Engineering Leadership Development: Contribution of Professional Skills to Engineering Undergraduate Students' Leadership Self-efficacy

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Abstract: Corresponding to industry trends and changes in engineering education accreditation criteria, non-technical professional skills training is now seen as central to baccalaureate engineering education. Beyond simply developing good managers in the engineering fields, engineering educators have adopted a goal to prepare engineering students to be leaders who can provide vision to their organizations with strong ethical standards. This study investigated engineering undergraduate students' leadership efficacy development associated with such professional skills as self-awareness, global competence, ethical awareness, creativity, and teamwork skills. Responding to an online survey, 247 engineering undergraduates who were enrolled in an engineering leadership course participated in this study. Results of this study indicated that there are positive associations among the five professional skills (e.g., self-awareness, ethical awareness, global competency, creativity, and teamwork skills), and engineering leadership self-efficacy for engineering undergraduate students. The five professional skills (self-awareness, ethical awareness, global competency, creativity, and teamwork skills) predicted 54% of the overall variance of engineering leadership self-efficacy.

Keywords: *Engineering leadership, leadership attributes, leadership development.*

Introduction

Undergraduate engineering education has traditionally aimed to prepare students for a career in engineering-related occupations, with a focus on technical engineering knowledge and skills such as engineering design, computing, product development, and engineering-related applied research, among other skills. However, in addition to technical engineering skills, professional skills including decision-making, leadership, and communication have been recognized to be imperative skills for engineers (Cox et al., 2012).

Responding to the needs of the engineering field, the engineering education accreditation organizations began to emphasize leadership and professional skills such as an ability to lead multidisciplinary teams; an ability to identify, formulate, and solve engineering problems; an understanding of professional and ethical responsibility; an ability to communicate effectively; and an understanding of the impact of engineering solutions in a global, economic, environmental, and societal context (Accreditation Board for Engineering and Technology [ABET], 2020). Therefore, the engineering education community began to embed professional skills according to ABET criteria into curriculum so that as undergraduates, engineering students are required to expand their technical portfolio with leadership skills including teamwork skills, written and oral communication, business acumen, problem solving, and multicultural understanding (Rottmann et al., 2015).

Further, the Unites States of America (USA) National Survey of College Graduates (Morgan, 2000) showed that engineers by degree and occupation typically perform a variety of tasks requiring diverse skills in their jobs, ranging from management of people or projects to applied research, design, and development. It is common in engineering-related industries that as engineers gain more technical and organizational experience in their companies, they transition into leadership positions. Another reason for engineers to develop leadership skills is related to job transitions among different industries. This report illustrated that there has been a trend of job transitions across engineering and engineering-proximate occupations. Interestingly, among those who moved from engineering occupations to engineering-proximate or

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non-engineering jobs, most went into managerial positions. As there seems to exist a common trajectory of promotion for engineers into management positions, the need is evident for most engineers to develop leadership skills to be successful in such managerial positions. In addition, the 2018 consensus study report from the USA National Academy of Engineering (NAE) showed that it is quite common for engineering graduates to embark not only on engineering-related careers but also to begin their careers in engineering-proximate and non-engineering occupations where they often play managerial roles for various projects.

Thus, corresponding to industry trends and changes in accreditation criteria, non-technical professional skills training is now seen as central to baccalaureate engineering education. Beyond simply developing good managers in engineering disciplines, engineering educators have adopted a goal to prepare engineering students to be leaders who can provide vision to their organizations with strong ethical standards. In response, higher education engineering institutions have begun to incorporate non-technical professional leadership skills development into their engineering curricula. Incorporating these skills has led to the establishment of various types of co-curricular and non-curricular programs including minors, certificate programs, and workshops (Klassen et al., 2016). An early example is Penn State University's engineering leadership development (ELD) program established in 1995.

The initial educational objectives of this program were to enhance teamwork, communication skills, and innovative thinking, while providing a connection between business and engineering (Schuhmann, 2010). The program contains four core themes: leadership principles and theory, business skills/project management, entrepreneurship, and global competency/multicultural awareness. These themes are meant to help students develop engineering leadership, at the individual, team, and organizational levels. Schuhmann (2010) claimed that engineering leadership development programs provide necessary non-technical professional skills such as creativity, communication skills, and decision-making for engineering students to prepare them to be well-rounded engineers before they enter the workplace.

