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Evaluating the Effectiveness of an Undergraduate Engineering Leadership Development Minor on Graduates

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Abstract

Leadership development programs aim to meet the professional development needs of our graduates while aligning program curriculum to the needs of our graduates' employers. This research paper reports assessment results from a survey of alumni from an undergraduate engineering leadership development (ELD) program as well as undergraduate engineering students not in the leadership program that served as comparisons. The overarching goal of the study was to assess the degree to which the program is meeting its leadership development goals, which include ensuring that the program targets the skills needed in today's workplace. Graduates of the ELDM program (n=147) and graduates not in the program (n = 133) were surveyed and compared to better understand the impact of the ELDM program on the development of skills needed for today's engineering work. Alumni from both groups were asked to rate their agreement with how well their undergraduate experience (and ELD minor specifically) prepared them for their professional career with respect to a number of leadership competencies: 1) leading teams (lead meetings, identify personality preferences and adjust environment/style) 2) think strategically by applying mission, vision, and values statements to a team or organization 3) work effectively in teams 4) apply project management processes to projects 5) give and receive feedback 6) self-reflection on leadership skills and how to improve 7) recognize ethical issues & practice ethical decision making 8) develop a culture that promotes creativity and innovation 9) cross cultural/ global competencies (appreciation of other cultures, understanding bias, working in a culturally diverse team) 10) emotional intelligence (regulate emotions and manage conflict) 11) communicate effectively (oral and written, adapt to audience) 12) understand basic business concepts (finance, accounting, marketing, supply chain/operations) 13) confidence in taking initiative with new responsibilities within the organization. Ratings were made using a Likert scale: Extremely well, Fairly well, Moderate, Poorly, Not at all) for each skill separately. Both groups also rated the importance of each skill to their professional work. Differences in alumni's' evaluation of their undergraduate program's preparation for their professional career and importance of leadership skills were evaluated between engineering leadership development minor (ELDM) alumni compared to non-ELDM College of Engineering (CoE) alumni (CoE Comparison Group). Out of the 13 competencies listed above compared across the ELDM and the CoE Comparison groups, ELD minor participants consistently rated the ELD minor significantly higher than the CoE Comparison group ratings of their undergraduate program at preparing/enhancing their ability for their professional career regarding all the leadership competencies/learning outcomes.

Introduction and Background

From 2016-2026, there is an estimated 139,300 new jobs projected by the Bureau of Labor Statistics in various engineering fields ranging from Civil to Agricultural (Engineers: Employment, pay and outlook, 2018). Yet as the market becomes saturated with prospective

hires, leadership skills such as initiative, communication, interpersonal interactions, teamwork and engagement all become vital aspects of a well-rounded engineering hire (Hartman et al., 2017). Therefore now, more than ever, the success of university engineering programs in their ability to help their engineering students succeed in the job market rests on the curriculum and opportunities provided (Hartman et al., 2017). Building on an understanding that leadership can be taught and learned, additional time needs to be allocated for leadership training. Hartmann et al. (2017) has already validated the importance of engineering leadership in the workplace, and it is important to gain an understanding of how leadership programs are structured along with understanding their impact on graduates to determine the effectiveness and successes of leadership programs. It is important to understand the attributes that today's engineers need for success in their careers and to structure engineering leadership development programs to support the development of these critical attributes. Additionally, engineering leadership development programs also need to regularly assess their programs to ensure that they are achieving the desired learning outcomes and goals of their programs.

Important Skills for the Success of Todays Engineer

It is first important to understand the skills that are needed for an engineer's success by understanding some of the basic ideology in leadership studies. Engineering can be loosely defined as "the study of how to best utilize engineering concepts, methods, and tools and integrate them with information technology and other relevant sciences to generate improved results" (Snee & Hoerl, 2012). When discussing leadership, many do so with respect to differentiating it from management. You can compare a leader and a manager for projects in engineering in how they conduct their work (Burton, 1996). Managers see that work gets done, work within existing technologies, focus on doing what is ethical, work hard to maintain improvements, and manage the overall process (Burton, 1996). Whereas leaders see that work gets done differently and hopefully better, try to mesh groups together to get to the desired goal, focus on doing the right thing, create improvements and lead and develop people (Burton, 1996). In the environment of engineering, it is vital to have both managers and leaders and having more leaders can often quickly advance companies towards future goals. (Semuel et al., 2017). President Dwight D. Eisenhower commented that "Leadership is the art of getting someone else to do something that you want done because he wants to do it" (Hardiman, 2016). To be an effective leader, it is important to understand management processes while having a strong core of leadership ideals (Burton, 1996). When focusing on engineering leadership, engineers need guidance on how to get from point A to point Z when such concepts, methods and tools must be applied in a professional work environment (Compton-Young, 2015).

In order to be an effective leader, engineering students must develop both technical and nontechnical soft skills to provide an advantage in the workplace (Burton, 1996). In current programs, with their demanding engineering curriculums, students often don't have the time or inclination to pursue business courses, which often include the professional skills that engineers lack (Compton-Young, 2015). In a survey conducted by EE Times, 77 percent of the engineers reported they have acted as team leaders and 83 percent have written reports for internal use (Kumar et al., 2007). With this understanding of how engineers can be successful, it is crucial that they possess these skills prior to graduation (Kumar et al., 2007). With previous reports indicating that a majority of engineers lack the soft skills necessary to be successful due to lack

of time or inclination to pursue certain courses (Kumar et al., 2007), an increase in leadership training is becoming increasingly important.

