.

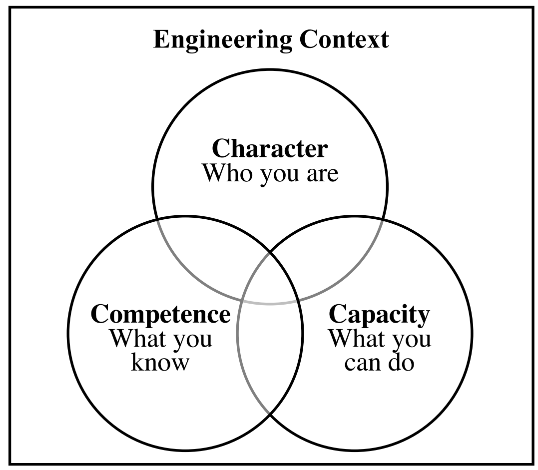

Fig. 3. E-Lead Engineering Leadership Framework

In the E-Lead program, we do not subscribe to any single theory of leadership beyond the framework above. Rather we survey a variety of theories in our courses through the use of Northouse's text [7]. Therefore, the closest we come as a program to emphasizing a single leadership theory is that of Situational Leadership, in that the style and theory of leadership that should be at play depends on the context and requirements of the people and opportunity at hand [17].

Engineering leadership development is an explicit goal of our program. Not only is it in the title of the department and the degree, but it motivates everything we do and how the degree has been designed. When we have conversations in class or when there are moments when students need to be corrected, it often falls back to "what would an effective leader do?". For example, when our students do not turn in homework on a team project because they did not feel like it, the conversation may revolve around asking what is going on in the student's life as well as reminding them that that is not the behavior of an effective leader.

When compared to other EL frameworks, such as those above, our framework is largely inclusive of the other frameworks, as things like courage, trust, and loyalty could be considered elements of a leader's character. However, our framework differs in that it is not a prescriptive list of required skills or attributes but is an actionable framework for where leadership development should be facilitated based on the unique context and values of the student, faculty, companies, and program in which it is applied.

B. Integration of Engineering Leadership in the Degree

In the E-Lead program, we do not offer a single leadership course. Rather, leadership theory is dispersed throughout the BSEL core courses and practice is fostered through our culture, teamwork on projects, and an advanced set of immersion activities available to students based on their level of interest. Therefore, leadership development is intentionally scaffolded to help our students build the capacity to achieve a variety of leadership attributes.

In doing so, we used a curriculum integration model similar to that of the Threaded Model described by Fogarty [18]. The threads in our program include engineering leadership, design thinking, entrepreneurship and innovation, and business acumen. The following is a description of how we have created this thread of leadership, alongside the other threads, throughout the degree. Of the 125-hour degree plan, the E-Lead program directly teaches two core-courses per academic year. Therefore, students also take general engineering and university core courses along with their E-Lead courses.

In our first-year courses, we begin with a focus on helping students develop intrinsic motivation [19] and personal identity [20]. By person identity, we do not strictly mean engineering identity, though that is included, but a growing awareness of their attributes and skills as it pertains to self-actualization and leadership. We believe this is important for students who are just beginning their leadership journey. Especially those at UTEP, a Hispanic Serving Institution where our student body largely consists of low-income and first-generation college students [21]. This first year, therefore, focuses on the *character* element of our framework.

In the second year, the courses focus on developing fundamental analysis and engineering skill sets. As we do so, we seek to build upon how their skill sets identified in their first year can be used to analyze complex data (whether quantitative or qualitative). This year, therefore, focuses on engineering *competence* as it relates to leading engineering teams. Leadership *competence* is integrated through the use of leadership texts and case studies in each E-Lead course.

In the third year, courses are built around understanding customer needs to develop effective products within an entrepreneurial space. Combined with the analysis skill sets developed during their second year, the experiences lead to a combined development of competence and capacity to deal with the unknown aspects of design thinking. Further, leadership in a teaming environment that must respond to customer needs is the emphasis in the third year. Therefore, the third year of the program focuses on student's *capacity* to lead.