For the past two decades, engineering education has recognized the need for effective methods of incorporating leadership skills into engineering curricula, a theme reflected in recent reports of empirical research but one that needs further work. Focused on this need, the current project examined the level of leadership self-efficacy reported by students in an engineering leadership course. The current study also addressed whether critical components of leadership, as identified in the literature, acted as predictors of leadership self-efficacy. In the next section, the results of a review of the existing literature are presented, addressing the attributes that emerged as most frequently identified as essential to engineering leadership.

Literature Review

ABET criteria specifically requires universities to assess student outcomes relevant to key attributes related to leadership in the engineering context. These attributes include teamwork, ethics, global awareness, and creativity. In the current study, we are particularly interested in the relationship between leadership self-efficacy and self-awareness in four areas identified as ABET student outcomes: ethical awareness, global competence, teamwork skill, and creativity. The results of the literature review in each area are presented in the next sections.

Leadership Self-Efficacy. Most of the engineering-related self-efficacy development has relied on Bandura (1993a)'s self-efficacy theory. According to his theory, *self-efficacy* refers to an individual's belief in their own ability to succeed in specific tasks and one's self-efficacy can play a significant role in the way one approaches goals, tasks, and challenges. Bandura proposed four sources of influence that impact one's self-efficacy: (1) performance accomplishments or mastery experiences, (2) vicarious experiences, (3) verbal or social persuasions, and (4) physiological states. As Bandura (1993b) explained, individuals' self-efficiency influences various aspects of their lives, including their short-term and long-term goals, the decisions they make, and the amount of effort they invest on their tasks. According to Bandura's self-efficacy theory, one's self-efficacy is highly associated with self-regulation including goal setting, levels of perseverance when faced with difficulties, stress management in challenging situations, and critical decision-making that are fundamental attributes as leaders.

Incorporating Bandura's (1993a) self-efficiency theory, McCormick (2001) reported that a successful leader is persistent, self-confident, energetic, alert to the environment, adaptable to the situation, as well as assertive and goal-directed. He also found that self-efficacy regarding one's job performance was key to a leader functioning well in a challenging situation and that it impacted a person's belief in their ability to lead a group successfully. According to self-efficacy theory, individuals' self-efficacy is significantly associated with work or academic performance, levels of perseverance when facing adversities, levels of stress experienced in challenging situations, and emotional regulation that may play a significant role for leadership practices. Lastly, Healey and Hays (2012) reported that self-efficacy was highly associated with individuals' self-awareness as professionals and work motivation. In other words, individuals' professional discipline specific competency and level of engagement with the profession is related to development of self-efficacy. However, research on engineering leadership self-efficacy and associated factors are presently underdeveloped.

Self-awareness: Self-awareness, while associated with self-efficacy, is also described by several researchers as foundational to effective leadership in general, as it positions leaders to know their strengths and weaknesses and allows them to make better decisions and handle uncertain situations (Bratton et al., 2011). Goleman et al. (2001) posited that self-awareness

alerts a leader to emotional states that can be instrumental to leading and managing others effectively. Other researchers have found self-awareness to be associated with high levels of leadership performance and team effectiveness as it influences one's ability to empower others (Church, 1997; Fletcher, 1997; Jordan & Ashkanasy, 2006). In addition, the U.S. National Aeronautics and Space Administration's behavioral framework for highly effective technical executive positions showed self-awareness to be an integral part of relational competency (Morris & Williams, 2012).

Thus, self-awareness influences leader-follower relationships by way of positive impacts on followers' attitudes, behaviors, and performances (Avolio & Gardner, 2005; Moshavi et al., 2003). Further, Higgs and Rowland (2010) interviewed engineering leaders within an organization and observed experiences related to impacting change. Their findings suggested that leaders high in self-awareness had a positive impact on change, citing the importance of self-reflection and awareness of personal struggles. Self-aware leaders were observed to be more inspirational, calm, and centered; they also addressed challenges associated with change and effective and clear communication (Tekleab et al., 2008).

Additionally, some studies addressed the role of self-awareness in the undergraduate curriculum designed to develop engineering leadership. Farr and Brazil (2009) suggested a model for engineering leadership programs that incorporates self-awareness through assessment, ensuring that students understand their current attributes and reflect on where they would like to be, especially when leading technical teams. Bayless (2013) presented a class structure that focused on self-reflection for both the individual and the group for effective development of engineering students' leadership skills. As shown in an interview study of engineering recruiters during career fairs, self-awareness may assist in student success. Those who effectively demonstrated leadership showed self-awareness of their leadership competencies and effectively communicated relevant skills to potential employers (Handley et al., 2016).