Focusing on leadership specifically, Hartman et al. (2017) report trends in the competencies that companies desire when hiring entry level engineers. These competencies were further organized into the following five main themes: Initiative/ Confidence, Communication, Interpersonal interactions, Teamwork and Engagement (Hartman et al., 2017). Participants in this study were asked questions in each category focusing on knowledge, abilities, and behaviors. One important finding from this study was that all five leadership competencies were deemed important for undergraduates seeking fulltime employment. The ranking from highest to lowest hiring preference was initiative/confidence, communication, interpersonal interaction, teamwork, engagement.

When approaching the development of leadership competencies in engineers, it is important to maintain an understanding of the application of the obtained competencies. Specifically focusing on what exactly employers want and expect for entry level positions regarding non-technical professional skills. One method of developing leadership competencies in engineering students is to design and implement experiences that: include problem solving, are group based, integrate technical and communication skills, deal with business constraints such as schedules and budgets, and build on engineers' identity as problem solvers (The Engineer of 2020, 2005). This is an important structure as it is one that many engineers can relate to during their early engineering education though the basics of the engineering design process (The Engineer of 2020, 2005). Anderson et al. (2010) noted that design projects are often a good approach, but their effectiveness depends on their authenticity, client involvement, complexity, transfer of knowledge and assessment strategies. Not only is the general structure and technique of teaching engineering leadership important but also the frequency at which students' practice (Snee, 2012). The more engineering students understand the field and begin to connect with this sort of professional identity, the more likely they are to remain in engineering (Anderson et al., 2010). Therefore, if engineering students understand the importance of leadership professional skills and practice them frequently, they will have a better connection to the work they are doing in their undergraduate career and will continue to be dedicated in their respective workplace (Hartmann, 2017).

Similar Leadership Development Program Evaluations

Program evaluation is important for leadership programs to ensure that their program is meeting the learning outcomes and producing the desired impact on student's success after graduation. The School of Leadership and Education Sciences (SOLES) at the University of San Diego (USD) reported on the assessment of their leadership development program to gain feedback on areas of involvement, application of knowledge and skills, and to gain information on post graduate employment (USD-SOLES, 2015). For each of the programs offered by USD, ranging from PhD to Masters and non-profit programs, general reviews of areas such as employment rate before and after graduation, salary range, rating of enhanced career preparation, and overall satisfaction were considered. The study reported that 87-88 percent of alumni indicated a positive satisfaction rating across all aspects of the program that were assessed. While the study was limited by their small sample size (n=75), the results are useful in understanding how the

level of the leadership program impacted job placement after graduation. Overall, this study demonstrated results only for individuals who participated in leadership programs before entering the workforce, assisting in the understanding of how leadership training affects job placement after graduation (USD-SOLES, 2015).

Another approach to developing leadership is through engineering ambassador programs (Anagos et al., 2014). A study by Anagnos et al. (2014) compared two similar and semi-connected ambassador programs at two universities, one at Oklahoma State University (OSU) and the other at Howard University (HU). While Engineering ambassador programs can take on different formats, those who participated in them were able to obtain skills necessary for career success (Anagos et al., 2014). Specifically, OSU's program catered more towards presentations, activities, serving as tour facilitators, and as training heads for new recruits (Anagos et al., 2014). The responsibilities of ambassadors in the HU program include recruiting new members, organizing and delivering training to new members, defining program objectives, leading activity logistics, identifying skills and responsibilities for activities, and participating in after event assessments (Anagos et al., 2014). The core values for both programs included promoting research labs and STEM careers, and improving student development (including leadership development) through participation in the engineering ambassador programs (Anagos et al., 2014). A large majority of ambassador program participants felt strongly about the importance of influencing K-12 students about STEM, and around half of those surveyed indicated that they joined for self-improvement and development. Study participants noted that their participation in the program made them a better leader and the impact was greater the longer that they were a part of the program. Overall, this study demonstrated one method for the development of leadership skills as well as the influence of participation time on skill development (Anagos et al., 2014).

Additionally, an older, yet thorough, review from 875 students at 10 different institutions assessed whether student participation in leadership education and training programs impacted their educational and personal development (Cress et al., 2001). This study specifically focused on the knowledge and skills of students and if there were any relationships between leadership development and typical class progression (Cress et al., 2001). The study included pre- and post-survey assessments to evaluate student progress. Multivariate analysis and a hierarchical regression analysis model were used to control for any confounding variables. Results from the study indicated that growth was seen in three main areas: skills (decision making abilities), values (sense of personal ethics), and cognitive understanding (theory-based knowledge) (Cress et al., 2001). Some additional areas of activities such as opportunities for service, experimental activities, and active learning through collaboration directly impacted student development. In addition, this study found that the activity that benefited students the most was well developed group projects. Overall, a very important aspect is that the students who involved themselves the most in leadership training and educational programs had the highest increase in skills and knowledge. From this study, it can be observed that across these 10 universities, common trends emerged that indicated that active participation in group projects for longer durations improved a student's leadership skills and knowledge, making them a more desirable hire post-graduation (Cress et al., 2001).

