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Engineering leadership: Important themes identified by recruiters of entry-level engineers

by

Beth Lin Hartmann

A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Civil Engineering (Construction Engineering & Management)

Program of Study Committee:
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Iowa State University

Ames, Iowa

2016

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DEDICATION

This dissertation is dedicated in memory of my father:

George Lin, Jr., D.D.S.

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ABSTRACT

The purpose of this study was to investigate leadership requirements from the standpoint of prospective employers for full-time, entry-level engineering positions and create a survey instrument to evaluate them. Using the sequential exploratory mixed methods approach, the researchers used emerging qualitative data to inform the development of the quantitative survey instrument.

The qualitative phase of this study sought to understand if industry needs for leadership for two engineering undergraduate populations are the same or different. An analysis was first performed on job postings in the engineering career services database of job postings at a large Midwestern university. The two engineering majors chosen were construction engineering and electrical engineering; one which has *leadership* explicitly stated in the ABET Program Level Criteria and one which does not. Semi-structured interviews were conducted with recruiters with job postings specifically targeted for only construction engineering or electrical engineering undergraduates. Five leadership themes emerged from the interviews: initiative/confidence, communication, interpersonal interactions, teamwork, and engagement.

Using the transcripts and findings from the interviews, a quantitative survey instrument was developed to further explore the relative importance of the five themes. Cognitive interviews were conducted to refine and improve the instrument before release. The survey response rate was 25% (193 of 840). A confirmatory factor analysis determined validity and reliability of the instrument. The survey instrument was used to determine that the relative importance of the five themes is generally the same regardless of major being hired or job title category of the recruiter; the most important theme was

initiative/confidence, followed by communication, interpersonal interactions, teamwork, and engagement.

This study should be refined and repeated at other universities to investigate a larger sample size. In addition, this study serves as the starting point to determine which curricular and non-curricular activities should be included in engineering undergraduate programs to best prepare students for careers in the twenty-first century.

CHAPTER 1. INTRODUCTION

"An engineer is hired for his or her technical skills, fired for poor people skills, and promoted for leadership and management skills." (Russell & Yao, 1996)

Background of the Problem

The need for engineers to possess leadership skills has been a topic of conversation since the 1990's and was highlighted by the National Academy of Engineering (NAE) in two reports (NAE, 2004; NAE, 2005). NAE (2004, p.56) highlights engineering graduates "must understand the principles of leadership and be able to practice them in growing proportions as their careers advance."

Less than 14% of companies hiring today's entry-level engineers graduating from a large Midwestern university include *leadership* in the job description (Hartmann & Jahren, 2015), but nearly all will state they want an employee with leadership skills. Unfortunately, few go so far to define what this means. The problem remains that no one definition of leadership exists, let alone a definition of engineering leadership (Schuhmann, 2010). Many may use a large number of competencies to define leadership (Seemiller, 2013), while others strive to capture the essence into a single sentence. Some also argue the definition may change depending on context. With all of this in mind, it is important to frame this discussion appropriately.

To complement technical engineering skills, educators are acknowledging the need to prepare engineering students in "life and leadership skills" (Athreya & Kalkhoff, 2010). Instructors have a responsibility to prepare their students for industry by helping them develop the leadership skills required to be successful. Therefore, it is incumbent on

members of academia to understand what leadership means to industry and to develop curricula and experiences to incorporate appropriate materials and activities into the undergraduate engineering programs to create engineering leaders.

Purpose of the Study

The goal of this dissertation research was to determine what companies mean when they say they want an applicant to possess leadership (skills) for entry-level, full-time engineering positions. The quest for this answer was to further ascertain further whether different leadership knowledge, skills, and behaviors were needed for individuals entering engineering positions in distinct fields or majors. Discovering the answers to these questions can aid those teaching leadership to engineering undergraduates in developing appropriate curricular and co-curricular activities to best position their students for future employment. While many universities across the country are offering leadership courses, minors, and certificate programs, more work is required to define which leadership competencies are most important to companies hiring undergraduates for entry-level, full-time positions.

The researcher initially focused on the inclusion of leadership in job descriptions and how the word is interpreted by recruiters. The literature review revealed only one study (Yaacoub, Husseini & Choueiki, 2011) in which a similar review was performed by looking at professional skills or "soft skills" in Internet job postings. Then second goal was to determine if recruiters are looking for the same skills or different skills based upon the major of the job seeker. The final goal was to determine if the skills being sought are the same or different based on the job title category of the recruiter. While many studies reviewed the expectations of industry, especially from those serving on industrial advisory boards, the literature review revealed no studies targeted at recruiters.

With regard to comparing the requirements of different engineering disciplines, one report found no significant differences (Dudman & Weane, 2003). Most, however, failed to perform comparisons. As suggested by AlSagheer and Al-Sagheer (2011), more work is needed in this area to ensure students are receiving appropriate instruction and experiences for the major area of study and types of positions they are seeking.

Research Questions

The first two research questions guided the qualitative portion of the study. The findings from the qualitative work informed the quantitative research by highlighting five leadership themes: (1) initiative/confidence, (2) communication, (3) interpersonal interactions, (4) teamwork, and (5) engagement. Research questions 3-5 guided the quantitative portion of the project.

1. What do companies hiring full-time entry-level engineers mean by the word leadership when used in a job description?
2. What differences exist between what hiring representatives of construction engineering and electrical engineering graduates want?
3. What is the order of importance of the five leadership themes?
4. What is the order of importance of the five leadership themes by major hired?
5. What is the order of importance of the five leadership themes by job title category of recruiter?

In qualitative research hypotheses are not used; rather, findings emerge from the data based on research questions. Chapter 3 documents the qualitative portion of this investigation; therefore, no hypotheses are presented. The first two research questions are

presented and answered. The three remaining research questions and corresponding hypotheses are presented and discussed in detail in Chapters 4 and 5.

Definition of Terms

The meanings of terms used throughout the study are provided as follows:

Capstone: A culminating experience or project in education.

Co-op: Cooperative education; A multi-term work experience with the same company.

Experiential education: Job positions for internships and co-op positions. Work experiences ranging from summer internships to multi-term cooperative education employment (co-op).

Hard skills: Abilities that relate directly to the profession, such as ability to do math, proficiency with computer programs, reading, and typing.

Internship: A work experience that involves a single semester or several weeks in the summer.

People skills: A set of skills that allows a person to work well with others, communicate effectively, and resolve conflicts.

Project-based learning (PBL): A teaching method used to provide students a challenging and complex problem work on for an extended.

Service learning: A teaching and learning strategy that utilizes the integration of community service and reflection to enhance the learning experience for participants while helping the community.

Soft skills: Abilities more difficult to quantify than technical skills (hard skills). Soft skills include competency in the areas of communications, conflict resolution and negotiation, problem solving, team building, personal effectiveness, strategic thinking, influence, etc.

Dissertation Organization

This dissertation was written in the alternative journal paper format. It is organized as follows: Chapter 1 is an introduction to the mixed-methods study. Chapter 2 provides a synopsis of prior research, papers, and other material that suggest the continued importance of leadership skills for engineers.

Chapter 3 is the first journal paper, "Industry Needs for Entry-Level Engineering Positions." In this chapter, the qualitative portion of the study is described to include the analysis of job descriptions and semi-structured interviews with recruiters and hiring managers to understand what companies mean when they use the word leadership in a job description. The five emerging leadership themes are introduced and discussed.

Chapter 4 is the second journal article, "Validating the Importance of Leadership Themes for Entry-Level Engineering Positions." In this study, the five leadership themes from the first journal article are further utilized to develop a quantitative survey instrument. The survey instrument is validated and the importance of the five themes is studied.

Chapter 5 is the third journal article, "Engineering Recruiters Survey: Leadership Themes for Full-Time, Entry-Level Employment." This paper is a continuation of the quantitative study presented in Chapter 4. In this chapter, the importance of the five themes is analyzed by engineering major(s) being hired and by job title category of the respondents. Finally, Chapter 6 provides the general conclusions, limitations, and recommendations for practice and future research.

CHAPTER 2. LITERATURE REVIEW

> *Leadership education is an important need for students enrolled in engineering; however, this need has not yet been truly identified. In other words, it seems it has been identified, at least by a number of sources, but that it hasn't yet been given the significance and priority necessary in the engineering curriculum.* (AlSagheer & Al-Sagheer, 2011)

This chapter focuses on the review of literature relating to engineering leadership education and what must be done to prepare undergraduates for industry. The number of leadership books available is plentiful. Therefore, the literature review is focused on:

1. Engineering education background;
2. The call for engineering leadership;
3. Competencies;
4. Soft skills and leadership studies;
5. Overview of engineering leadership programs; and
6. Recommendations to prepare students for their careers in engineering fields.