Finally, Handley and Berdanier (2019) investigated the relationship between interpersonal competencies and engineering leadership. Their findings showed that technical forthrightness was an interpersonal competency for engineering leaders with foundational elements centered on self-awareness of technical skills and a willingness to accept constructive criticism. Aligned with literature that relates to self-awareness and leadership performance, self-awareness skills including emotional regulation and self-reflection seem central to core leadership activities such as communication, problem-solving, and team management.

Engineering Ethics: Considering the significance and impact of engineering practices to society, engineering ethics has been highlighted as an indispensable element of engineering disciplines (Harris et al., 1996). The increase in the need for ethics has been precipitated by various disasters that occurred by unethical decision-making or a lack of codes of ethics and professionalism in the past and potential threats related to rapid technological advancement.

Professional engineering associations and corporate leaders have developed engineering codes of ethics (Herkert, 2005; Spier & Bird, 2007). With these initiations to establish ethical standards, engineering ethics requirements became a widespread topic of discussion for engineering educators. Further, engineering curricular program objectives, which incorporate ethics, have been established and renewed so that engineering ethics education programs have received considerable attention and have strived to develop courses, seminars, or technical engineering courses to introduce engineering ethics requirements to develop well-rounded engineering leaders (Cox et al., 2012).

In accordance with the establishment of engineering professional organizations' codes of ethics, ABET also has emphasized professional and ethical responsibility in engineering disciplines and training students in accredited undergraduate engineering programs so that students can develop ethical awareness as engineers (Hess & Fore, 2018). The goal of the engineering code of ethics is to raise engineers who uphold the integrity of the engineering profession through protecting the public's safety and health while performing their duties with competence and honesty. Even though engineering ethics are emphasized by professional engineering organizations, engineering institutions have been struggling to operationalize the concept of engineering ethics for developing their students' ethical awareness (Bairaktarova & Woodcock, 2017). Newberry (2004) asserted that engineering ethical awareness is related to the development of knowledge of engineering ethics and involves an individual's ability to recognize and resolve ethical issues. In this way, he introduced the concept of ethical intelligence that describes one's moral reasoning skills and their ability to deal with conflict and ambiguity, which are core psychological attributes of engineering leaders.

Global Competence: The globalization of engineering has been increasing steadily since the 1980s. With increased globalization comes the need for engineers to combine their technical expertise with an understanding of the global marketplace, and an ability to work on cross-cultural/cross-disciplinary teams. Successful engineers, especially engineering leaders, should be aware of cultural differences and understand how cultural differences can impact team development, team dynamics, and one's ability to work on and/or lead cross-cultural engineering teams.

In a report by British Council (2013), the value that employers place on intercultural skills was examined on a global scale. Employers ranked 'soft skills', such as 'open to new ideas/ways of thinking', 'works effectively in diverse teams', builds trust', and 'demonstrates respect for others' as equal to or greater in value than all technical skills including qualifications related to 'job' and 'expertise related to field'. Two of the three most valued skills were 'demonstrated respect for others' and 'works effectively in diverse teams.' Across all companies surveyed globally, over two thirds noted that their employees have frequent engagement with colleagues outside their home country. Within the United States, many

companies have employees who interact with customers or partners overseas. However, employers indicated that the engineering education system does not contribute to improving engineering students' intercultural skills. Across all global employers, the top eight suggestions from employers on the needed contributions that education can make towards improving intercultural skills included: teach communication skills, encourage/require foreign languages, encourage/require studies overseas, develop international research partnerships, teach leadership skills, encourage/require classes on international subjects, and bring in international faculty/students.

In addition, the study reported that employers expressed that intercultural skills brought value to the organization through more efficient teams, new clients, and building trust and reputation. However, as noted above, many employers were not satisfied with the educational system's ability to adequately prepare students with the needed intercultural skills (British Council, 2013). Given current trends in globalization and the resulting increase in multicultural and multinational project teams, academic programs and industry have recognized the need for intercultural/global competence in engineering graduates. Over the last decade, engineering programs have increasingly been incorporating global components into their curriculum, either through co-curricular activities or through the addition of a course focused on developing intercultural/global competencies in engineering students.