Leadership skills continue to be an asset that engineers of the future are required to possess (The Engineer of 2020, 2005). Providing high quality content along with applying strategies to reenforce learning will greatly benefit future students (Snee, 2012). With the knowledge of how potential employees are identified by their leadership abilities, undergraduate preparation will continue to grow in importance (Hartman, 2017). It is important for leadership development programs to regularly assess the effectiveness of their programs in meeting their learning outcome goals and to ensure that their development goals are in alignment with industry needs.

The current paper reports on a subset of questions from our larger alumni survey. The overarching aim of the larger study is to assess the impact of the ELD minor on initial job placement (salary and job responsibilities), relevance to job responsibilities, effectiveness in preparing alumni for their job responsibilities, and career progression. The larger study will also evaluate the impact of co-variates such as years of work experience, supervisory responsibilities, discipline, and participation in volunteer activities on alumni perceptions regarding leadership competencies.

The research questions for this paper are:

1) Compared to the CoE Comparison group, do ELDM graduates perceive the minor program to have better prepared them for engineering leadership in the workplace?
2) Do EDLM graduates perceive the engineering leadership competencies as important to their professional work?
3) Compared to the CoE Comparison group, do ELDM graduates perceive the engineering leadership competencies as more important to their professional work?

Methods

Study Overview

Pennsylvania State University College of Engineering (CoE) undergraduate alumni were surveyed to assess the impact that their undergraduate program had in helping them to develop the skills needed for today's engineering work. Alumni were sent a link to a survey and offered a $10 gift certificate to Amazon and either a PSU CoE or Engineering Leadership Development Minor (ELDM) lapel pin (depending on their alumni cohort) for their participation.

Engineering Leadership Development Minor Program

The Engineering Leadership Development Minor program at Penn State was created in 1995, operational for 26 years now. When this program was built, it was one of a kind across worldwide universities and colleges (Burton, 1996). Initially founded as an initiative of the Leonard Center for the Enhancement of Engineering Education (Schuman et al., 2015), it has supported hundreds of undergraduate students in their future aspirations. ELDM is an undergraduate minor requiring 18 semester credits. While the minor has had modifications over

the last 26 years, many of the original requirements remain. The current minor format requires two courses: Leadership Principles and Technology-Based Entrepreneurship (3-credits each). An additional 6 credits are required from four courses within ELDM: Leadership in Organizations, International Leadership of Engineering and Development, Project Management for Professionals, or an independent study which could take the form of an international project, a coaching course, or an honors thesis). The last requirement includes an additional 6 credits of electives. During the time period of attendance for the majority of the study participants, the project management and coaching course were not options for the 6 additional required ELD credits. The ELDM curriculum focuses on the development of leadership potential within each student, a multicultural awareness, and hands-on, leadership challenges that provide opportunities to exercise students' skills.

Participants

Study participants were Penn State University undergraduate students grouped into two cohorts: 1) alumni of the Engineering Leadership Development Minor (ELDM) and 2) College of Engineering (CoE) alumni who did not participate in the ELD minor during their undergraduate studies. The CoE alumni (non-ELDM) served as the CoE Comparison group for comparisons between students that completed the ELD minor compared to similar graduates who did not complete the ELD minor. Data collection occurred over two separate time periods, and for the most part correspond to the two different study cohorts consisting of the ELDM alumni and CoE Comparison group. The ELDM alumni cohort was surveyed in 2018 and reported on previously by Gehr (2019) and Lang et al. (2020). Within the ELDM cohort, contact information was available for 451 alumni. A recruitment email was sent with a link to the study survey and 136 responded, resulting in a response rate of 30.2%.

The College of Engineering non-ELDM cohort was surveyed in 2019. Contact information was obtained through three LinkedIn alumni groups where an initial group of 600+ individuals were contacted to make initial connections. All contacts were consolidated from the following LinkedIn groups: "Penn State Engineering Alumni Society (Official)", "Penn State Chemical Engineering Society", or "Penn State College of Engineering Alumni".

Over a period of 3 months, contact emails were collected through individual LinkedIn profiles and conversations on the LinkedIn website, approximately 551 personal/work emails were obtained. These were then reviewed to ensure that there were no duplicates, or individuals who previously participated in the 2018 ELDM alumni survey. A personalized mass email with a link to the survey was sent using MailChimp, an email marketing company. Initially, 10 emails were bounced by the distribution software resulting in 541 successful emails. A total of 317 responses from our comparison group of the study were received, with a net response rate of about 59%, which is remarkably high for a survey sent to alumni through email (Baruch, 2008).

Of the 317 responses, there were approximately 184 survey participant responses that were removed, either due to incomplete surveys (less than 76% complete; n=77) or to better match the demographics of the initial ELDM survey distributed in 2018. During data cleaning, a large number of CoE comparison participants (n=107) were removed because their maximum age or

graduation year indicated that they graduated prior to the start of the ELD minor program, which was 1995, when the ELD minor was created. These responses were removed to provide a more comparable comparison group. After initial demographic review, an additional 8 CoE Comparison group participants were removed due to an excess of participants representing architectural engineering and age compared to ELDM participants. This small removal occurred to provide a more proportionate comparison between the two groups.

Participant Demographics

The study included 147 ELDM participants and 133 CoE Comparison group participants that were included in the final data analysis. Table 1 summarizes participants by age range and study cohort, providing a comparison between the numbers of ELDM alumni and CoE non-ELDM alumni (CoE Comparison group) by age. From Table 1, the CoE Comparison group has a relatively even spread including those in higher age ranges. On the other hand, a majority of ELDM survey participants were under the age of 35.