Engineering Education Background

The progression of engineering education has been over 60 years in the making. The Grinter Report (1955) helped to establish the basic requirements for all engineering curricula. This seminal work in engineering education remains the basis for accreditation and engineering programs today. Since the mid-1990's, more emphasis has been placed on non-technical skills. The call for a change in engineering education to include leadership, soft skills, and other non-technical skills began with the formative paper, The Green Report (1994). This report developed an action plan to urge engineering education programs to not only teach the technical requirements highlighted in the Grinter Report, but to expand them

to be "relevant, attractive, and connected" and "prepare their students for the broadened world of engineering work." (Green, 1994). Green (1994) specifically charged engineering programs to include the following items in their curricula:

- team skills, including collaborative, active learning;
- communication skills;
- leadership; a systems perspective;
- an understanding and appreciation of the diversity of students, faculty, and staff;
- an appreciation of different cultures and business practices, and the understanding that the practice of engineering is now global;
- integration of knowledge throughout the curriculum;
- a multi-disciplinary perspective;
- a commitment to quality, timeliness and continuous improvement;
- undergraduate research and engineering work experience;
- understanding of the societal, economic and environmental impacts of engineering decisions; and
- ethics.

This list served as the precursor to today's ABET (a) through (k) student outcomes (ABET, 2013). Although the ABET student outcomes do not explicitly include the word "leadership," many suggest that leadership is embedded in some of the knowledge, skills, and behaviors in the (a) through (k) criteria. The Lead Societies for three of the twenty-eight ABET engineering programs have chosen to elevate the importance of leadership by explicitly stating it in the curriculum requirements for their respective programs. As part of the Engineering Accreditation Commission (EAC) change criteria Engineering Criteria 2000 (EC2000), the word leadership was included in the program criteria for the Accreditation Cycle 2001-2002 by the American Society of Civil Engineers (ASCE) for the Civil Engineering and Construction Engineering programs, and by the Institute of Industrial Engineers for the Engineering Management or Similarly Named Engineering Programs.

The Call for Engineering Leadership

Studies, papers, and articles have followed the aforementioned seminal works and highlighted the need for all engineers, regardless of engineering discipline, to possess technical and non-technical skills (Dudman, 2003; "Educating," 1995; Farr, Walesh & Forsythe, 1997; Goleman, 1999; Hinkle, 2007; Meier, Williams & Humphreys, 2000; Newport & Elms, 1997; Toor & Ofori, 2008; Zaharim et al., 2010). During this same time period, civil engineering faculty and professionals focused on the specific need for civil and construction engineers to possess leadership skills (Bonasso, 2001; Bowman & Farr, 2000; Hilton, 1996; Russell & Yao, 1996).

In 2004 and 2005, the National Academy of Engineers (NAE) helped to bring this issue to the forefront with the publication of two reports, The Engineer of 2020: Visions of Engineering in the New Century (NAE, 2004) and Educating the Engineer of 2020: Adapting Engineering Education to the New Century (NAE, 2005). The NAE's 2004 report highlighted the role of all engineers in the future and the skills needed. Chapter 4, The Attributes of Engineers in 2020, specifically highlighted key characteristics for engineers. While many attributes were discussed, the following were emphasized: "strong analytical skills, creativity, ingenuity, professionalism, and leadership" (NAE, 2004, p. 59). The 2004 report served as a starting point for the 2005 report, which provided a discussion on how to shape engineering curricula to best prepare engineering undergraduates for the workforce. The second report delved deeper into trying to determine what must be done to engineering education to produce technically competent engineers with skills to enable them to work. While these reports mention leadership as an attribute or trait, they do not go into depth on the definition of leadership.

As noted earlier, civil engineering and construction engineering are two of the three ABET programs with explicit requirements for leadership. Therefore, it comes as no surprise that the American Society of Civil Engineers (ASCE) continued to highlight the need through their own publications, "The Vision of Civil Engineering in 2025" (2007) and "Civil Engineering Body of Knowledge for the 21st Century – Preparing the Civil Engineer for the Future, 2nd Edition (2008)," also known as BOK2. In "The Vision of Civil Engineering in 2025" eight long-term action items were identified to reach the vision, the first item of which was, "A more robust educational path for civil engineers that prepares them for leadership and provides multifaceted non-technical skills to serve on projects affecting the public good." (ASCE, 2007)

In the ASCE BOK2, the "body of knowledge" is defined as the "knowledge, skills, and attitudes necessary for entry into professional practice" (ASCE, 2008). This document specifically addressed the requirements for civil engineering professionals to be successful in industry. The Body of Knowledge Committee identified three categories of outcomes, (1) functional, (2) technical, and (3) professional. The committee determined the level of proficiency desired for each of the twenty-four outcomes at three different times in a civil engineer's development: (1) bachelor's degree, (2) master's degree or equivalent, and (3) professional licensure experience. Leadership (Outcome 20) was placed in the professional category. Leadership is briefly defined as "organize and direct efforts of a group" (p.17) and in more detail later in the report (pp. 145-146). Using Bloom's Taxonomy of Education Objectives, the level of proficiency for leadership for the undergraduate level was determined to be knowledge, comprehension, and application. Of note, Communication (Outcome 16)

and Teamwork Outcome 21) were also included in the professional outcomes group (ASCE, 2008).

Regardless of engineering discipline, the emphasis on engineering leadership at the undergraduate level has intensified since these national reports were published as evidenced by (1) a white paper to capture a "snapshot" of engineering leadership programs worldwide (Graham, Crawley & Mendelsohn, 2009); (2) the issuance of a Position Statement in 2010 by the National Society of Professional Engineers (NSPE) to add six engineering education outcomes to the ABET (a) through (k) student outcomes, the first of which was "apply principles of leadership" (NSPE, 2010); (3) more papers on the topic, including special issues of journals dedicated to engineering leadership education, such as the Journal for STEM Education (Raju, 2010); (4) the publication of books to deliver thoughts from industry and academia (Gordon, 2012) and to assist engineering students and professionals to develop their leadership skills (Bennett & Millam, 2012); and (5) the formation groups dedicated to engineering leadership education, such as the Community of Practice of Leadership for Twenty-first Century Engineers (COMPLETE) in 2010 (Rice Center for Engineering Leadership, 2014) and the Leadership Development (LEAD) Division of the American Society for Engineering Education (ASEE) in 2013.

Competencies

A large body of work exists in the area of leadership for all students. For the purposes of this study, the literature review was narrowed to a few key works. Hemphill and Coons (1957) seminal work in leadership competency questionnaires paved the way for others (Kouzes & Posner, 1998; Posner, 2010, Seemiller, 2013, Seemiller & Murray, Tyree, 1998) to follow. Seemiller and Murray (2013) were very detailed in their approach, identifying a

total of 244 competencies (61 competencies across 4 dimensions). By analyzing outcomes of 475 academic programs, including engineering programs, the authors constructed a comprehensive list "Student Leadership Competencies" (SLCs). Of note, engineering programs had the lowest number of SLCs of all programs analyzed.

A plethora of work has been completed to identify and measure "competencies" required by engineering undergraduates (Brumm, Hanneman & Mickelson, 2006; Meier, Williams & Humphreys, 2000; Özgen, Sáchez-Galofré, Alabart, Medir & Giralt, 2013; Passow, 2012). Others identified these similar sets and subsets of knowledge, skills, abilities, attitudes, traits, and behaviors using the word "capabilities" (Bernard M. Gordon, 2011; Crumpton-Young et al., 2010), "qualities" (Farr, Walesh, & Forsythe, 1997; Newport & Elms, 1997), or "attributes" (Sunthonkanokpong, 2011). Some of these authors explicitly address "leadership," while others may imply its presence by discussing ABET skills, professional skills, "soft skills" (Phani, 2007; Yaacoub et al., 2011), or "non-technical skills." While the terminology may not be perfectly aligned, these works are very closely related and help to set the stage for a discussion about engineering leadership.

Competencies (or capabilities, qualities, skills, etc.) to be studied and/or measured were developed or identified in a number of ways. Bernard M. Gordon-MIT Leadership Program (2011) and Brumm et al. (2006) surveyed participants across populations of employers, students, faculty members, and others. Some created lists of competencies by using all or parts of other sources (Dudman & Wearne, 2003; Ellis & Petersen, 2011; Passow, 2012; Yaacoub, Husseini & Choueiki, 2011); others developed their own lists as part of their research methodology (Cox et al., 2012; Crumpton-Young et al. 2010; Itani & Srour, 2015; Meier, Williams, and Humphreys, 2000). Finally, some researchers developed their

capabilities through a combination of from other sources and research participants (Martin, Maytham, Case & Fraser, 2005).

Soft Skills and Leadership Studies

Soft Skills Studies

Sageev and Romanowksi (2001) and Riemer (2007) focused solely on communications in their studies. The researchers found that engineers who had graduated between three and five years earlier from the State University of New York at Buffalo reported spending 64 percent of their time on written or oral communications and 32 percent of their working time in teams. This is in line with findings from Crumpton-Young et al. (2010) who stated, “Communication skills were identify (sic) by both the students and professional participants as the most important skills for engineering leaders.” (Crumpton-Young et al., 2010).