To understand the global competencies needed in engineering graduates, Parkinson (2009) identified 13 dimensions/attributes of global competence needed in engineering graduates and assessed their importance through expert rankings from academia and industry. The top six ranked competencies were: appreciation of other cultures (understanding and avoiding ethnocentrism); work in teams of ethnic and cultural diversity; communicate across cultures (understanding cultural differences); practice engineering in global context (international internship, service learning, virtual global engineering project, etc.); and deal with ethical issues that arise from cultural or national differences.

Further work in this area by Warnick (2011) identified the top global competencies reported by employers as 'important': 'an ability to exhibit a global mindset', 'an ability to appreciate and understand different cultures', 'an ability to communicate cross-culturally', and 'an ability to work in international teams.' He also recommended that higher education engineering programs prepare engineering students for a global environment by developing professional skills, fostering international internships, teaching an appreciation for other cultures, implementing international collaborations, and promoting foreign language skills. Ball et al. (2012) also conducted a study of industry and academic experts to further explore the most important global competencies needed in engineering disciplines. The top industry rated competencies were 'appreciate and respect cultural differences', 'collaborate and work on a multicultural team', 'use collaboration technologies in intercultural interactions', 'practice tolerance and flexibility', and 'practice cultural equality.'

In summary, with increasing globalization, we have more companies working across borders, both within multinational organizations including intra-organizational interactions as well as between employees and external stakeholders such as customers or international partner organizations. Therefore, intercultural/global competencies are inevitably needed by those leading diverse teams, those working on diverse teams, and anyone working across borders, whether physically or virtually.

Teamwork skills: In today's engineering environment, teamwork skills rank among the most important attributes for an effective technical contributor (Lent et al., 2006). Also ABET (2020) recognizes this criticality in Criterion 3, Student Outcome 5, "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives". As a result, most engineering institutions incorporated teamwork (e.g., capstone projects, team presentation, etc.) into their curriculum to meet ABET criteria (Carter et al., 2016). However, Lingard (2010) noted that while team-based projects are common in engineering curricula, teamwork skills are not commonly taught, leaving the student with a negative impression of the value of teamwork. Further, research into the learning outcomes for teamwork in the capstone courses indicates a disconnect with teamwork skills needed in industry (Chowdhury & Murzi, 2019).

Thus, providing team skills training can help to foster a more positive view in engineers regarding the value of and their ability to effectively work in and lead engineering teams. In addition, Avery et al. (2011) claimed that teamwork skills are a core leadership competency in the modern engineering industry. They noted that an efficacious leader sets goals that are challenging, with an optimistic expectation of success, for team projects because such challenging, yet potentially successful, goals can engage and motivate team members.

In addition, Waldman et al. (2001) mentioned the role of student leaders includes monitoring, mentoring, and providing feedback on members' performance via valid assessments by team members, trained peer coaches, and the instructor. Further, the team members, by way of observing and critiquing the other team members as they rotate through the leadership role, experience the successes of their fellow team members.

Choi et al. (2003) investigated the relationships between team leaders' leadership self-efficacy and effective team performance when the projects assigned had deliverables, sponsors, and deadlines, placing a realistic "stress" upon the leaders. Furthermore, Direito et al. (2012) notes that there is a positive association between perceived self-efficacy and successful team performance and extend this conclusion to the development of "teamwork skills" for engineers.

Engineering creativity: Cropley (2016) noted that creativity is linked with the daily basic work that engineers do such as finding solutions to various problems and challenges. He claimed that creativity is a vital element for engineers to succeed, however the role of creativity is often ignored, especially in engineering education. For instance, Atwood and Pretz (2016) reported that engineering students who scored higher on perceived creativity are less likely to complete engineering degrees since creativity was not fostered properly in students.

Charyton et al. (2008) claimed that engineering creative processes include divergent thinking, convergent thinking, constraint satisfaction, problem finding, and problem solving. Further, they also explain that engineering creative design is composed with three constructs: originality, flexibility, and fluency. Similarly, Charyton and Merrill (2009) suggested that creative problem-solving skills in engineering students can be improved by promoting fluency, flexibility, originality, problem finding, and open-ended questions in engineering education.