Table 1: Number and percentages of study participants by age range and group (ELDM versus CoE Comparison Group)

Participant Age Range				
	ELD Minor		**CoE Comparison Group**	
Age Range	**N**	**% of ELDM**	**N**	**% of CoE Comparison**
24-26	21	14.3%	8	6.0%
27-29	37	25.2%	25	18.8%
30-32	23	15.6%	30	22.6%
33-35	34	23.1%	21	15.8%
36-38	22	15.0%	21	15.8%
39-40	5	3.4%	13	9.8%
41-43	5	3.4%	15	11.3%
Total	147		133	

Table 2 summarizes study participants by gender, displaying a fairly higher percentage of females in the ELDM group (31.5 %) compared to the CoE Comparison group (24.8 %). Table 3 summarizes participants by race/ethnicity and study group, indicating fairly similar percentages across race/ethnicities.

Table 2: Number and percentages of participants by gender and group (ELDM versus CoE Comparison group).

Participant Gender				
	ELD Minor		**CoE Comparison Group**	
Gender	**N**	**% of ELDM**	**N**	**% of CoE Comparison Group**
Female	46	31.5%	33	24.8%
Male	100	68.5%	100	75.2%
Total	146		133	

Table 3: Number and percentages of participants by Race/Ethnicity and group (ELDM versus CoE Comparison group).

Participant Race/Ethnicity				
	ELD Minor		CoE Comparison Group	
Race/Ethnicity	**N**	**% of ELDM**	**N**	**% of CoE Comparison**
White	125	85.6%	112	84.8%
Black or African American	2	1.4%	1	0.8%
Hispanic, Latino	3	2.1%	4	3.0%
Round Asian	12	8.2%	12	9.1%
Asian, Native Hawaiian or Pacific Islander		0.0%	1	0.8%
Other		0.0%	2	1.5%
I do not wish to share	4	2.7%		0.0%
Total	146		132	

Table 4 summarizes study participants by undergraduate major. The top two majors represented in both groups were mechanical engineering and industrial and manufacturing engineering. The most unequal representation by major was observed for architectural engineering with 10.4% in the CoE Comparison group compared to 1.4 % in the ELDM group. This large difference most likely occurs because of the structure of the architectural engineering degree. The B.A.E. degree is a five-year program that includes a senior thesis, resulting in a significantly greater academic burden compared to the four-year degree programs and may be the reason for the much smaller percentage of architectural engineering students that pursue the ELDM.

Table 4: Participant undergraduate major by group (ELDM versus CoE Comparison group).

Participant Undergraduate Major				
	ELD Minor		CoE Comparison Group	
Major	**N**	**% of ELDM**	**N**	**% of CoE Comp.**
Aerospace Engineering	9	6.2%	4	3.1%
Agricultural and Biological Engineering	1	0.7%	1	0.8%
Architectural Engineering	2	1.4%	14	10.8%
Biomedical Engineering	3	2.1%	2	1.5%
Chemical Engineering	12	8.3%	16	12.3%
Civil and Environmental Engineering	15	10.3%	16	12.3%
Computer Science	8	5.5%	1	0.8%
Electrical Engineering	14	9.7%	17	13.1%
Engineering Science and Mechanics	2	1.4%	3	2.3%
Industrial and Manufacturing Engineering	26	17.9%	19	14.6%
Mechanical Engineering	35	24.1%	25	19.2%
Nuclear Engineering	2	1.4%	1	0.8%
Other	16	11.0%	11	8.5%
Total	145		130	

Survey Instrument Design & Distribution

The survey instrument was developed by ELDM to assess the impact of the ELD minor on initial job placement (salary and job responsibilities), relevance to job responsibilities, effectiveness in preparing alumni for their job responsibilities, and career progression and to evaluate several potential co-variates. The survey also had built in progression for those who did not participate in the minor during their undergraduate career. The survey was developed for the intended purpose to make comparisons between Penn State University ELDM alumni and CoE non-ELDM alumni who served as the CoE Comparison group. The survey instrument was developed using Qualtrics Survey Software. The questions used in the survey were mostly Likert scale questions. The use of Likert-scales has been proven over decades and is not new to surveying large groups as it provides a five- or seven-point scale allowing individuals to express how much they agree or disagree with provided statements (Nachar, 2008). In addition to Likert-scale questions there were text entry responses, yes/no responses, multiple selection, and single selection questions. The most important survey questions were placed at the beginning in case participants did not complete the entire survey. Less important, longer response and more personal questions such as testimonials and demographics were placed towards the end of the survey. While most of the questions focused on the undergraduate experience versus the ELDM experience, it was crucial that the survey also captured the current needs of engineering careers in today's workplace. This survey required between 10-20 minutes of time from each participant.

The survey instrument was developed to align with the learning objectives of the ELD minor courses (Schuman et al., 2015) and had two primary objectives: 1) to assess the impact of participation in the ELD minor on initial job placement and career progression and 2) assess the impact of the ELD minor in preparing participants for their professional career and enhancing their ability relative to the program learning objectives. Similarly worded questions were provided to CoE Comparison group participants for comparison across the two groups. This paper reports on a set of questions focused on assessing the ELD minor in preparing participants for their professional career and enhancing their ability relative to the 13 primary program learning outcomes as well as an evaluation of the importance of the ELDM targeted leadership competencies/learning outcomes for both ELD minor and CoE Comparison group alumni.