The fourth-year capstone courses are meant to combine all of the educational experiences students have had in serving an external customer/client with a non-theoretical multifaceted problem in an expanded team environment that is loosely scaffolded. These two courses resemble traditional capstone senior design courses, but with the additional requirements that each client must present a problem that is not solely an engineering design project but must contain a high degree of other mitigating factors within business, customer satisfaction,

TABLE I. ENGINEERING LEADERSHIP DEVELOPMENT ACTIVITIES ACROSS THE E-LEAD PROGRAM

E-Lead Leadership Development Overview										
	1st Year		**2nd Year**			**3rd Year**			**4th Year**	
Themes	Values Leadership Exposure									
	Leadership Foundation		**Leadership Tactics**			**Leadership Strategy**			**Leadership Philosophy**	
Outcomes	Fall Leadership Exposure	Spring Leadership Awareness	Fall Small Scale Practice	Spring Small Scale Practice	Summer 1 Lead & Manage	Fall Large Scale Practice	Spring Large Scale Practice	Summer 2 Field Applications	Fall Management Define Self	Spring Management Define Self
FOR ALL										
Course Title	Fundamentals of Engineering Leadership and Graphics	Design Nature	Modeling and Simulation	Engineering Measurements	Professional Practice 1	Engineering Design: People to Products	Engineering Entrepreneurship: Products to People	Professional Practice 2	Senior Capstone 1	Senior Capstone 2
Assessment	Self Assess	Self Assess	Peer Assess Self Assess Faculty Assess	Peer Assess Self Assess Faculty Assess	Self Assess Mentor Assess	Peer Assess Self Assess Faculty Assess	Peer Assess Self Assess Faculty Assess	Self Assess Mentor Assess	Peer Assess Self Assess Faculty Assess	Peer Assess Self Assess Faculty Assess
Activities & Experiences	*Northouse:* Chpts. 1, 2, 3 Individual Identity Project, Small Team-Based Rat Trap Car Project	*Northouse:* Chpts. 12, 14 Small & Medium Team-based Bio-Inspired Design Projects	*Northouse:* Chpts. 4, 5 Individual and Small Team-based Systems Modeling Projects	*Northouse:* Chpts. 6, 15 Small Team Engineering Measurements Projects	Professional Practice 1 (Field Opp, Internship, Com. Service)	*Northouse:* Chpts. 7, 8 Team-based Human Centered Design Projects	*Northouse:* Chpts. 11, 16 Team-based Business Model Semester Project	Professional Practice 2 (Field Opp, Internship, Com. Service)	*Northouse:* Chpts. 9, 10 Year-long Team-based Project with Industry Partner	*Northouse:* Chpt. 13 Year-long Team-based Project with Industry Partner
	ePortfolio development to showcase projects, internships, and leadership initiatives									
FOR MANY										
Assessment						Spot Assess	Spot Assess		Spot Assess	Spot Assess
Activities & Experiences	Mining for E-Leaders - Mentee	Mining for E-Leaders - Mentee	Mining for E-Leaders - Mentee	Mining for E-Leaders - Mentee		Mining for E-Leaders - Mentor	Mining for E-Leaders Mentor		Mining for E-Leaders - Mentor	Mining for E-Leaders - Mentor
	Ropes course every 2 years									
	E-Lead Student Organization Planned Activities									
	Attend UTEP Leadership Alive Seminar and/or the Halliburton Series on Leadership									
FOR FEW										
Activities & Experiences		Ethics Conf.	Intern/Observation TA in E-Lead	Intern/Observation TA in E-Lead	Intern/Observation	Intern/Observation Project Team Lead TA in E-Lead	Intern/Observation Project Team Lead TA in E-Lead	Intern/Observation	Intern/Observation Capstone Team Lead	Intern/Observation Capstone Team Lead
	E-Lead Student Organization									
	Attend a Signature Event									
			Student Senate Leader							

and environmental constraints. This fourth year is, therefore, the opportunity for students to exercise their character, capacity, and competence in a quasi-real-world environment on a meaningful project.