Scott and Yates (2002), and Riemer (2007) both emphasized the importance of communications and “emotional intelligence” for enhancing early career success for engineers. The term emotional intelligence (or EQ), which is defined as “the ability to recognize, understand and manage our own emotions and the ability to recognize, understand, and influence the emotions of others” (IHHP, 2016), was created by researchers Peter Salavoy and John Mayer in 1990. The term was also made popular from author Daniel Goleman (1995). Many people may refer to these skills as “people skills” (Naguib, 2007).

People skills are often listed as a soft skill. Phani (2007) created a list of 60 soft skills required by engineers; the list served as the basis for the review of 4,334 electronic job postings by Yaacoub, Husseini and Choueiki (2011). The researchers performed keyword searches to capture the frequency of keywords that could be linked the list of soft skills. This

study was the only one reviewed to look specifically at job postings. Communication skills, team skills, and interpersonal skills topped the list of those discovered in the job postings analyzed.

Shuman, Besterfield-Sacre, and McGourty (2005) demonstrated that the ABET "professional skills" (ABET student outcomes (d), (f), (g), (h), (i) and (j)) can be taught and assessed, while Passow (2012) focused on determining which of the ABET competencies are most needed by professionals. After a thorough review of other ABET "importance" studies, Passow (2012) performed a quantitative study spanning seven years to capture data from undergraduate alumni in eleven engineering majors at various point in their careers (0, 2, 6 & 10 years after graduation) to discover which ABET competencies are most important in their professional careers. Passow (2012) found their research aligned with many of the aforementioned studies in that most graduates identified the soft skills of teamwork and communication (along with data analysis and problem solving) as more important than the other outcomes, including math, science and engineering, and design.

Many other authors used the ABET (a) through (k) student outcomes to frame their studies and/or compare their findings to these outcomes (Agoki, 2007; Baytiyeh & Naja, 2010; Bowman & Farr, 2000; Brumm al, 2006; Itani & Srour, 2005; Kumar & Hsiao, 2007; NSPE, 2010; Passow, 2012; Riemer, 2007; Schuhmann, 2014; Shuhman et al., 2005; Warnick & Schmidt, 2014; Yaacoub et al., 2011). Again, the competencies most cited in these studies also include teamwork (ABET Outcome d) and communication (ABET Outcome g).

In the Brumm et al. (2006) study, 212 "stakeholders" helped to develop fourteen competencies to measure the ABET (a) through (k) outcomes. Leadership was not identified

in their list, but could possibly be implied in some of their findings. This is suggested by Kumar and Hsiao (2007), with the conjecture that the ABET professional skills are meant to prepare students to become leaders.

Leadership Included in Soft Skills Studies

In some of the "soft skills" studies, researchers briefly include leadership into the discussion, with some adding leadership as a separate category. In some cases, leadership is combined with teamwork, management, or other competencies; in other studies, leadership is included as a stand-alone category. It is important to note that limited definitions, if any, are provided for "leadership" in these studies

Newport and Elms (1997) aimed to discover qualities for effective engineers. Utilizing interviews, they identified over 200 qualities and by combining like words developed a list of 68 qualities, which included initiative, leadership skills, interpersonal skills, and teamwork skills. Surveying 82 engineers-supervisor pairs, they found that effective engineers were perceived not only having better interpersonal skills, but that "an effective engineer is not necessarily more technically competent than a less effective engineer" (Newport & Elms, 1997, p. 331).

Meier et al. (2000) also noted the importance of interpersonal skills. The researchers identified seven themes of competencies to assess competency gaps in STEM fields, with a focus on non-technical skills. The researchers identified the largest gaps in people and communications skills and business management skills and underscored communications, leadership, and teamwork as areas requiring more focus.

Dudman and Wearne (2003) repeated a 1979 survey to look at "managerial skills and expertise" needed by engineers in the United Kingdom. Under one category titled

"leadership," the researchers included: (1) make formal presentations, (2) plan and chair formal meetings, (3) motivate others, and (4) supervise others. This was the highest rated category of the nine studied with 96% of the respondents identifying leadership as the top requirement for their job. They looked at the requirements of leadership by ten different institutions (professional groups) for various engineering disciplines. The results were similar across all groups, ranging from 80% to 100%.

Some researchers concentrated on only one engineering discipline (Martin, Maytham, Case & Fraser, 2005; Grant & Dickson, 2006; Sunthonkanokpong, 2011), while others, elected to study more (Dudman & Weane, 2003; Baytiyeh & Naja, 2010; Itani & Srour, 2015).

Martin, Maytham, Case, and Fraser (2005) performed a qualitative study to determine how well chemical engineering graduates felt they were prepared for industry. Through sixteen interviews, graduates reported strengths in "technical background, problem solving skills, formal communication skills and life-long learning abilities." They identified their weaknesses as: "work in multi-disciplinary teams, leadership, practical preparation and management skills."

Grant and Dickson (2006) also studied chemical engineering graduates upon graduation and after a few years of employment, with an emphasis on "personal skills." In their study, the top rated skill for work was "Ability to work effectively as a member of a team." "Ability to communicate effectively" was ranked 3 of 26 of the skills and abilities measured, while "Ability to be a leader" was ranked 13 (Grant & Dickson, 2006).

Sunthonkanokpong (2011) surveyed 172 industrial engineering graduates on successful attributes needed for career success. This research emphasized the influence of

globalization on engineering practice, thereby creating engineering positions requiring more non-technical skills. The top attributes identified and ranked in this study were:

1. lifelong learners
2. ability to frame problems, putting them in socio-technical and operational context
3. dynamic/agile/resilient/flexible
4. high ethical standards and a strong sense of professionalism
5. good communication skills with multiple stakeholders
6. possess strong analytical skills
7. exhibit practical ingenuity; posse's creativity
8. business and management skills; leadership abilities. (Sunthonkanokpong, 2011)

In contrast to the single discipline studies, Baytiyeh and Naja (2010) surveyed 188 new practicing engineers about learning deficiencies that hinder "novice engineers" in five different engineering disciplines. In this quantitative study, they placed skills into three categories: technical, interpersonal, and personal. Among the nine interpersonal skills were oral and written communication, decision-making, confidence, and the ability to work effectively in a team. Leadership and managerial skills were included in the list of nine personal skills and were identified as second-to-lowest-rated skill before starting the career. It was also highlighted as one of the largest differences from "before starting career" to after "practicing engineering." Although they captured data from these five engineering disciplines, no analysis was performed to compare findings from each distinct discipline.

Finally, Itani and Srour (2015) surveyed engineering seniors from four disciplines to ascertain the perceptions of "soft skills, industry expectations, and career aspirations." One of the 34 questions specifically concentrated on the importance of engineers' recruitment factors. Twelve items were rated on a scale of 1-5, with a mean score of 3.5 perceived as important. The items were ranked as shown below, with teamwork and leadership combined into one category. Mean scores ranged from 4.43 (Education) to Gender and physical

appearance (2.79), with only the bottom two factors receiving scores below 3.5. Similar to Baytiyeh and Naja (2010), no comparisons were made based upon major.

1. Education (reputation of degree and university)
2. Motivation and need for achievement
3. Teamwork and leadership skills
4. Relevance of education with applied position
5. Creativity and optimism
6. Communication and writing skills
7. Internship
8. Connections
9. Cumulative average (GPA)
10. Risk-taking propensity
11. Extracurricular activities
12. Gender and physical appearance. (Itani & Srour, 2015, p. 8)

Engineering Leadership Studies

In the engineering leadership studies, researchers frame their studies by identifying leadership competencies, capabilities, skills, etc. Rather than leadership being one item among many others, all items measured are defined as components of leadership.

Crumpton-Young et al. (2010) surveyed 264 practicing engineers to determine their perception of strength areas and areas needing improvement with regard to leadership capabilities. In this study, practicing engineers stated confidence in solving problems, leading a team, and listening. They reported a lack of confidence in oral presentation skills, written communications, and persuasion abilities. Similarly, of students 213 surveyed, written and oral communications were ranked the lowest of all skills studied.

In two studies, Ellis and Petersen (2011), and Özgen et al. (2013) utilized 360-degree feedback tools. Following the restructuring of accreditation requirements and to satisfy the directive of the vice chancellor of the University of the West Indies, Ellis and Peterson (2011) developed a way to assess leadership abilities in graduate students in civil engineering

and construction management. The authors reviewed the engineering leader abilities identified by Rao and Rao (1995), choosing ten abilities to measure in a 360-degree feedback tool for their students. They found that the students' self-assessments were higher that those from their peers.

In the Özgen et al. (2013) study, engineering student leadership competencies of eleven fourth year engineering students in the project management in practice (PMP) were studied using a 360-degree feedback tool. The researchers used competency framework was from the European Foundation for Quality Management (2003) Excellence Model. Leadership competencies included: (1) Client orientation; (2) Commitment to learning; (3) Drive for excellence; (4) Integrity; (5) Interpersonal communication; (6) Responsiveness to change; (7) Results orientation; and (8) Teamwork. Surprisingly, their findings did not match those mentioned earlier with student leaders showing the highest level of competency in commitment to learning, interpersonal communication, teamwork and results orientation.