Data Analysis

The data were exported from Qualtrics into Microsoft Excel for review and cleaning and analyzed in SPSS Statistics software. Descriptive statistics and group differences were determined using SPSS Statistics software. For each survey question with a Likert-scale response, means were determined for each group (ELDM versus CoE Comparisons) and are reported for descriptive purposes only. Because of the uncertainty in the intervals between scale points introduced by Likert scales (bumc.bu.edu, 2016), the Likert scale data was treated as ordinal and a nonparametric Mann-Whitney U-test was used to determine group differences based on Mean Rank. Significant differences are reported at $p \leq 0.05$.

Results

This paper focuses on a single grouping of questions from the full alumni survey, additional in-depth analysis will be conducted on the remaining survey data at a later time. The primary survey questions reported in the results section are:

> **Survey question 1 (Given to both groups: ELDM and CoE Comparisons):**
>
> **Part 'a':** *Indicate how well your (PSU undergraduate degree (Major & Minor courses, extra-curricular activities, etc.)) prepared you for your professional career and enhanced your ability relative to each of the following. (list of 13 competencies)*
>
> **Part 'b':** *How **important are the following** to your professional work? (list of 13 competencies)*
>
> **Survey question 2 (Only given to the ELDM group):** *Indicate how well the ELD Minor program prepared you for your professional career and enhanced your ability relative to each of these leadership competencies. (list of 13 competencies)*

Both of these questions were worded almost exactly the same with the only difference regarding the "PSU undergraduate degree (Major &Minor courses, extra-curricular activities, etc.)" and the "ELD Minor program". Additionally, the first survey question (given to both groups) was presented in a two-part matrix with the leadership competencies along the left in rows and the two parts along the right in columns, allowing the participant to rate a) how effective their program was at preparing/enhancing their ability for each competency and b) how important each competency is to their professional work. The matrix header for part 'a' read: "Prepare/Enhance your ability:" and included a 5-point Likert scale (Extremely well; Fairly well; Moderately; Poorly; Not at all). The matrix header for part 'b' read: "How important are the following to your professional work?" and included a 5-point Likert scale (Extremely Important; Fairly Important; Moderately Important; Slightly Important; Not Important).

Table 5 summarizes the results from question 1 (part a and b; given to both groups) as well as question 2 (given to the ELDM group only). The table includes the 13 leadership competencies/learning outcomes that were evaluated in the far-left column, followed by five columns of results. The second and third columns include the results for the ELDM group ratings on how participant's undergraduate program (column 2) and ELD minor (column three) prepared/enhanced their ability for their professional career (question 1a and question 2). The fourth column includes the results for the CoE Comparison group's ratings of their undergraduate program (question 1a). The last two columns in Table 5 include the results for the ELDM and CoE Comparison groups' ratings of how important each learning outcome/competency is to the participant's professional work (question 1b).

Means and standard deviations are presented. Group differences were evaluated between ELDM alumni and CoE alumni to assess the efficacy of the ELD minor in helping to prepare students for their professional career. This assessment was through a comparison of ELDM responses to question 2 compared to CoE Comparison responses to question 1a. In addition, group

differences between the ELD minor and CoE Comparison groups were also assessed to look at perceptions of the importance each competency/learning outcome is to the participant's professional work. This assessment was through a comparison of group responses to question 1, part b. The final comparison that was made was to determine whether ELDM alumni rated the ELD minor differently than their undergraduate program (as a whole) in preparing/enhancing their ability relative to each leadership competency/learning outcome. This assessment was through a comparison of responses to question 1a and question 2 for the ELDM alumni only. Significant group differences are indicated by superscripts for the following three comparisons: 1) [a] significant differences between ELDM participant ratings of their undergraduate program (UG) and ratings of the ELD minor ($p \leq 0.05$); 2) [b] significant differences between ELDM ratings of the ELD minor and CoE Comparison group ratings of their undergraduate (UG) program ($p \leq 0.05$); and 3) [c] significant differences between ELDM ratings of importance versus CoE Comparison group ratings of importance ($p \leq 0.05$).

Table 5: Ratings of leadership competencies/learning outcomes by ELDM and CoE Comparison groups. Likert scale group Means and Standard Deviations are presented for how well programs prepared/enhanced students' abilities regarding each competency/learning outcome and how important each was to their professional work.