McCuen (1999) considered that engineering leaders should be equipped with creativity as an important element of leadership to help their team members to accomplish the team goals. Further, Zappe et al. (2015) reported that creativity was an essential attribute of a multi-faceted engineering leader, as it is a core aspect of finding solutions to difficult problems as well as design solutions. As Petkus (1996) noted, as engineering students' education progresses, they begin to identify as an engineer and develop engineering self-efficacy and creativity that influences their professional identity as engineers. He claimed that creativity in engineering is often focused on prototype design linked with products or any other outcomes and creativity of engineers comes not only from a creative climate, or from overall organizational initiatives and organization-granted access to resources, but also from engineers' mindset and own identity as engineers.

Methodology

Research Design

In the current study, leadership self-efficacy was defined as an individual's perceptions of their ability to perform adequately in the specific area of engineering leadership. ABET criteria for accreditation require universities to assess student outcomes related to leading teams, ethics, global awareness, and creativity. The purpose of this study was to demonstrate the connection between measures of self-awareness, ethical awareness, global competence, creativity, and teamwork skills, and engineering leadership self-efficacy for engineering students completing an undergraduate engineering leadership course. The following research questions were explored:

1. What is the contribution of self-awareness, ethical awareness, global competence, creativity, and teamwork skills to a prediction of students' engineering leadership self-efficacy?

2. What is the additional contribution to predicting engineering leadership self-efficacy of being enrolled in the engineering leadership minor program?

Participants

Survey response data were collected from 247 students (71% male; 29% female) enrolled in several sections of an introductory engineering leadership course. Participants' semester standings were 27.7% seniors, 31.8% juniors, and 27.5% sophomores. In addition, a few freshmen (6.7%) and graduate students (5.9%) participated in the survey. Of survey participants, 70% were White, 14.7% Asian, 6% Hispanic or Latino, 4.8% Middle Eastern, 3.4% Interracial, and 0.2% Black. Of 247 students, 100 (40%) students were enrolled in the engineering leadership minor program and 147 students (60%) were not in the minor program.

Study Setting and Procedures

The participants were students taking an introductory leadership principles course that can count as an elective toward their engineering degree or it can count as part of an undergraduate minor in engineering leadership development. The leadership principles course is designed to introduce the fundamentals of leadership: leadership theory, self-awareness, ethical awareness, teamwork skills, leading creativity, and cultural sensitivity. The course involved students in lectures on leadership concepts with an assignment to work in teams on an engineering project. Participants completed a Qualtrics survey during the last week of the course. The survey consisted of several demographic questions and 28 items related to the identified leadership competencies from the literature, with ratings on a 5-point Likert scale (strongly disagree = 1...strongly agree = 5).

Measures

A total of 28 items were adapted from a previous study within the same program (Hochstedt et al., 2013). Then, exploratory factor analysis (EFA) was conducted as a validation and to determine fitness of items to the specific factors. STATA®14 was used to conduct an exploratory factor analysis with a principal axis factoring (PAF) extraction method and Promax rotation. The number of factors were determined by the following criteria: Eigen-values larger than 1 and scree plot examination. Low factor-loading coefficients and cross-loading items were eliminated as a part of EFA procedures (Comrey & Lee, 2013).

After eliminating eight items because of low factor loadings, 15 items remained with a five-factor solution for the predictor variables. The thirteen items were removed because they had either higher than 0.32 cross-loadings on more than one factor or less than 0.35 loading on any one factor (Ford et al., 1986). The five factors of self-awareness, ethical awareness, global competence, teamwork skills, and creativity aligned well with the initial literature review and were labelled accordingly. Appendix 1 presents the five factors, number of items for each factor, Cronbach alpha values ranging from .72 to .84, and sample item questions. The outcome variable involved five items measuring students' beliefs in their leadership self-efficacy. An exploratory factor analysis (EFA) resulted in a one-factor solution with three items. The Cronbach's alpha for students' scores of leadership self-efficacy was 0.81.