C. Implementation of the EL Framework

As a program, we tend to fall more heavily on the practice, rather than theoretical, side of teaching engineering leadership. We believe the theory one finds in a textbook on leadership is intuitive enough to our students that if we put them in a leadership situation, they will come up with a leadership framework. Then, based on reflection, we reinforce their learning and provide them with leadership vocabulary through teaching theory. Therefore, we implement a framework where there are specific development activities designed for all students, many students, and a few students based on their level of interest (Table I). The specific activities are selected to emphasize each of the elements of our engineering leadership development framework: Competence, Capacity, and Character. These activities are highly experiential and are intentionally designed not to be just a cognitive exercise with a reanalysis of concepts presented. Therefore, we have incorporated best practices and concepts presented in the literature (e.g. [14], [22], [23]) and adapted them in collaboration with Olin College (www.olin.edu) to achieve the outcomes of our program.

For all students, our program relies heavily on teaching leadership theory through both case studies and practice in the context of teaming experiences. Therefore, our primary leadership text, used in all eight core courses, is Northouse's *Leadership: Theory and Practice* 7th Ed. 2005. Similarly, we use Mohit Arora and Haig Baronikian's *Leadership in Project Management*, 2nd Ed. 2013. Development of specific in-class activities for the assigned chapters in each course is largely left up to the discretion of the instructor-of-record. Typically, however, these activities include group discussion of case studies and application of concepts in ongoing engineering projects. In contrast, for many students, we facilitate extracurricular activities such as ropes challenge courses, the Mining for E-Leaders Mentoring program, student organization leadership, and other leadership development workshops. For a few students, we also offer leadership opportunities within E-Lead as a teaching assistant, mentoring opportunities with community members, and off-site leadership conferences.

In teaching engineering leadership, we seek to design our courses to be as intrinsically motivating and as realistic as possible to the experiences that our students can expect when they begin their careers. Motivation, specifically intrinsic, is important to us as that is a Character quality that tends to stand out in effective leaders. We have, therefore, largely relied on a flipped, project/problem-based approach to teaching as this allows for ample time to provide teaming experiences for students to practice their leadership skills and for students to receive feedback from peers and faculty on their leadership development [24], [14], [15]. In one course, we take student leadership development and intrinsic motivation to such an extreme that past students re-design and teach the course, under faculty supervision, each semester [25].

In developing our students as engineering leaders, we heavily emphasize the role of value. To us, value is a subcomponent of character in our framework. As such, we spend the first few weeks with our students on an Identity Sculpture where they attempt to express who they are, where they are coming from, and where they are going. In other words, we want our students to begin to understand who they are and what they value before they attempt to lead others. Value also comes into play in the focus of the engineering design projects our students work on. At the core of our philosophy of design, is a human-centered approach that focuses first on the needs of the user before the generation of solutions and business models [26]. Further, value also comes into play in our entrepreneurship course where students must weigh the needs of a company with those of key partners and stakeholders and the impact it will have on users or the environment.

D. Research Question

The focus of this paper is on describing our framework and its implementation. Also, we seek to begin validating our approach, by determining the impact that the implementation of this framework has had on our graduate's engineering leadership development. However, leadership is notoriously difficult to assess. As a program, we are still determining the effectiveness and appropriateness of our assessment plan. Currently, assessment is done by faculty, peers, mentors, and clients, many on an informal non-structured basis. Therefore, the goal of this study is to help begin that assessment process by understanding the perspectives of recent graduates on the impact the activities have had on their pursuit of a career. From there, we will be able to adjust the design of the program as well as our leadership assessment plan to incorporate both qualitative and quantitative measures. As such, we seek to answer the following research question using a qualitative approach: Which activities did graduates believe most impacted their leadership development?