University Programs

While there still exists a lack of teaching soft skills, including leadership, to engineering undergraduates, some universities have developed leadership programs, minors, and certificates to address this need and close the gaps identified by others. In 2009, Graham, Crawley and Mendelsohn performed a comprehensive review of leadership programs worldwide. They investigated over 40 programs, in two categories "explicit" (primary focus on leadership development) and "non-explicit" (involves some leadership development). According to their report, the United States was leading the way with introducing leadership into engineering curricula. At the time of their study, many of the programs examined had been in existence for less than five years (Graham et al., 2009).

The Bernard M. Gordon-MIT Engineering Leadership Program sponsored the 2009 report by Graham et al. The "capabilities of an engineering leader" briefly discussed in the white paper and in more detail in "Capabilities of Effective Engineering Leaders" (Bernard M. Gordon-MIT Engineering Leadership Program, 2011) were used as a basis to compare and contrast all the programs reviewed. In addition to the broad review, the researchers highlighted four case studies, (1) Engineering Leadership Development Minor (ELDM) at Penn State University; (2) Engineering Leadership Program at Iowa State University; (3) Gordon-MIT Leadership Program at MIT, and: (4) Leadership in a Technological Environment at Monash University,

The use of the word "snapshot" in their title was well chosen. Some of the programs included in their report are no longer in existence, while many new programs have emerged in recent years. Iowa State University is an excellent example of the dynamic nature of these programs. The Engineering Leadership Program (ELP) at Iowa State University (Athreya et al., 2007; Athreya & Kalkhoff, 2010) was highlighted as an "explicit" program by Graham et al. (2009). While an excellent leadership development scholarship program funded by 3M, the pilot program did not extend past its initial funding and ended in 2010. Running in parallel to the ELP, an NSF Scholarships in STEM program called the E2020 Scholars Program began at Iowa State University in 2008. This program focused on developing students in four areas: leadership, systems thinking, innovation, and global awareness. This program ended after providing instruction and scholarships to 73 undergraduates (E2020 Scholars Program, 2013; Rover et al., 2013). In the wake of these two programs, Iowa State University launched the Engineering Certificate in Leadership and Strategy in spring 2009. This 21-credit hour program remains in existences and provides students with knowledge and

experience in leadership styles and strategies, communication skills, public administration, organizational behavior, and ethics, as well as a leadership capstone (Engineering Leadership Certificate, 2013).

Engineering leadership minors have become more and more popular since the Graham et al. (2009) report was published. Two examples of new programs include the Purdue Engineering Leadership Minor, which began in 2013 (Leadership @ Purdue, 2016), and the Georgia Tech Leadership Studies Minor with a focus in Global Engineering Leadership, which was launched in 2015 (Georgia Tech School of Civil and Environmental Engineering, 2016).

Due to the various funding types and emphases of these programs, identification of all of the current leadership programs globally is a challenging endeavor. Some may have a distinct and recognizable leadership title while others may be embedded into the current curricula and nearly impossible to identify without an insider's perspective. While many of these programs were presented in NAE (2012), work is currently being performed by the ASEE LEAD Division to benchmark the numerous programs in existence today (Bennett email, December 9, 2015).

Developing Undergraduate Leaders

With the emergence the ASEE Leadership Division and engineering leadership as a discipline, more emphasis is being placed on how to teach leadership and soft skills to students. While there are many engineering minors and similar programs, there is an impetus that all undergraduate students receive this training and development. Cox, Cekic, and Adams (2010), and AlSagheer and Al-Sagheer (2011) discovered that faculty members did not feel equipped to teach topics such as leadership. They expressed concerns about

limitations in the subject area and no formal training on how to teach leadership to their students. This issue must be addressed to help effect change in this area.

There are many ways to introduce leadership into undergraduate engineering programs. Twelve faculty members interviewed by Cox et al. (2010) suggested integrating leadership topics into the curriculum, leveraging capstone courses, real-life experiences, and extracurricular activities as means to reach all students. These recommendations and others were featured in NAE's *Infusing Real World Experiences into Engineering Education* (NAE, 2012).

Schulz (2008) advocated "Embedding the training of soft skills into hard skills courses is a very effective and efficient method of achieving both in an attractive way of teaching a particular content and an enhancement of soft skills (p. 146)." Integration of leadership and soft skills into the curriculum was discussed by others (Agoki, Boon-Chai, & Johnson, 2007; Farr, Walesh, & Forsythe, 1997; Grant & Dickson, 2006). These authors suggested embedding leadership into existing engineering courses.

Design projects and multidisciplinary teamwork were highlighted as another way to foster non-technical skills development (Baytiyeh & Naja, 2010; Crumpton-Young, 2010; Ellis & Petersen, 2011; Farr et al., 1997; Grant & Dickson, 2006). Project based learning (PBL) was also explored in detail (Rover et al., 2013; Russell & Yao, 1997; Walters & Sirotiak, 2011). Walters & Sirotiak (2011) studied PBL in courses, which remain a popular place for programs to embed soft skills training (Bowman & Farr, 2000). While capstone courses present opportunities for this purpose, leadership should be introduced early in programs and continue through the senior year (ASCE, 2008; Athreya et al., 2007; Athreya & Kalkhoff, 2010; Bowman & Farr, 2000; Farr & Brazil, 2009; Warnick & Schmidt, 2014).

Experiential education (internships and co-ops) is an important path to develop skills required in the engineering industry (Brumm et al., 2006; Grant & Dickson, 2006). These experiences are required for graduation by some programs and strongly encouraged by others. Brumm et al. (2006) validated the importance of experiential education in the development of their fourteen "ISU Competencies."

Extracurricular activities provide unique opportunities for students to develop leadership skills (ASCE, 2008; Itani & Srour, 2015; Martin et al., 2005). Brumm et al. (2006) found that engineering student organizations were overall more effective in developing thirteen of the fourteen "ISU Competencies" over non-engineering student organizations. Faculty members must encourage students to get involved outside of class to broaden their experiences and capabilities.

Another way to foster leadership skills is through service learning projects. Although not mentioned by faculty members in Cox et al. (2010), service learning was emphasized by many by (Athreya & Kalkhoff, 2010; Athreya et al., 2007; Graham et al., 2009; Kumar & Hsiao, 2007; Rover et al., 2013; Shuman et al., 2005; Warnick & Schmidt, 2014) as an excellent avenue for developing leadership skills.

Finally, some formal leadership programs have created "leadership labs" to create a safe environment for students to practice leadership skills (Pitts & McGonagle, 2013). These labs may be exported to other universities and embedded into existing courses.

Summary

The literature reviewed emphasized the need for undergraduates to receive formal training and development in leadership throughout their education careers, as well as prepare faculty members to deliver these experiences. "The key to embedding leadership in the

formal education process is to mirror the real world" (Bowman & Farr, 2000, p. 19). With overwhelming evidence of the importance of communications, teamwork, and other soft skills when developing leaders and strong proof of ways this can be achieved, a focus on what recruiters are looking for from job applicants is still needed. Work must be continued in this area to assist engineering educators in their quest to best prepare engineering undergraduates for successful careers as 21st century engineers.

CHAPTER 3. LEADERSHIP: INDUSTRY NEEDS FOR ENTRY-LEVEL ENGINEERING POSITIONS

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Abstract

This paper presents the results of a study that sought to identify and highlight what the most prominent competencies companies are seeking when they use the word *leadership* in job descriptions for entry-level, full-time engineering positions. Seven years of job posting data were analyzed to first understand the frequency and use of the word leadership in job descriptions. Using a systematic approach, six participants from engineering companies hiring students from a Midwestern university were selected and interviewed. Emerging themes from the interviews include the following leadership competencies: initiative/confidence, communication, interpersonal interactions, teamwork, and engagement. The goal of this ongoing research is to assist engineering programs to assess, refine, and develop curricula, advising materials and methods to best prepare students for industry.

Keywords: leadership, ABET, engineering education

Leadership: Industry Needs for Entry-level Engineering Positions

Engineering industry representatives have identified leadership skills as necessary for engineers entering today's workforce. Some companies have specifically included the word *leadership* in entry-level job descriptions. However, few go so far to define what this means. While there is a clear demand signal being sent from industry for engineering programs to create graduates with leadership skills, it is incumbent on members of academia to understand what leadership means to industry and to develop curricula to incorporate appropriate materials and activities into the undergraduate engineering programs to create engineering leaders.

The purpose of this case study was to explore what are the most prominent competencies companies are seeking when they use the word leadership in job descriptions. We first investigated job postings to understand the trends and the current landscape of positions requiring leadership. We then selected job postings for those positions advertised exclusively for construction engineering and electrical engineering majors and interviewed key personnel in companies hiring these groups of jobseekers. Finally, we synthesized responses from our interviews into five themes. The emerging themes outlined in this study have the potential to help to shape engineering leadership curricula.