Data Analysis

Bivariate correlations were used to calculate relationships between all variables, the outcome variable of leadership self-efficacy, and the five predictor variables. Hierarchical regression was then used to determine the amount of variance that the predictor variables would account for in a measure of leadership self-efficacy. As is usual in conducting regression analysis, the assumptions of normality, linearity, and homoscedasticity were first tested and confirmed via quantile-quantile and scatter plots. The regression compared four models to determine which variables were significant in predicting engineering students' leadership self-efficacy. Model 1 included the control variables of gender (0 = male; 1 = female), race/ethnicity (0 = non-white; 1 = White), year in school (0 = junior/senior status; 1 = freshman/sophomore), and whether enrolled in the engineering leadership minor (0 = no; 1 = yes). Models 2, 3, and 4 added the predictor variables in three steps. Model 2 added the predictors of self-awareness and ethical awareness, both professional skills that seemed rooted in intra-individual processes. Model 3 added the variables of global competence and teamwork skills, aspects of professional skills that seemed social and outward-directed. Model 4 added the last predictor variable of creativity, a characteristic often mentioned as a professional skill that seemed to bridge engineering technical skills and the higher-level cognitive skill of problem-solving. All variance inflation factor (VIF) coefficients were less than 2 for all models indicating that there were no multicollinearity issues in any of the regression models.

Results

Bivariate Correlations

Addressing the first research question, the relationships among the five professional skills identified (self-awareness, ethical awareness, global competency, creativity, and teamwork skills) and engineering leadership self-efficacy, Table 1 displays the bivariate correlations among outcome and predictor variables as well as means and standard deviations for each variable. The correlations between leadership self-efficacy and the five predictor variables were all significant at $p \leq$ 0.001 and correlation coefficients ranged from .38 to .72. For four of the predictors, the correlations with leadership self-efficacy were moderate, but the correlation of leadership self-efficacy and teamwork skills was high (r = 0.72), suggesting that teamwork skills may be particularly important for individual leadership self-efficacy.

Table 1. Correlation among Predictor Variables and Outcome Variables Measures

	Mean (SD)	1	2	3	4	5
1. L-ship self-efficacy	4.37 (.53)	-				
2. Self-awareness	4.40 (.48)	0.48	-			
3. Ethical awareness	4.06 (.64)	0.44	0.29	-		
4. Global competence	4.13 (.56)	0.38	0.22	0.35	-	
5. Creativity	4.11 (.63)	0.44	0.29	0.36	0.33	-
6. Teamwork skills	4.38 (.54)	0.72	0.50	0.44	0.40	0.41

Note: All correlation coefficients are significant at the 0.001 level (2-tailed).

Hierarchical Multiple Regression

To address the second research question, the additional contribution of being enrolled in the engineering leadership minor program to a prediction of the levels of engineering leadership self-efficacy, a hierarchical multiple regression was conducted to determine which predictor variables were significant in predicting the engineering students' leadership self-efficacy (see Table 2).

Model 1 indicated that the student characteristics of gender, ethnicity, year in school, and whether enrolled in the ELD minor did not significantly predict leadership self-efficacy. Model 2, which added self-awareness and ethical awareness to the previous demographic variables, indicated that 30.3% of the variance in leadership self-efficacy was explained by these predictor variables. Again, none of the demographic variables were significant predictors, but both intra-individual professional skills were positive and significant ($p \leq 0.01$) predictors of engineering students' leadership self-efficacy.

Table 2. Results of Hieratical Linear Regression Predicting Leadership Self-efficacy

Variables	Model 1 β	Model 1 p	Model 2 β	Model 2 p	Model 3 β	Model 3 p	Model 4 β	Model 4 p
(Constant)	-	.000	-	.000	-	.093	-	.243
Control variables								
Female	.064	.323	.016	.770	.069	.122	.079	.073
White	-.036	.578	.009	.873	-.008	.866	-.009	.832
Frshmn & Sophmr	.058	.368	.059	.276	.052	.235	.598	.164
Minor program	.045	.484	.043	.433	.092*	.037	.114*	.010
Predictor variables								
Self-awareness			.374**	.000	.126*	.014	.109*	.029
Ethical awareness			.323**	.000	.108*	.031	.080	.106
Global competence					.083	.095	.059	.237
Teamwork skills					.581**	.000	.550**	.000
Creativity							.157*	.002
Adj R^2	.000		.303**		.549**		.566**	
Delta Adj R^2	.000		.303**		.246**		.017**	

Note: $p^* < 0.05$, $p^{**} < 0.01$

Model 3 added the variables of global competence and teamwork skills to the variables tested in Model 2, explaining 54.9% of the variance in leadership self-efficacy ($p \leq 0.01$) with a significant increase in R^2 compared to Model 2 ($p \leq 0.01$). The two variables accounted for an additional 24.6% variance in leadership self-efficacy after excluding the 30.3% of 54.9% explained by student characteristics and self-awareness and ethical awareness variables. Model 3 indicates that the student characteristic variable of enrolling in the engineering leadership minor program was significant as were self-awareness, ethical awareness, and teamwork skills. Model 3 indicates that the teamwork skills variable has the highest beta coefficient ($\beta = 0.581$, $p < 0.001$) value. The standardized β value for these significant predictors ranged from 0.08 to 0.58.