III. METHOD FOR ASSESSING IMPACT OF FRAMEWORK ON EL DEVELOPMENT

To answer this research question and begin to assess the impact of the E-Lead framework, we conducted semi-structured interviews with recent graduates of our program. The interviews were conducted in-person or over the phone based on the participant's preference. Lasting approximately 30 minutes, the interview included a mixture of open-ended and Likert-style questions. Our Institutional Review Board approved this human subject research before initiation.

Following two questions related to participant demographics, the remaining twenty-one interview questions were framed around understanding the impact of the E-Lead program on career goals, shifts in their perspective of engineering leadership, specific applications of their learnings from E-Lead, aspects of the program they believe could be improved, and which experiences most impacted the development of their character, capacity, and competence. To determine the relative impact of each major course and extracurricular activity, two Likert-style questions asked participants to rate each course and major activity on a scale of 1 to 5, where 1 is "not at all" and 5 is "a great deal". Questions were also included to allow students to reflect on their experiences outside of E-Lead for comparison and to expand on responses in the Likert-style questions. The audio was recorded for each interview and transcribed for qualitative thematic analysis [27].

As we have thus far only had one graduating cohort from the spring of 2017 at the time of data collection, the total potential population size is relatively small (n=11). We have thus far been able to complete interviews with eight of these graduates, resulting in a response rate of 73%. Participants were contacted via email, telephone, and social media to schedule the interview. Interviews were not conducted by a faculty member in the program, but by undergraduate research assistants. Of those that completed the interviews, two identified as female and six identified as male. All identified as being of Hispanic ethnicity. The study participant demographics are representative of the UTEP College of Engineering, where 20% of our students are female and 80% identify as Hispanic [21].

IV. Results

Responses from all eight participants were transcribed and coded for common themes. Responses resulted in the following themes: impact of the E-Lead program on student's occupation and on building character, capacity, and competence; evolution in their definition of leadership; relative impact of each E-Lead course; relative impact of major E-Lead curricular and extracurricular activities; non-E-Lead curricular and extracurricular activities; and, finally, suggested changes to the E-Lead program. For Likert-style questions, descriptive statistics were calculated due to small sample size.

A. *Impact of the E-Lead Program on Student Occupation and Leadership Development*

Of the students that completed the interviews, two were in traditional engineering positions, two in management positions, one was a small business owner, and one was working in customer service. The other two were still pursuing their education. When asked about why they pursued their current occupation, students reported a variety of motivations. Three students reported that their professional practice experience, a requirement of the E-Lead program, was the main reason they chose their occupation. Others reported their need for financial stability, the influence of an E-Lead mentor, or their desire to pursue a personal passion as the reason they pursued their current occupation.

When asked about the overall impact and role that the E-Lead program has had on helping them prepare for their current occupation, six participants believed that the program helped them obtain their current position, either due to the training received or the networks established. For example, as one student stated, "E-Lead helped me to realize that besides just the technical world of engineering, there's a lot more to be taken account for. For example, the communication skills, I really think this position has helped to build on those communication skills, and also the program itself, all the presentations that we do, all the interactions that we have with professors, and other people, pushes you out of the comfort zone that you're in, to explore and grow, and, in order to be a good engineer, you need to be aware of this."

When asked about the specific experiences in the E-Lead program that most impacted student's Character (who you are), Capacity (what you can do), and Competence (what you know), given their, on average, 10.4 months of employment, there were several stand-out activities reported. With regards to Character, Students commented on how it was the experiences in E-Lead that forced them to decide who they are as a leader and reflected their character. Specifically, two students pointed out that the emphasis on reflection helped them build their character. Two other students mentioned the amount of time spent on team-based projects. Three others specifically mentioned the experiences during the third year and how the interaction with customers helped them refine their character.