Background

Engineering Leadership Definition

There is a plethora of literature about leadership and important qualities needed, including the most basic, such as knowledge of self, emotional intelligence, motivation, etc. (Goleman, 1998; Goleman, Byatzis, & McKee, 2002; etc.), however, defining *engineering leadership* is in relatively early stages. Although industry and academia concur that

leadership skills are essential for engineering graduates, no agreement has been made regarding a single definition for engineering leadership (Schuhmann, 2010, p.61). Some argue that engineering leadership is no different than leadership in general, while others believe engineering leadership must include an element of engineering design. To understand the current landscape, three definitions of engineering leadership discovered during a review of current literature are provided. The first definition provides an explanation geared at effectively leading others, while the other two describe the process to help understanding about how engineering leadership can be achieved.

"Engineering Leadership is the ability to lead a group of engineers and technical personnel responsible for creating, designing, developing, implementing, and evaluating products, systems, or services" (Crumpton-Young et al., 2010, p. 10).

"Engineering leadership is the process of envisioning, designing, developing, and supporting new products and services to a set of requirements, within budget, and to a schedule with acceptable levels of risk to support the strategic objectives of an organization" (Shaw, 2003).

The Gordon-MIT Engineering Leadership Program defined engineering leadership as "the technical leadership of change: the *innovative* conception, design and *implementation* of new products/processes/projects/materials/molecules/software/ systems, supported by the *invention* of enabling technologies, to meet the needs of customers and society." (Bernard M. Gordon-MIT Engineering Leadership Program, 2011)

While an effort persists to define engineering leadership adequately, numerous academic institutions are currently delivering education and training to develop engineering leaders through formal programs and/or activities embedded into existing curricula.

Engineering Leadership Programs

The effort to highlight the need for leadership in engineering education has been ongoing since the 1990s. As stated earlier, representatives from academia and industry continue to search for a common definition of engineering leadership. This work has been performed primarily to assist undergraduate, graduate, and professional programs by highlighting some of the prominent engineering leadership expectations in the hiring process as they develop leadership curricula for engineering students and professionals.

Graham, Crawley & Mendelsohn (2009) identified over forty engineering leadership programs globally. Their report "aims to provide insight into current provision, highlight international variations in approach and identify examples of good practice." With many more programs in existence, no two are alike.

Need for Leadership

Leadership has been emphasized in various engineering reports, including ABET (2013) and the National Academy of Engineering (NAE, 2004, 2005). While many (e.g., Athreya &Kalkhoff, 2010; Bowman &Farr, 2000); Cox et al., 2010; Crumpton-Young et al., 2010; Farr &Forsythe, 1997; Graham et al., 2009; Schuhmann, 2010) cited a need for engineers to have leadership skills, only three of the twenty-eight engineering programs used the term leadership in their Program Criteria under the Accreditation Board for Engineering and Technology (ABET) Criteria for 2014-2015. From review of the *Criteria for Accrediting Engineering Programs* from the ABET website, *leadership* is only used four times: once in reference to Institutional Support and Leadership, the other three times in the description for Program Criteria for (1) Civil, (2) Construction, and (3) Engineering Management and Similarly Named Engineering Programs (ABET, 2013). Additionally, Seemiller and Murray

(2013) found that engineering programs contained the least amount of "Student Leadership Competencies" of the eighteen categories of academic programs they reviewed.

While not explicitly stated in the ABET program criteria for most engineering majors, many posit that leadership is embedded into many of the ABET (a) through (k) student outcomes; researchers have mapped leadership knowledge, values, attitudes, skills, and abilities to these outcomes, as well as other lists (Farr & Forsythe, 1997; Bowman & Farr, 2000; Brumm, Hanneman & Mickelson, 2006; Passow, 2012; Yaacoub, Husseini & Choueiki, 2011; Schuhmann, 2014). A number of programs have also involved members of industry to help shape their curricular and extracurricular activities, however, limited studies have been performed to define the meaning of leadership when used in a job description.

One study did review job descriptions for soft skills required by industry. Yaacoub, Husseini & Choueiki (2011) performed a quantitative content analysis approach with job descriptions posted on various career websites. While they did not specifically identify any of these skills as leadership skills, the researchers mapped the descriptions to sixty different soft skills identified by Phani (2007) to ABET (a) through (k) outcomes.

In addition to the aforementioned efforts, in 2011 supporters of engineering leadership development and education created the Leadership Development Constituent Committee within the American Society for Engineering Education (ASEE). With over 300 members in 2014, the group received Division status and was renamed the Engineering Leadership Development Division. With an impetus to study and understand this need for engineers to possess leadership skills, an increasing number of papers are being presented at the annual ASEE conference each year to share best practices (e.g., Pitts, McGonagle, & Klosterman. 2013; Warnick, 2014). In addition, Bennett and Millam (2013), and Gordon

(2012) published books dedicated to topics about leadership for engineers and engineering educators.

Research Study

The purpose of this qualitative research study is to identify the most important leadership competencies undergraduates seeking full-time employment should possess when applying for positions. The study was conducted at a land-grant institution in the Midwest. The institution serves over 32,000 students and has roughly 6,300 faculty and staff members. The College of Engineering contains eight academic departments and offers 12 majors. The college hosts one of the largest indoor career fairs in the nation, with approximately of 300 companies represented and 3,000 to 6,000 students and alumni in attendance each semester.

In the study's first phase, data from full-time job postings posted in the university's career management system from 1 August 2006 through 31 July 2013 were analyzed to identify companies explicitly citing leadership in job descriptions. In the second phase, one-on-one interviews were conducted with representatives of six companies to determine which competencies companies most desire from applicants when using leadership in a job description.

Phase I: Job Description Analysis

Phase I of the study was a review of full-time, entry-level job postings for all engineering majors at the aforementioned university. In this phase, we analyzed job postings and specific job descriptions to identify companies meeting the criteria for inclusion in Phase II of the study. Using this methodical approach, we were able to select participants using *purposeful selection* (Light et al., 1990, p. 53). The goals of purposeful selection in this study

were to identify typical companies that hired within disciplines that represented extreme cases – construction engineering and electrical engineering. A discussion of the selection of these two majors is provided later in the paper.

Engineering Job Posting Review

Engineering career services personnel provided job posting information from 1 August 2006 through 31 July 2013. For the seven-year period, a total of 16,173 jobs were posted in the system for all students and alums in the college of engineering. After filtering out positions for underclassmen, Master's/PhD students, and alumni, 7,235 job postings remained, of which 982 (13.6%) contained the word leadership in the job description. Table 3.1 provides a detailed breakdown of these job descriptions and leadership job descriptions by year. It was noted that these numbers include positions posted for specific engineering majors, as well as those posted for "All Majors" and "College of Engineering." A histogram illustrating these data is provided in Figure 3.1.

Table 3.1. Full-Time, Entry-Level Engineering Job Postings

Year	All	Leadership	%
2006-2007	929	117	12.6
2007-2008	920	119	12.9
2008-2009	502	69	13.8
2009-2010	405	49	12.1
2010-2011	1079	136	12.6
2011-2012	1555	212	13.6
2012-2013	1845	280	15.2
Total	7235	982	13.6

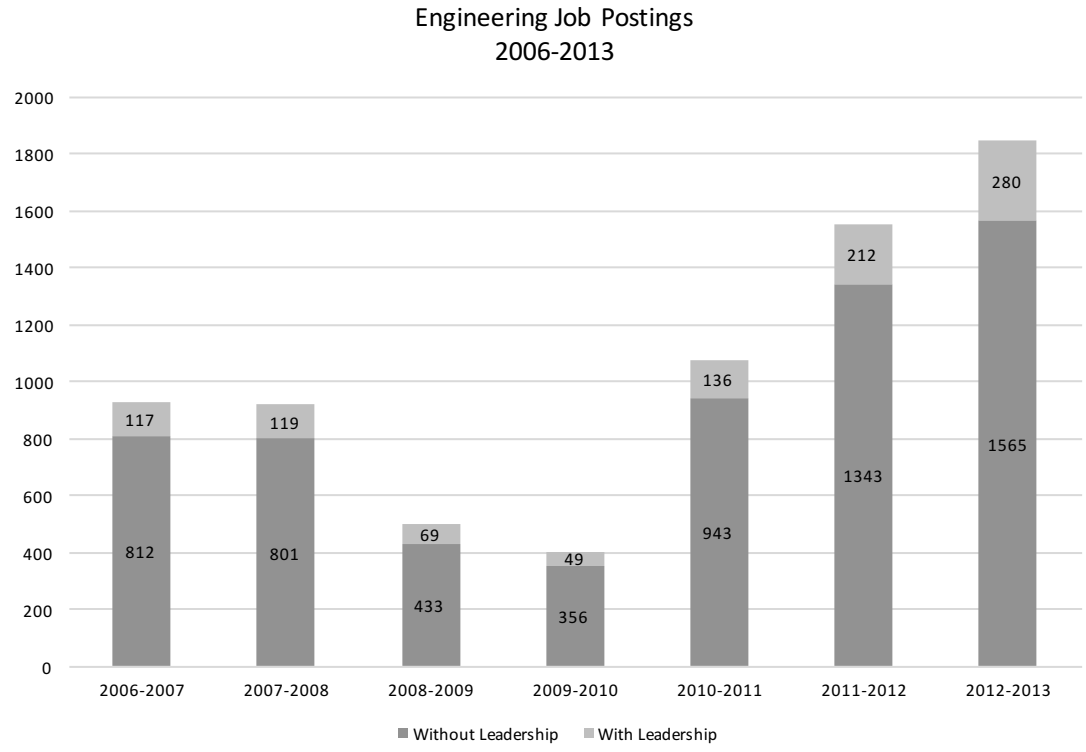

Figure 3.1. Engineering Job Postings by Year

The data were further evaluated to identify job descriptions posted for a single engineering major as opposed to job postings that target more than one major. For the purposes of this study, these announcements will be referred to as *targeted* job postings. Isolating these job descriptions enabled the identification of companies with needs for specific engineering disciplines. During this review, it was noted that the total number of positions posted for a targeted engineering major was 1,555 for the same seven-year period, with only 177 (11.4%) including the word leadership.