Leadership Competencies / Learning Outcomes	**Prepared/Enhanced ability.**			**Importance to prof. work. (Q1b)**	
	ELD Minor		**CoE Cont.**	**ELD Minor**	**CoE Comp.**
	UG Prog. (Q1a)	**ELDM (Q2)**	**UG Prog. (Q1a)**		
Leading teams (lead meetings; identify personality preferences and adjust environment/style)	4.20 (0.785)	4.30 [b] (0.774)	3.55 [b] (0.988)	4.60 [c] (0.675)	4.74 [c] (0.566)
Think strategically by applying mission, vision, and values statements to a team or organization.	4.06 (0.907)	4.18 [b] (0.797)	3.84 [b] (1.10)	4.52 (0.903)	4.72 (0.515)
Work effectively in teams	4.50 (0.678)	4.55 [b] (0.655)	4.21 [b] (0.699)	4.75 (0.635)	4.84 (0.426)
Apply **project management** processes to projects.	3.96 (0.916)	4.04 [b] (0.838)	3.41 [b] (1.003)	4.40 (0.818)	4.60 (0.608)
Give and receive **feedback**.	3.68 (1.006)	3.90 [b] (0.884)	3.13 [b] (1.041)	4.47 (0.736)	4.36 (0.811)
Self-reflection on leadership skills and how to improve	3.77 [a] (0.983)	4.05 [a b] (0.833)	2.99 [b] (0.965)	4.25 (0.886)	4.28 (0.869)
Recognize ethical issues & practice **ethical decision making**.	3.84 (0.987)	4.01 [b] (0.939)	3.51 [b] (1.136)	4.26 (0.962)	4.40 (0.857)
Develop a **culture** that promotes **creativity and innovation**.	3.95 [a] (0.897)	4.14 [a b] (0.897)	3.55 [b] (1.058)	4.11 (1.021)	4.20 (0.855)
Cross-cultural/global competencies (appreciation of other cultures; understanding bias; working in a culturally diverse team).	3.77 (1.219)	4.03 [b] (1.095)	3.36 [b] (1.199)	3.98 (1.182)	3.93 (0.953)
Emotional intelligence (regulate emotions and manage conflict).	3.64 [a] (0.967)	3.88 [a b] (0.939)	2.95 [b] (1.148)	4.36 (0.841)	4.45 (0.731)
Communicate effectively (oral and written; adapt to audience).	4.34 (0.783)	4.42 [b] (0.731)	3.95 [b] (0.790)	4.72 [c] (0.622)	4.91 [c] (0.310)
Understand **basic business concepts** (finance, accounting, marketing, supply chain/operations).	3.43 [a] (1.165)	3.72 [a b] (1.015)	2.91 [b] (1.226)	4.16 [c] (0.964)	4.38 [c] (0.872)
Confidence in **taking initiative** with new responsibilities within the organization.	4.10 (0.861)	4.24 [b] (0.810)	3.58 [b] (0.996)	4.55 (0.724)	4.58 (0.624)

[a] significant differences between ELDM ratings of UG and ELD minor ($p \leq 0.05$);

[b] significant differences between ELDM ratings of ELD minor and CoE Comparisons ratings of UG program ($p \leq 0.05$);

[c] significant differences between ELDM ratings of importance versus CoE Comparisons ($p \leq 0.05$)

Impact of Programs on Preparing/Enhancing Students Ability in Professional Career

Overall, ELDM participants rated the ELD minor as 'fairly well' or better (greater than 4 mean rating out of 5) for 10 of the 13 learning objectives that were evaluated. Whereas ELDM participant mean ratings of their undergraduate program were 'fairly well' or better (greater than 4 mean rating) for 5 of the 13 learning objectives. CoE Comparison group participants rated their undergraduate program as 'fairly well' or better on average for only 1 of the 13 competencies.

Within the ELDM group, the top 5 rated competencies that were most impacted by the ELD minor in preparing/developing the participants' ability in their career were (in order of rating): work effectively in teams; communicate effectively; leading teams; confidence in taking initiative with new responsibilities within the organization; and think strategically by applying mission, vision, and values statements to a team or organization (mean rating of 4.55 to 4.18 out of 5).

Within the CoE Comparison group, the top 5 rated competencies that were most impacted by the CoE Comparison group's undergraduate major program in preparing/developing the participants' ability in their career were (in order of rating): work effectively in teams; communicate effectively; think strategically by applying mission, vision, and values statements to a team or organization; confidence in taking initiative with new responsibilities within the organization; and a tie for fifth with leading teams and develop a culture that promotes creativity and innovation (mean rating of 4.21 to 3.55 out of 5). Interestingly, four of the top 5 rated competencies were the same across the ELDM and CoE Comparison groups.

When comparing across the ELDM and the CoE Comparison groups, ELD minor participants consistently rated the ELD minor significantly higher than CoE Comparison group ratings of their undergraduate program at preparing/enhancing their ability for their professional career regarding all of the leadership competencies/learning outcomes.

ELDM group participants also rated the same 5 competencies higher when evaluating their full undergraduate program. However, when comparing within the ELDM group, ratings of the ELD minor compared to ratings of their full undergraduate program, were significantly higher for 'self-reflection on leadership skills and how to improve', 'develop a culture that promotes creativity and innovation', emotional intelligence (regulate emotions and manage conflict), and 'understand basic business concepts (finance, accounting, marketing, supply chain/operations). Additional trends were also noted, although not statistically significant, for 'give and receive feedback' ($p=0.061$) and cross-cultural/global competencies (appreciation of other cultures, understanding bias, working in a culturally diverse team) ($p=0.082$).

The wording of the question evaluating the full undergraduate experience included any minors and for ELDM participants one could assume that the ratings of the full undergraduate experience would be higher than the ELD minor alone, but the reverse was seen with ELD minor ratings being higher than the full undergraduate program, as assessed by the ELDM participants.

From these results, it was assumed that the question specific to the minor elicited a more specific response regarding the impact of the minor, thus it was chosen for the comparisons with the CoE Comparison group.