Finally, Model 4 added the predictor variable of creativity to all previous predictors as tested in Model 3, with a resulting R^2 of 0.566 ($p \leq 0.01$) and a significant increase in R^2 from Model 3 ($p \leq 0.01$). In this final model, among the five predictor variables, three variables significantly and positively predicted engineering students' leadership self-efficacy: self-awareness ($\beta = 0.109$, $p < 0.05$), teamwork skills ($\beta = 0.550$, $p < 0.001$), and creativity ($\beta = 0.157$, $p < 0.01$). Ethical awareness was no longer a significant predictor. As students' self-awareness, teamwork skills, and creativity increased, their leadership self-efficacy increased. Also, being enrolled in the leadership minor program continued to be a positive predictor of students' leadership self-efficacy.

Discussion

Non-technical professional skills (e.g., effective communication, teamwork, ethical decision-making, etc.) are highly desired by industry for students graduating with engineering degrees. It is imperative for engineering educators to help students develop professional skills and attributes and many institutions are incorporating leadership development programs and curriculum to address these industry identified skill requirements. While engineering education literature addresses the development of leadership-related professional skills in engineering students, only a few studies have empirically investigated and provided suggestions for how students can develop professional skills. Results of this study showed that there are positive relationships among the five professional skills identified (self-awareness, ethical awareness, global competency, creativity, and teamwork skills), and engineering leadership self-efficacy for engineering undergraduate students, and those five skills contribute to a prediction of the levels of engineering leadership self-efficacy explaining 54% of the overall variance.

In this study, engineering students' self-awareness is also shown as a key component that is associated with their leadership self-efficacy. This finding aligns with Steffens et al. (2021) reporting that individuals' self-awareness is essential for their effective leadership. Two survey items of self-awareness in this study were: "I understand my leadership style" and "I have a good understanding of myself." These two survey items addressed the self-awareness of not only an individual's personal characteristics, strength, or weakness, but also the individual styles of leading their team members. Because leadership originates from the individual, the performance of a team can highly depend on an individual's self-awareness of their character and personal attributes that contribute to their leadership styles (Kirkpatick & Locke, 1991). Furthermore, Avolio and Gardner (2005) reported a higher level of leaders' self-awareness positively influencing followers' attitudes, behaviors, and work performances.

Another factor that strongly influences participants' leadership self-efficacy is ethical-awareness, which refers to recognizing and addressing ethical challenges, and seeking, understanding, and resolving differences among team members in decision-making processes. Particularly, ethical awareness has been emphasized in recent decades in engineering education (ABET, 2020). Farr and Brazil (2009) reported that ethical awareness is one of the essential

leadership attributes across different engineering positions such as senior executive, middle engineering management, and at the level of junior engineers. Bairaktarova and Woodcock (2017) also reported that engineering students' ethical awareness positively contributed to their ethical behaviors. In this study, ethical-awareness was a significant factor that predicted leadership self-efficacy in Model 2 and 3. Ethical-awareness along with self-awareness explained 30.3% of leadership self-efficacy variance. However, it was no longer significant in Model 4, possibly due to a significant strong contribution of teamwork skills to leadership self-efficacy.

Next, global competence became an imperative leadership skill due to globalization, which refers to an informed and contemporaneous view of the world, ability to assess those diverse talents and expertise reside everywhere, and that all peoples and nations are strongly interconnected. Although global competence was positively and significantly correlated with leadership self-efficacy, it was not a significant predictor of engineering students' leadership self-efficacy after accounting for self-awareness, ethical awareness, teamwork skills, and creativity in this study.