Only construction engineering (ConE) and electrical engineering (EE) postings were selected for study for two main reasons. First, ConE has leadership included specifically in the ABET program criteria; EE does not. Second, we perceived these two majors, ConE and EE, on opposite ends of a spectrum that addresses practical content to theoretical content,

respectively. The thought was that by studying these two majors any differences in industry preference would be more clearly recognized. Table 3.2 illustrates the number of targeted ConE and EE job postings, as well as the subsets of those postings containing the word leadership. Overall, companies hiring both ConE and EE candidates included leadership in 10.5% of their respective job postings. This low number may suggest that the majority of the companies are seeking applicants with leadership competencies, but do not explicitly use the word leadership in their job descriptions.

Table 3.2. Targeted Job Postings

	Construction Engineering		Electrical Engineering	
Year	All ConE	Leadership ConE	All EE	Leadership EE
2006-2007	34	5	56	4
2007-2008	20	2	89	12
2008-2009	10	2	37	2
2009-2010	7	1	26	1
2010-2011	18	1	77	9
2011-2012	21	1	112	13
2012-2013	32	3	88	10
Total	142	15	485	51

Job Description Investigation

The 66 job descriptions were analyzed to locate the word leadership in the job description and classify its general meaning into groups. Six categories were identified. The 15 ConE and 51 EE job descriptions were further reviewed to identify possible participants.

Categories of job descriptions. The job postings were placed into the following categories: (1) applicant skills, abilities, and/or capabilities (2) influence or role the applicant will play, (3) job title, (4) development of applicant, and (5) company description and/or qualities. Categorization was performed by a graduate research assistant and validated by the first author. Those job postings falling into the first two categories were considered for

further study, since they are specific to the applicant qualifications and immediate influence/role in the company.

Applicant skills. This category includes job descriptions highlighting a need for leadership skills, abilities, and capabilities. The job descriptions contained phrases similar to the following "Must have excellent leadership skills and capability of supervising others; and must be able to work closely with others."

Influence/role. Positions categorized in this area outlined the role the applicant would play if selected for the position. One example of this is: "Provide leadership to the project team."

Job title. The job descriptions placed into this grouping included the word leadership in the following manner, "Manufacturing Leadership Development Engineer," or similar.

Development. Positions placed into this category included statements like, "During your two-year training program with [Company], you will develop a core understanding of [Company] business systems and culture that will help prepare you for a leadership role within the company."

Company qualities. Job postings listed in this category included language referring to leadership as part of the company or how the applicant would interface with others. These positions included phrases such as, "Our unique business strategy provides us with an unmatched leadership position and ability to build and sustain loyalty to our brands."

Construction engineering job description review. Eleven companies posted the fifteen full-time positions in the targeted ConE leadership data set. These job postings were separated into the categories described previously, and are summarized in Table 3.3 and Figure 3.2.

Table 3.3. Categories of Leadership in ConE Positions

Category	Number of Postings
Applicant skills	5
Influence/role	5
Job title	0
Development	1
Company qualities	4
Total	15

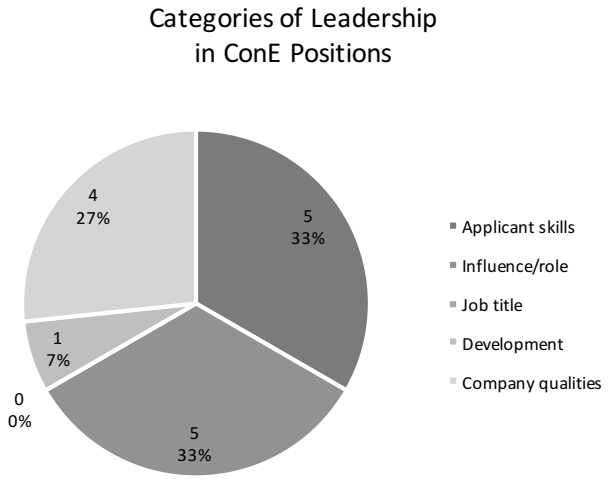

Figure 3.2. Categories of Leadership in ConE Positions

Once the job description information was reviewed and catalogued, it was determined that ten construction engineering companies met the requirements for Phase II of the study. These companies were those with jobs in the applicant skills and influence/role categories. Again, the uses of leadership in the other categories were not about the applicant's qualifications or immediate impact to the company.

Electrical engineering job description review. The comprehensive review of the 51 positions targeted for EE seniors was performed to categorize the use of the word leadership in these postings. Thirty companies were attributed to these postings, ranging from one to six

postings per company. Applicant skills and influence/role contributed the largest numbers of postings. The breakdown of the fifty-one job postings can be seen in Table 3.4 and Figure 3.3.

From this review, companies with job descriptions in the first two categories were identified for possible interviews. Twenty-five companies met these criteria, with eighteen posting job descriptions categorized in the applicant skills category and seven in the influence/role category. Those companies with job postings in the applicant skills category

Table 3.4. Categories of Leadership in EE Positions

Category	Number of Postings
Applicant skills	21
Influence/role	14
Job title	6
Development	7
Company qualities	3
Total	51

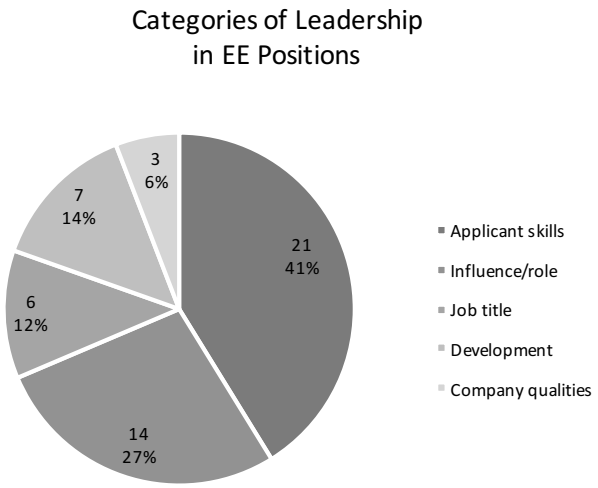

Figure 3.3 Categories of Leadership in EE Positions

were highlighted as preferred for interviews, since this category appears to be more closely related to the research question.

Phase II: Identifying Leadership Competencies

The companies identified in Phase I of the study were contacted for possible participation in the interview portion of the study. Through email, each company was asked to identify one person with the most knowledge about the job posting(s), meaning of leadership, hiring practices, and the needs of the company. From these initial contacts, three participants were selected for each of the cases – construction engineering and electrical engineering companies.

Qualitative Data Collection

The first author utilized the nine steps for interviewed, as described by Creswell (2013, pp. 163-166). Using a four-item interview protocol, the first author conducted interviews with six industry personnel involved in hiring and/or supervising entry-level engineers. One-on-one, semi-structured interviews were conducted at each company's location to gather qualitative data to answer the question, "What do companies hiring full-time entry-level engineers mean by the word leadership when used in a job description?" A sub-question we hoped to answer was, "What differences exist between what hiring representatives of construction engineering and electrical engineering graduates want?"

Exploratory questions were tested with two members of a construction engineering industrial advisory board who hire entry-level engineers at a large Midwestern university. This effort allowed the interviewer to have a better understanding of how the questions were being interpreted and better prepare for the interviews.

We began the interviews by asking participants about their employment at the company, including job title, job responsibilities, and number of years with the company. These questions helped to build rapport between the interviewer and participant before the protocol questions. Interviewees included personnel with experience in human resources, engineering, or both. Additional information about the participants is presented in Table 3.5.