Importance of Leadership Competencies/Learning Outcomes to Professional Work

Evaluations of importance of each leadership competency/learning outcome to participants professional work revealed interesting results on which competencies were most important as well as significant differences in ratings across ELDM and the CoE Comparison groups. The top 5 rated competencies by ELDM participants based on importance to participant's professional work were: work effectively in teams; communicate effectively; leading teams; confidence in taking initiative with new responsibilities within the organization; and think strategically by applying mission, vision, and values statements to a team or organization (mean rating of 4.75 to 4.52 out of 5). These were the same top 5 competencies identified as being impacted by the ELD minor regarding preparing/enhancing participants ability for their professional career.

The top 5 rated competencies by CoE Comparison group participants based on importance to participant's professional work were: communicate effectively; work effectively in teams; leading teams; think strategically by applying mission, vision, and values statements to a team or organization; and apply project management processes to projects (mean rating of 4.91 to 4.60 out of 5).

Across both the ELDM and CoE Comparison groups, 4 of the top 5 rated competencies by importance were the same for both groups. It was also quite surprising to see in general higher ratings of importance by the CoE Comparison group compared to the ELDM group for 10 of the 13 competencies with statistically significant differences in 3 of the 13 competencies. These were not in the direction that was expected. CoE Comparison group participants rated the following three competencies as significantly more important compared to ELDM participant ratings: leading teams (lead meetings; identify personality preferences and adjust environment/style); communicate effectively (oral and written; adapt to audience); and understand basic business concepts (finance, accounting, marketing, supply chain/operations).

Discussion

The goal of this study was to evaluate the effectiveness of the Engineering Leadership Development minor in meeting the leadership competency development/learning outcomes goals of the program. The study utilized a non-ELDM College of Engineering comparison group to provide additional insights into the effectiveness of the program in achieving the learning outcomes by making comparisons with students that attended the same undergraduate engineering university but not in the ELD minor.

The results of this study suggest that the Engineering Leadership Development minor is preparing/enhancing student's abilities in their professional career across many critical leadership competencies compared to College of Engineering students that have not participated in the ELD minor program. Across all 13 competencies assessed, ELDM participants rated the

ELDM minor higher than the CoE Comparison group ratings of their undergraduate program at preparing/enhancing their leadership abilities in their professional career.

These results are as expected as the leadership competencies assessed in this study correspond to the intended learning outcomes for the program and are the focus of instructional activities in the ELD minor courses.

In a comparison of ELD minor participant ratings of both their ELD minor and their undergraduate program as a whole, consistent patterns were evident across the various competencies. For example, ELD minor participants rated the same 5 competencies the highest when asked how effective their undergraduate major and the ELD minor were at preparing/enhancing their ability. Conversely, they also rated 4 out of 5 of the same competencies lowest for both their major and ELD minor at preparing/enhancing their abilities.

There were however a few areas of significance including "Self-Reflection on leadership skills and how to improve", "Develop a culture that promotes creativity and innovation", "Emotional Intelligence" and "Understand basic business concepts". For these four competencies, ELDM alumni rated their ELD minor experience greater when comparing it to their undergraduate program. Within the ELD minor program, these four areas are heavily emphasized and are a primary focus of several core courses within the minor. ELD minor courses focus on not only leadership competencies such as self-reflection and emotional intelligence, but basic business concepts as well as promoting an entrepreneurial mindset.

The final set of comparisons were focused on the ratings of importance of the various leadership competencies/learning outcomes. Across both the ELD minor and CoE Comparison groups, 12 of the 13 competencies were rated as 'fairly important' to 'extremely important' (greater than 4 out of 5). The only competency not rated 'fairly important' or higher was 'cross-cultural/global competencies (appreciation of other cultures, understanding bias, working in a culturally diverse team)'. This competency had a mean rating of 3.97 in the ELDM group and a 3.92 in the CoE Comparison group. While these mean ratings are close to 'fairly important', given the current political climate, this may be an area to target within the ELD curriculum for further development to foster an environment where cultural differences and diversity are valued equally with the other leadership competencies.

Four of the top five rated leadership competencies by importance within both the ELDM and CoE Comparison groups were shared across the two groups and included: work effectively in teams; communicate effectively; leading teams (lead meetings, identify personality preferences and adjust environment/style); and think strategically by applying mission, vision, and values statements to a team or organization. As mentioned previously, what was striking in these results was that the CoE Comparison group rated 10 of the 13 competencies higher in importance than the ELDM group rated them, with statistically significant higher ratings for 3 competencies: leading teams (lead meetings; identify personality preferences and adjust environment/style); communicate effectively (oral and written; adapt to audience); and understand basic business concepts (finance, accounting, marketing, supply chain/operations).

It was expected that the ELDM alumni would rate their preparedness and importance to professional work higher than CoE alumni not in the ELD minor. The expectation regarding importance was made given the stress that is placed on the importance of these competencies within the minor. It was thought that the focus of importance within the ELDM curriculum might have primed the students to believe that the competencies were more important. However, the CoE Comparison group consistently rated the competencies as more important than ELD graduates. Given the significantly lower ratings in preparedness by the CoE Comparison group, combined with the general higher ratings of importance (although only significant for 3 of the competencies), one might speculate that the CoE Comparison group lacked the additional competency/skill development garnered through participation in the ELD minor and was impacted more by the lack of the competencies resulting in a higher importance rating of the professional skills that were needed and missing in their early career. However, it is also important to note that ELDM graduates were also younger than the CoE Comparison group and this could also have impacted the ratings as the CoE Comparison group would have had more work experience to draw upon and potentially more leadership responsibilities due to their tenure.