For building Capacity, two students again pointed to group-based projects as key experiences that built their capacity to lead. Two other students pointed to the training and practice they received in developing their interpersonal skills. One student mentioned that the mentorship of the faculty is what helped them develop their capacity to lead. The final student pointed to their involvement in student organizations. As one student put it, "[…] the emphasis that they placed on group projects and working in those group contexts helped my capacity. Senior design, right, where we were given this […] objective, we were given a client, we were given a set of vague set of specifications, and we had to kind of come up with something. [That] Was something that helped me become more comfortable in those types of situations and take control, to a certain degree, and to be able to produce a final product." As another student put it, "I would say the group projects that we had in those courses and the interactions that I had with the people in my groups were definitely a big part of it. The conflict that we encountered. For example, senior design, we had a problem with one of the group members. And we had to learn to work around that; it's something that I employed. Right, because out in the field there also are people that don't want to do their work, kind of thing. So, learning to deal with that and in the end still getting the job done without burning yourself out is a big, big thing."

With regards to Competence, students pointed to not only the leadership textbooks and activities in-class but also the overarching emphasis the program places on learning *how* to learn. As one student put it, "From the start, E-Lead was very heavy on not just teaching you things, but kind of helping you to learn how to learn." According to the graduates, this degree prepares them well for occupations where they need to be more than just an engineer.

When asked about the impact that the E-Lead program had on student's definition of leadership, students described how their definition evolved from being more hierarchical and position based, to something more fluidic and based on the specific context and people involved. As one student described it, "[B]efore the E-Lead program, I always thought a leader was somebody who was a boss, and I don't think about it that way anymore. Being a leader is somebody who helps a group of people in a constructive manner to reach goals…before, I just thought a leader was just somebody who gave orders." We see a pattern of students having a more nuanced definition of leadership after completing the program and all of the teamwork and leadership positions they acquired through the degree.

B. Impact of E-Lead Courses

Realizing that students were reporting an impact on their leadership, we now turn our attention to the specific courses in the program to identify which ones were having the greatest impact. In doing so, we can identify strengths and weaknesses in the degree plan. To determine the impact of each course, students were given the following prompt: “On a scale of 1 (not at all) to 5 (a great deal), how much did the following courses help you develop as an engineering leader.” Students were asked to rate the ten EL courses and other non-EL courses in general. The average rates for each course are summarized in Table II.

TABLE II. PROGRAM COURSE RATINGS

On a scale of 1 (not at all) to 5 (a great deal), how much did the following courses help you develop as an engineering leader?	**Average**	**STDEV**
EL 1405 Fundamentals of Engineering Leadership and Graphics	2.4	1.9
EL 1302 Intro to Engineering Design and Leadership (a.k.a Design Nature)	3.8	1.5
EL 2301 Modeling and Simulation (a.k.a. Mod Sim)	3.1	0.4
EL 3302 Engineering Measurements (a.k.a. Real World Measurements)	3.3	1.3
EL 3331 Engineering Design: People to Products	4.3	0.5
EL 3304 Engineering Entrepreneurship: Products to People	4.3	1.0
EL 4395 Capstone Design I: Definition & Exploration	4.7	0.5
EL 4396 Capstone Design II: Development & Evaluation	4.7	0.5
EL 3003/3103 Professional Practice I	4.6	1.1
EL 3005/3105 Professional Practice II	5.0	0.0
Other non-E-Lead courses?	2.6	1.0

When asked to rate each E-Lead course, seven out of eight students, thought that the most helpful courses were the professional practice courses (Professional Practice 1 had an average score of 4.57, and Professional Practice 2 had an average of 5). In these courses, students have an opportunity to apply what they have learned from the program in an internship or community service activity of their interest. These courses were the highest scoring because the students enjoyed learning about something they are passionate about and in applying what they have learned in the program. As one student described it, “We have to focus on the things we love. That is what I love about E-Lead. You get to work on things that you love.” The second most impactful course is the capstone design course. This may be because the students were beginning to feel like they were in a real working environment while working on a project that required them to meet deadlines while simultaneously dealing with the stress of life, work, school, or social obligations. According to one student, "[Capstone] is hard because they are trying to give us a real-life problem in the industry setting, especially for the technical knowledge". Close behind the capstone design courses, students also reported that People to Products (average of 4.3) and Products to People (average 4.3) were helpful because students were able to see the business aspect of engineering and saw the real struggle of running a business and the implications it had on their leadership styles. Further, students reported that these courses helped them develop their capacity and competence at the same time because they had to understand what the customer wanted and make it happen. Further, when compared to non-E-Lead courses, students felt that the E-lead courses were helping their leadership development considerably (2.57 vs. 4.06).