Participants were then asked about what they are looking for when meeting, interviewing, and reviewing resumes for applicants for entry-level engineering positions. The semi-structured interview format allowed the interviewer to ask appropriate follow-up questions as each conversation unfolded. With interviewee consent, interviews were digitally recorded, and lasted 45-60 minutes each.

Table 3.5. Industry Personnel Interviewed

Industry and gender	Job title	Years at company
Construction		
Female	Human Resources Director	9
Female	Director of Learning and Development	8.5
Female	Human Resources Manager	2.5
Electrical		
Male	Application Engineering Manager	15.5
Female	Human Resources Representative	25
Male	Manager of Substation Engineering	15.5

Qualitative Data Analysis

Interviews were transcribed for each participant. Each participant reviewed their transcript and performed a member check for accuracy. The first author read revised transcripts and listened to interview tapes before uploading the transcripts to NVivo for Mac (Version 10.1.0) software. The “analytic option” utilized aligns closely with the categorizing strategies described by Maxwell (2013, p. 105). The transcripts were also manually coded,

evaluated, and analyzed by two independent reviewers. All coders used "open coding" (Corbin & Strauss, 2007, pp. 195-204) to develop their own themes. An examination of all reviewer codes and notes prompted numerous discussions and more refined coding. Through this iterative process, final codes and observations were achieved.

Analysis of the transcripts revealed employers define leadership in many ways; no two participants described it in an identical way. Each participant articulated several competencies desired by employers for applicants for entry-level engineering positions. An initial review of transcripts was conducted to identify each distinct attribute, skill, or ability discussed by the participants. During this review fifty items were captured as potential themes. Through an iterative process of analysis and discussion with the independent coders, themes were combined and refined.

Five themes clearly emerged: initiative/confidence, communication, interpersonal interactions, teamwork, and engagement. All six participants identified these five themes, also known as leadership competencies, during their interviews. The trustworthiness of these findings was achieved through acquiring rich data (verbatim transcripts), respondent validation (member checks), and the use of three coders (primary researcher and two independent reviewers).

Emerging leadership themes and examples. The five themes identified as the most important are discussed in more detail for a deeper understanding. Additionally, one or two sample participant quotes for each theme is included in this section.

Initiative/confidence. Five of the six interviewees used the word "initiative" several times during their interview. The other participant talked about "stepping up" and "going that extra step." All participants cited "confidence" and/or "self-confidence." Additionally, all

interviewees included "ask(ing) questions" when discussing initiative and/or confidence. One participant stated, "To me I think leadership is initiative -- having the confidence to step up to the plate and do what is necessary, engage individuals to become a team and work towards a common goal" (Company 3).

Communication. All interviewees discussed the importance of communication skills. Included in this theme were written, oral, non-verbal, and listening skills, as well as the ability to conduct crucial conversations. The quotes below are characteristic of other qualitative data used to create this theme:

> Leadership is mainly from the front, stepping out modeling the way, leading by example, so in this case what (sic) possess good written and oral communication skills it is having the ability to be a straight talker to be a part of the team upfront and some cases for a new leader entry level employee that has taken some risk. (Company 6)

> But even in their communication to subcontractors, to owners -- we live in a plugged in world so they have to be able to craft a sentence [laughs] they have to able to make sense, they have to be able to put words together that make sense to convey their message. (Company 5)

Interpersonal interactions. All six participants identified "people skills" as required. Five of the six specifically included a discussion about "relationship building," three identified conflict resolution, while two participants identified accountability to the team/company. The three companies citing the ability to resolve conflict were all hiring construction engineers. This is the only notable difference between ConE and EE discovered during the interviews. The following quotes represent the statements used to categorize comments into this theme.

> Project managers are constantly talking to subcontractors, they need to know how to push them to get things done without breaking a relationship and that's not something that's easily taught." (Company 1)

> Sometimes the project engineers and project managers are looked at to be the experts when like I said before they might be much younger than the individuals that they're dealing with. But having the kind of a quiet resolve to just soak in everything that's going on I think about the best solution and then be able to express that is one of things that I found seems to work best and they've even said in the interns have said it from their exit interviewers. That those are the traits that they appreciate a lot from their PMs is the ability to listen to all sides but yet to be able to come to a consensus, build consensus and then move on from that. (Company 3)

Teamwork. All participants mentioned teamwork and/or being a team player as a requirement to leadership. This theme captures comments about accountability to the team, collaboration, and building consensus. The quote provided represents the qualitative data for this theme:

> We are looking for basic GPA, some initiative, self-confidence; they are a team player, those types of components… Not thinking they have all the answers so knowing that the person next to you might be able to help you out or you might have something that can help them out not always having to be the one in charge doing the cool thing that sometimes the grunt work is part of the team that gets you to that next level. Being able to communicate with each other and know how your work affects the other persons' work so that you know that you are in it together. (Company 2)

Engagement. This theme captures discussions about being engaged in extracurricular activities and volunteer service, as well as at work if hired. Five participants specifically discussed involvement in student organizations and fraternities/sororities. Three interviewees highlighted caring and social responsibilities. The following quote is illustrative of the comments used to create this theme:

> We will look at that they have done maybe it is more than their GPA. We would look at the additional work or things that they have been involved with on their resume and how does that fit in [Company 5] is showing our leadership. It is showing them being engaged, it is showing them that they care, the social responsibilities of whatever they are doing they. Are giving back? It also shows us this is a person who tends to be engaged. (Company 5)

Findings

Our initial findings suggest that when companies use the word leadership in a job description for full-time entry-level engineering positions, they have a primary goal is to seek individuals with strong communication, teamwork, and interpersonal interaction skills. Through their resume, interviews, and internships, engineering undergraduates must also show the potential employers they possess initiative and confidence, as well as are engaged in extracurricular and/or volunteer activities. The study also revealed one notable difference in what construction engineering and electrical engineering companies are seeking; construction engineering firms emphasized "conflict resolution skills" as an additional proficiency in interpersonal interactions. These competencies, while not engineering-specific, were identified as the most important leadership capabilities for new graduates to possess when seeking employment in entry-level, engineering positions.

To develop our understanding of our findings fully, we mapped our themes to other works. While Schumann et al (2014) developed a crosswalk from ABET (a) through (k), correlating it to Bowman and Farr (2000), MIT Leadership Capabilities (2011), and their findings, we structured our crosswalk starting with our themes as the basis to the framework.

Our crosswalk shown in Table 3.6. highlights the connections between our themes and the Gordon-MIT Leadership Capabilities, ISU Workplace Competencies (Brumm et al, 2006), and a popular press leadership book, *The 21 Indispensable Qualities of a Leader* (Maxwell, 1999), as well as the ABET Student Outcomes.

Stakeholders of the MIT program through consensus developed the Gordon-MIT Leadership Capabilities (2011). The document has evolved over time into its current form. The capabilities are organized into six main categories: (1) The Attitudes of Leadership; (2)

Relating; (3) Making Sense of Context; (4) Visioning; (5) Delivering on the Vision; and (6) Technical Knowledge and Reasoning (Gordon-MIT, 2011).

Brumm, Hanneman & Mickelson (2006) presented a mapping of "workplace competencies" to the ABET Student Outcomes. Their work specifically addressed developing and assessing competencies through internships and cooperative learning experiences at Iowa State University (ISU). Working with 212 stakeholders, the authors identified fourteen "ISU Competencies" and mapped them to the ABET (a) through (k) Students Outcomes. While their study did not address leadership specifically, there are indications that many competencies may have a connection to leadership.

We also compare our findings to John C. Maxwell's (1999) *The 21 Indispensable Qualities of a Leader,* from the popular press. Maxwell presents twenty-one "character qualities" and an individual must possess in order to lead others effectively.

This range of literature – university program/industry work, peer reviewed journal article, and bestseller leadership book – highlights the numerous and varied definitions for leadership. As many other authors have done, we mapped our findings to the ABET Student Outcomes, since this is a common metric for engineering programs. It was noted that two of the six Gordon-MIT leadership capabilities highlighted the findings of this study. Likewise, nine of the twenty-one Maxwell qualities were highlighted in the comparison. The authors acknowledge the missing items did not emerge as themes during the interviews, however, this does not suggest that they are not important nor absent from our study, only that they did not emerge as the most important qualities highlighted by the interviewees in this context.

The categories presented in Table 3.6 confirm that many employers may be seeking new graduates with leadership competencies without explicitly using the word leadership in

Table 3.6. Crosswalk of Other Works to Leadership Themes from This Work

Derived Themes from this Study	Gordon- MIT Leadership Capabilities	ISU Workplace Competencies	Maxwell 21 Qualities of Leadership	ABET Criterion 3. Student Outcomes
Initiative/Confidence	(1) The Attitudes of Leadership	Initiative	Initiative, Courage	Embedded in (a), (b), (c), (d), (e), (g), (i), (k) per Brumm et al.
Communication	(2) Relating	Communication	Communication	(g) An ability to communicate effectively
Interpersonal Interactions	(2) Relating	Not specifically addressed	Relationships, Character, Charisma, Listening	Combination of (d) An ability to function in multidisciplinary teams and (g) An ability to communicate effectively
Teamwork	(2) Relating	Teamwork	Relationships, Listening	(d) An ability to function on multidisciplinary teams
Engagement	(1) The Attitudes of Leadership	Development of competencies through extracurricular activities	Commitment, Responsibility	Not specifically addressed

their job descriptions. Additionally, this comparison helps highlight that leadership may be implied in many of the ABET (a) through (k) criteria.