Among the five factors, teamwork skills had the highest standardized coefficient, followed by creativity and self-awareness. The teamwork skills factor consisted of items, such as "I am confident in my ability to work with people with different personalities", that reflect the importance of interpersonal skills as a part of teamwork skills. Another item emphasized demonstrating visions and goals in a positive manner to team members. This result is aligned with Mostafapour and Hurst's (2020) study reporting that teamwork skills are highly related to engineers' leadership style and to their work performance. It is inevitable that engineering graduates will be expected to participate in and/or often lead various projects, and such skills make team projects effective and efficient (Waldman et al., 2001). The results of this study showed that teamwork skills are critical components for one's leadership self-efficacy.

In addition, the level of creativity contributed to the participants' leadership self-efficacy. This result is aligned with Zappe et al. (2015) that engineering creativity is considered an important aspect for developing engineering technical skills as well as professional skills. They claimed that one's creativity is positively associated with problem solving ability, creating new value, and innovation, which are core performance indicators of successful engineering leaders (Komarek et al., 2021).

In terms of demographic variables, none of the characteristics were statistically significant predictors in Models 1 and 2. On the other hand, the minor program was a significant predictor in Model 3 after adding global competence and teamwork skills compared to Model 2 and remained significant in Model 4 after adding creativity to the variables included in Model 3. Perhaps students who are in their minor program already have an established leadership self-efficacy compared to non-minor program students. It is worthwhile to investigate how this engineering leadership minor program helps engineering students have a higher level of leadership self-efficacy.

The importance of these results for the field of engineering education is that it provides the insights that engineering students should learn concepts and acquire professional competencies in aspects of their future careers that go beyond technical expertise. This study informs incorporating professional skills into engineering curriculum aligning with ABET accreditation criteria of leadership and professional skills in engineering education. In other words, results of this study suggest an imperativeness of raising future engineers with appropriate professional skills along with engineering technical skills. As results of this study showed, students' leadership self-efficacy was highly associated with self-awareness which is a key component of leadership decision-making and team-building strategies. Therefore, engineering education should focus on learning objectives and outcomes associated with increasing students' self-awareness. Further, engineering leadership development, both in terms of concepts and professional engineering identity-related effects, may help engineering students develop into more well-rounded engineers.

Conclusion

This study highlighted engineering undergraduate students' leadership efficacy development associated with such professional skills as self-awareness, global competence, ethical awareness, creativity, and teamwork skills. Results of this study indicated that there are positive associations among the five professional skills (e.g., self-awareness, ethical awareness, global competency, creativity, and teamwork skills), and engineering leadership self-efficacy for engineering undergraduate students. The five professional skills (self-awareness, ethical awareness, global competency, creativity, and teamwork skills) impacted engineering leadership self-efficacy.

Limitations

There are several limitations that constrain the generalization of these results. First was the reliance on self-reported data, a limitation that comes from having no independent verification of what student's claim are their self-perceptions on leadership attributes as well as their assessment of their own level of leadership self-efficacy. Further, this study requires another iteration of survey items validation by conducting a confirmatory factor analysis. For example, additional teamwork skills items are needed to further explain various teamwork skills that are needed on engineering projects as a leader. With a validated instrument, future research can investigate the effectiveness of interventions designed to increase leadership attributes within leadership courses and whether such increases are connected to leadership self-efficacy.

Finally, this study lays the groundwork for future empirical tests that would use a full pre/post intervention or control design to determine the effectiveness of a leadership course in terms of various aspects of leadership development.

Authorship Contribution Statement

Park: Conceptualization, design, analysis, writing. Handley: Design, analysis, writing, editing/reviewing. Lang: Writing Editing/reviewing. Erdman: Writing, editing/reviewing

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Appendix

Exploratory Factor Analysis Results for Measures

Factor	# of Items	Alpha	Sample items
Predictor variables			
Self-awareness	2	0.63	I have a good understanding of myself I understand my leadership style
Ethical-awareness	3	0.73	I can apply a professional code of ethics to analyze an ethical problem I have a clear understanding of why ethics is important to my success as a leader
Global competence	4	0.79	I have a good understanding of how my perspective is different from other countries I have a strong desire to be informed of what is going on around me and in the world
Creativity	3	0.83	I am able to develop solutions outside of the ordinary I can apply creativity to problem solving in general I am confident in my creativity
Teamwork skills	3	0.82	I am confident in my ability to work with people with different personalities I am confident in my ability to establish team goals and garner team support I am confident in my ability to work with people
Outcome variable			
Leadership self-efficacy	3	0.81	I am confident taking on leadership roles on projects I am confident that I can lead a team I am confident in my project management skills