Overall, in Table II, there is a gradual increase in the student's sense of the leadership and skills that they are learning throughout the program. This is not a surprise as this was the first time these courses were being offered and, to an extent, the program was continuing to hone course activities. While different instructors were teaching each of the courses, the curriculum development was done collaboratively, and therefore, the program improved overall alongside student leadership development. However, it should be noted that students and faculty did not feel that the first course met the expectations of the program and was completely redesigned the following year [25]. Thus, scores for the first course likely changed in following years. Although the class has since improved, it is still not a five according to one student, “For 1405, when I took it, it was very different to what it is now, so I gave it a one. When I took it, it was very bad. If I were to rate it to what I see now, I would give it a 4.” The remaining courses have not had quite the same level of redesign, only seeing minor revisions along the way. Also, the ModSim and Real World Measurements courses are more traditional in their design and more technical in their focus. Therefore, it is also not surprising to see somewhat lower leadership scores as these courses do not offer as many leadership development opportunities as those in the third and fourth years.

C. Impact of Individual Curricular and Extracurricular Activities

After reviewing each course at a high level, we now turn to individual activities to assess the impact they have on student engineering leadership development. These activities and the average scores from participants are listed in the largely chronological order in Table III. This list includes both curricular and extracurricular activities. E-Lead curricular activities include the corresponding course number.

Overall, individual mentors had the strongest impact on student's leadership development (average score of 5). Students expressed how their mentors helped them not only succeed in their educational endeavors but also in their personal life. As one student put it, the reasons why it helped them was because the mentor encouraged them to network and maintain a balanced life.

The second strongest impact was the activities within the E-Lead courses (overall average of 4.2). The projects that students reported helped them the most was the People to Products semester-long project (4.4) and the Products to People business model development project (4.6) that occur in the junior year as part of an innovation and entrepreneurship course sequence. As one student put it, "[these projects] helped me to put all of the pieces together. It asked me to be technically proficient, and it asked me to deal with people in a group setting, and it asked for [for me to] manage a lot of different things to be able to have a successful product."

Going in the opposite direction, other curricular and extracurricular activities were the lowest scoring activities (2.0 and 2.9 respectively). In fact, many expressed that the extracurricular activities were more of a distraction rather than helpful in their career trajectory. Of the E-Lead activities, the Inside Out Project, an identity sculpture, was the lowest scoring (3.5). Students did not understand the reason behind the project and expressed feeling like the point of the project was not clearly stated. Therefore, they did not understand the significance of the project. As discussed previously, this is not surprising as the course has been since wholly redesigned.

TABLE III. PARTICIPANT SCORES FOR INDIVIDUAL CURRICULAR AND EXTRACURRICULAR ACTIVITIES

On a scale of 1 (not at all) to 5 (a great deal), how much did the following activities help you develop as an engineering leader?	Average	STDEV
Inside Out Identity Sculpture Project (EL 1405) *Only three responses	3.5	2.1
Inventor Nature-Mimicking Project (EL 1302)	4.2	0.8
Board Game project featuring Nature Mimicking element (EL 1302)	4	0.7
Sharks-Rays-Scallops Project (EL 3201)	3.8	1.1
Mod-Sim Final Project and poster competition (EL 3201)	4	1.0
People to Products design project (EL 3331)	4.4	0.5
Products to People business model development project (EL 3304)	4.6	0.5
Senior Design Project (EL 4395 and EL 4396)	4.4	0.5
Professional Practices (EL 3003/3103 and EL 3005/3105)	4.2	0.8
Professional development books in E-Lead courses (such as Good to Great or Designing your Life)	4	0.7
Participation in a student organization	3.6	0.9
A particular mentor or role model in E-Lead	5	0.0
Other extracurricular activity	2.9	1.1
Other curricular activity	2	1.2