Future Directions:

This was the first alumni assessment conducted for the ELDM program resulting in an assessment of some alumni that graduated up to 25 years ago. Reflecting on experiences that far back in the past could introduce recall problems. The program plans to continue this type of assessment with surveys conducted every 3-5 years to ensure that the data are captured early in our alumni's career and stay current. Long term goals for the program are to conduct pre- and post-learning outcome assessments of the ELDM program as well as these longitudinal assessments.

Future work will also explore whether participation in the leadership development program results in differences in salary level, job placement, career progression, and leadership responsibilities as compared similar graduates not in the leadership program. The survey described in this paper collected information related to these areas for both cohorts, the ELDM and CoE Comparison groups, and the aim of this work is to better evaluate co-variates related to leadership competencies and utilize the comparison group to control for these co-variates in order to more fully assess the impacts of the ELD minor.

Study Limitations

Our goal for using a CoE alumni Comparison group was to be able to match ELDM alumni to similar CoE alumni based on demographics and other variables, such as GPA and engineering discipline, that may impact career placement and progression, in an effort to assess the impact of the ELD minor relative to a similarly matched comparison group. This was the program's first attempt to recruit CoE Comparison group participants and while the response rate was very high, the demographics of the respondents were not a perfect match to the ELDM demographics. Over half of the initial 2020 survey population was removed due to survey incompleteness and

graduation years outside of the ELDM program's existence. This resulted in a larger number of ELDM Alumni compared to the CoE Comparisons group, with additional demographic differences in engineering disciplines.

Additionally, the CoE Comparison group participants trended more towards older participants, potentially impacting areas such as salary, undergraduate major, and questions that reflect on work experience, with older participants having a much broader experience on which to reflect. While these differences in demographics may not have a major impact on the results reported in this paper, future work aims to assess differences in starting salary and career progression and can be impacted by these demographics as well as other areas such as GPA, volunteerism, etc. The intention is to control for these differences based on demographics and related co-variates. For example, more experienced individuals tend to make a higher salary, but inflation will also need to be considered. Additionally, Penn State undergraduate majors have changed quite a bit since 1995, as well as the industry demand. There are also a few smaller aspects that need to be addressed in future alumni surveys. The wording of a few questions could be clarified such as the main question focused on in this paper, asking about the impact of the participant's undergraduate program "Major Courses, Minor Courses, Extra-curricular, etc.). This question was originally worded this way to serve as a control question but was then given to both the ELDM and CoE Comparison groups for further comparison. However, as worded, there is no way to determine how the individual averaged or focused in on one or all of these types of experiences during their response to the question at hand. This is particularly problematic when asking ELD minor students to respond to both versions of the question. Technically the question regarding participants' undergraduate program would include the ELD minor so it might be expected that alumni would respond the same to both versions of the question. Lastly, self-selection bias might have influenced the ELDM alumni participation in the study. ELDM Alumni who enjoyed the program or felt that they may have benefited from the program could have been more likely to respond to the survey.

Conclusions

ELD minor alumni consistently credited the ELD minor with a moderate to major effect on preparing or enhancing their leadership competencies in their professional career. The ELD minor was also rated by ELDM alumni as significantly more effective in preparing/enhancing leadership competencies compared to College of Engineering undergraduate programs in general.

Based on ratings from College of Engineering non-ELDM alumni, for 12 of the 13 competencies, non-ELDM alumni rated their undergraduate program as only moderately to less than fairly effective in preparing/enhancing participants' abilities in their professional career. The one area where the undergraduate program is doing well was in preparing/enhancing participants ability to work effectively in teams. College of Engineering non-ELDM alumni also rated all leadership competencies (except cross-cultural/global competencies) as fairly to extremely important to their professional career.

These results highlight the importance of these competencies and the lack of development within the College of Engineering programs overall. Both groups (ELDM and CoE non-ELDM) rated all leadership competencies (except cross-cultural/global competencies) as fairly to extremely important to their professional career. The top five competencies rated by importance in participants' professional work across the ELD Minor and College of Engineering non-ELDM alumni (in order of highest to lowest ratings of importance were: **communicate effectively; work effectively in teams; leading teams; think strategically by applying mission, vision, and values statements to a team or organization;** apply project management processes to projects; and confidence in taking initiative with new responsibilities within the organization. The bolded competencies were rated as the top four within both the ELD Minor and CoE non-ELDM alumni Comparison groups. In general, College of Engineering non-ELDM alumni rated most of the competencies higher in importance compared to the ELD minor alumni, with significantly higher ratings for 'leading teams', 'communicate effectively', and 'understanding basic business concepts'. Although not statistically significant, ELD minor alumni rated 'give and receive feedback' higher in importance than CoE non-ELDM alumni. The higher ratings of importance by CoE non-ELDM alumni may have been a result of the greater struggles experienced by alumni that had not had the leadership training during their undergraduate program. Realizing the need for the competencies and potential lack of prior training may have had a bigger impact on participant importance ratings. However the higher importance ratings in the CoE non-ELDM Comparison group may also be due to the differences in age (a surrogate for work experience) between the two groups, with the CoE non-ELDM group having larger numbers of participants in older age ranges.

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