D. *Suggested Program Improvements*

There were various points of view on what should be done to improve the program. Other than the redesign of the EL 1405 course, the most common (2 responses), was the desire to see the technical aspect of the leadership courses enhanced. Other recommendations included providing more leadership experiences, continued involvement of students in developing the program, and bringing in more guest speakers. Interestingly, one student also pointed out that student buy-in is important, potentially more important than improving the program or changing the way the faculty teach. As they put it, "I believe it depends on the student, not on the professors. We need to understand professors are not going to give us the qualities or anything, they are just going to show us the tools, and we have to know what we want to do and how we want to do it. We need to change something, but it is not up to the professors, it's the students. The professors need to have higher standards."

V. STUDY LIMITATIONS AND FUTURE WORK

One major limitation of this study was the available sample size. Only eleven students had graduated from the program at the time of data collection. However, we partially overcame this limitation by treating this by ensuring that we had a high response rate (73%). Further, as the students interviewed were from the first graduating class, most have not completed some of the activities and experiences now available to students currently in the E-Lead program, such as the redesign of the EL 1405 course.

Further, the responses from students were self-reported based on a small amount of experience post-completion of the program. Therefore, one area of future work in this project is to begin assessing engineering leadership development in the program from a qualitative perspective at key milestones in the degree plan. Also, we would like to survey students after they have had several years of experience post-graduation. However, now that we have feedback from students about their general experience in the program, we plan to incorporate that feedback into a more comprehensive mixed-methods assessment plan that utilizes qualitative and quantitative approaches.

VI. CONCLUSION

Based on the 3C's Framework for Engineering Leadership development in the E-Lead program, this paper describes the framework used for leadership development and the key activities dispersed throughout the engineering leadership thread. Further, this study sought to determine which activities used to implement this framework most impacted student engineering leadership development. Based on interviewing 73% of our first graduating cohort, students identified specific activities that most influenced their leadership development. Of the leadership development activities, graduates reported that individual mentors had the strongest impact on student's leadership development (average score of 5). The second strongest impact were those activities within the courses (overall average of 4.2). The weakest were those activities outside of class not explicitly associated with E-Lead, such as student organizations and extracurricular activities, and other curricular activities outside program (2.9).

REFERENCES

[1] "The Engineer of 2020: Visions of Engineering in the New Century." National Academy of Engineering, 2004. [Online]. Available: https://nae.edu/Publications/Reports/25876.aspx [Accessed March 19, 2018].

[2] R. Graham. "Achieving Excellence in Engineering Education: The Ingredients of Successful Change," Royal Academy of Engineering, 2012. [Online]. Available: https://www.raeng.org.uk/publications/reports/achieving-excellence-in-engineering-education [Accessed Feb. 2, 2018].

[3] J. J. Duderstadt, "Engineering for a Changing World," in *Holistic Engineering Education*, Springer, New York, NY, 2010, pp. 17–35.

[4] S. Stawiski, A. Germuth, P. Yarborough, V. Alford, and L. Parrish, "Infusing Twenty-First-Century Skills into Engineering Education," Journal of Business and Psychology, vol. 32, no. 3, pp. 335–346, Jun. 2017.

[5] M. Klassen, D. Reeve, C. Rottmann, R. Sacks, A. Simpson, and A. Huynh, "Charting the Landscape of Engineering Leadership Education in North American Universities," 2016.

[6] M. R. Kendall, D. Chachra, K. Roach, E. Tilley, and K. Gipson, "Convergent Approaches for Developing Engineering Leadership in Undergraduates," in *ASEE Annual Conference and Exposition*, Salt Lake City, UT, 2018, p. 20.

[7] P. G. Northouse, *Leadership: Theory and Practice*. Sage Publications, 2015.

[8] D. Reeve *et al*., "Curricular and co-curricular leadership learning for engineering students," *Collected Essays on Learning and Teaching*, vol. 8, no. 1, pp. 41–56, 2015.

[9] "Curriculum - The Gordon Engineering Leadership Program at Northeastern University | The Gordon Institute of Engineering Leadership at Northeastern University." [Online]. Available: http://www.northeastern.edu/gordonleadership/about-the-institute/curriculum/. [Accessed: 04-Feb-2018].

[10] K. S. Athreya and M. T. Kalkhoff, "The Engineering Leadership Program: A co-curricular learning environment by and for students," *Journal of STEM Education: Innovations and Research*, vol. 11, no. 3/4, p. 70, 2010.

[11] "Mapping of Criterion 3: A-K to Criterion 3: 1-7," ABET, 2018. [Online]. Available: http://www.abet.org/wp-content/uploads/2018/03/C3_C5_mapping_SEC_1-13-2018.pdf. [Accessed March 19, 2018].

[12] "Penn State Engineering: Engineering Leadership Development Program", Sedtapp.psu.edu, 2018. [Online]. Available: http://www.sedtapp.psu.edu/eld/index.aspx. [Accessed: 01- Jun- 2018].

[13] "Advance on Leadership: - Northwestern University", Lead.northwestern.edu, 2018. [Online]. Available: https://lead.northwestern.edu/leadership/index.html. [Accessed: 01- Jun-2018].

[14] S. Bell, "Project-Based Learning for the 21st Century: Skills for the Future," *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, vol. 83, no. 2, pp. 39–43, Jan. 2010.

[15] K. Cain and S. Cocco, "Leadership Development through Project Based Learning," *Proceedings of the Canadian Engineering Education Association (CEEA)*, Montreal, QC, June 2013.

[16] "Building the Capacity to Lead," United States Military Academy, West Point, New York, 2009. [Online]. Available: http://www.usma.edu/strategic/siteassets/sitepages/home/building%20the%20capacity%20to%20lead.pdf. [Accessed March 19, 2018].

[17] Hersey, P. and Blanchard, K. H. (1977). Management of Organizational Behavior 3rd Edition– Utilizing Human Resources. New Jersey/Prentice Hall.

[18] R. Fogarty, "Ten Ways to Integrate Curriculum," *EDUCATIONAL LEADERSHIP*, p. 6, 1991.

[19] R. M. Ryan and E. L. Deci, "Intrinsic and extrinsic motivations: Classic definitions and new directions," *Contemporary educational psychology*, vol. 25, no. 1, pp. 54–67, 2000.

[20] J. P. Gee, "Identity as an analytic lens for research in education," *Review of research in education*, vol. 25, no. 1, pp. 99–125, 2001.

[21] C. Lester, A. Barua, M. Yee Kim, X. Wang *et al*. "The University of Texas 2014-2015 Fact Book," 2015. [E-book]. Available: http://cierp2.utep.edu/pastfactbooks/UTEP%20Fact%20Book%202014-15.pdf

[22] S. Snook, N. Nohria, and R. Khurana, The handbook for teaching leadership: Knowing, doing, and being. Sage, 2012.

[23] E. V. Velsor, C. D. McCauley, and M. N. Ruderman, *The Center for Creative Leadership Handbook of Leadership Development*. John Wiley & Sons, 2010.

[24] J. L. Bishop and M. A. Verleger, "The flipped classroom: A survey of the research," in *ASEE National Conference Proceedings, Atlanta, GA*, 2013, vol. 30, pp. 1–18.

[25] Y. Montoya, A. E. P. Rimada, E. I. Delgado, I. N. Webb, and M. R. Kendall, "Developing Leaders by Putting Students in the Curriculum Development Driver's Seat," in *2015 ASEE Annual Conference & Exposition*, 2015.

[26] The Field Guide to Human-Centered Design. IDEO.org, 2015.

[27] J. Fereday and E. Muir-Cochrane, "Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development," *International Journal of qualitative methods*, vol. 5, no. 1, pp. 80–92, 2006.