Limitations and Future Research

Limitations to this study include the small number of interviews performed. This includes the total number of interviews, as well as the number in each of the disciplines studied. This study did not allow us to explore other themes that were mentioned by only two or three participants; however, the small number did allow us to gain a deeper understanding of the most important leadership competencies in this context.

Our future studies will use these findings to develop and administer a quantitative survey instrument for industry personnel involved with hiring entry-level engineers for positions in all disciplines of engineering. Job title information will also be captured to determine if responses differ based on type of position of respondents.

Through our mapping and reviewing the keywords in the initial job descriptions, we have confirmed our initial beliefs that most or all companies are seeking employees with leadership skills without specifically using the word leadership in their job description. Confirmation of this premise offers the potential for more survey participants.

Conclusion

This study sought to identify the most important leadership competencies that engineering undergraduates should possess when applying for full-time engineering positions. Using qualitative research methods, we identified five themes that were common across construction engineering and electrical engineering companies and also

confirmed no major differences between what representatives in each discipline desired from applicants. Of the engineering undergraduates seeking full-time positions, companies strongly favor those applicants with communication, teamwork, and interpersonal interaction skills, and those who display initiative and confidence, as well as engagement in extracurricular and volunteer activities, to other leadership competencies.

Discovering and understanding what companies hiring full-time, entry-level engineers are seeking with regard to leadership is the first step to ensure undergraduate engineering programs adequately address this need. From this work, we can begin to assess, refine, and develop curricula and advising materials and methods to best prepare our students for industry.

For this dissertation, minor changes were made to my published article: Hartmann, B. L., & Jahren, C. T. (2015). *Journal of STEM Education: Innovations and Research, 16*(3), 13. The published article focuses on leadership and industry needs for entry-level engineering positions.

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CHAPTER 4. VALIDATING THE IMPORTANCE OF LEADERSHIP THEMES FOR ENTRY-LEVEL ENGINEERING POSITIONS

A paper submitted to *Journal of Professional Issues in Engineering Education and Practice*

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Abstract

There is a strong demand signal from the engineering industry for entry-level engineers to possess technical skills and leadership skills. Limited research has been performed to define what companies mean by *leadership* when used in a job description. Using qualitative research methods in an earlier study, the first author found that personnel from engineering companies involved with hiring entry-level engineers are most interested in five themes or leadership competencies from applicants: initiative/confidence, communication, interpersonal interactions, teamwork, and engagement. This study extends the prior research by developing and validating a quantitative survey instrument based on these five themes, as well as presents a ranking of the importance of these themes. Validating and understanding which themes are most important for new graduates to possess can inform engineering educators in creating, developing, and refining leadership education for engineers, as well as aid in the further development of this instrument.

Author Keywords: leadership; engineering; entry-level positions; ABET.

Introduction

There is a strong demand signal from the engineering industry for entry-level engineers to possess technical skills and leadership skills. Some researchers have focused on these capabilities required by companies hiring engineers, and/or how to best prepare undergraduates for these positions (Brumm, Hanneman & Mickelson 2006; Passow 2012; Walters & Sirotiak, 2011; Yaacoub, Husseini, & Choueiki, 2011); others have narrowed their attention specifically to leadership competencies and requirements (Athreya & Kalkhoff, 2010; Bernard M. Gordon Leadership Program, 2011; Bowman & Farr, 2000; Crumpton-Young, McCauley-Bush, Rabelo, Meza, Ferreras, et al., 2010; Farr, Walesh & Forsythe, 1997; Graham, Crawley, & Mendelsohn 2009; Schuhmann, Magarian & Huttner-Loan, 2014; Schuhmann, 2010). Additionally, NAE (2012) has identified and highlighted many best practices taking place across the U.S. to introduce real world experiences into undergraduate engineering programs.

Using qualitative research, Hartmann & Jahren (2015) performed a study to discover the prominent competencies desired by engineering companies when using the word *leadership* in job descriptions. The themes that emerged from these in-depth interviews include: initiative/confidence, communication, interpersonal interactions, teamwork, and engagement. In this study a quantitative survey instrument was developed to measure these five themes and provide a relative ranking of the order of importance. This mixed method approach is called “sequential exploratory” and is helpful when developing and testing a new instrument (Creswell, 2013).

The goal of this paper is to validate the survey instrument and to present the results from the pilot survey to contribute further to the effort to understand the needs of

industry. The purpose of this research is to define and understand the most important leadership themes associated with entry-level engineering positions to determine instructional and experiential experiences to best ensure engineering undergraduates are prepared to enter the workforce.

Background

Representatives from industry and academia have cited the need for including leadership development in engineering education for many years. The National Academy of Engineering has emphasized this need (NAE 2004, NAE 2005). Other researchers have also added to this topic, citing the pressing requirement for engineers to possess leadership skills (Athreya & Kalkhoff, 2010; Bowman & Farr, 2000; Cox, Cekic, & Adams 2010; Crumpton-Young et al., 2010; Dugan & Haber, 2007; Farr et al., 1997; Schuhmann 2010).

While there remains an emphasis for engineering undergraduates to receive leadership development education and training, only 3 of the 28 ABET engineering programs include the word leadership in the ABET Program Criteria: Civil, Construction, and Engineering Management and Similarly Named Engineering Programs (ABET, 2013). As the founding society for two of these three programs, the American Society of Civil Engineering (ASCE) leads the way in explicitly including leadership in the ABET Program Criteria for civil engineering and construction engineering.

ASCE also emphasizes the need for civil engineers to possess technical and professional skills in two key publications, The Vision for Civil for Engineering in 2025 (ASCE, 2007) and the second edition of the ASCE Body of Knowledge (ASCE, 2008), also known as BOK2.

ASCE acknowledged that civil engineers are required to continually build upon the knowledge, skills, and abilities gained during their undergraduate experiences. They reported, “U.S. civil engineers can be catalysts in sharing the vision with the global civil engineering community.” In support of this ideal, the ASCE has outlined key actions to ensure “a more robust educational path for civil engineers that prepares them for leadership and provides the multifaceted non-technical skills to serve on projects affecting the public good” (ASCE, 2008). According to the ASCE BOK2, entry into the civil engineering profession is most successful upon twenty-four categorized outcomes achieved. The outcomes were categorized as either: (1) foundational, (2) technical, or (3) professional. Using Bloom’s Taxonomy for the levels of achievement desired, ASCE also identified level of proficiency desired for each outcome at three points in an engineer’s career: (1) bachelor’s degree, (2) master’s degree or equivalent, and (3) professional licensure experience. According to the BOK2, engineers should be proficient in the knowledge, comprehension, and application of Leadership (Outcome 20), a professional outcome, at the undergraduate level and synthesis at the professional licensure level (ASCE, 2008).

While anyone can request changes to the ABET criteria, this rarely occurs. Changes to the program level criteria are generally initiated by the relevant professional society, which is ASCE for Civil, Construction, and Architectural Engineering. Modifications are identified frequently during ABET reviews. Once identified for Civil Engineering (CE), these changes are vetted through department chairs and compared to the ASCE Body of Knowledge (BOK). ASCE has made a commitment to CE that changes will be made no more often than every eight years. This cycle is consistent with

BOK revisions, and also ensures that ABET reviews of specific university academic programs will not always be performed during the same year ABET changes are implemented (J. O'Brien, personal communication, April 16, 2016).

While the word leadership is not prominent in ABET documents, researchers have performed studies to include discussions about the (a) through (k) student outcomes and the likelihood of leadership being embedded in those outcomes (Bowman & Farr, 2000; Brumm et al., 2006; Kumar & Hsiao, 2007; Passow, 2010; Schuhmann et al., 2014). Others have studied the perceptions of engineering students and/or new graduates with regard to their preparation for industry (Itani & Srour, 2015; Martin, Maytham & Fraser, 2005). These studies highlighted the need for both technical and non-technical competencies, including leadership. With all of these efforts, engineering is still lagging behind other academic programs as evidenced by Seemiller and Murray (2013).

In the past several years, work to define the term *engineering leadership* has become more concentrated and engineering leadership programs have been under increased review. As one example, Graham et al. (2009) located and studied over 40 engineering leadership programs. Identifying and comparing these programs generated interest on a national level and spurred the beginning of regular meetings of several academic institutions to share best practices for inculcating leadership into engineering programs through formal and informal means. This group of engineering leadership champions created a consortium known as COMPLETE or Community of Practice for Engineering Leadership Education for 21st Century Engineers. With eleven founding member institutions (Rice Center for Engineering Leadership, 2014), COMPLETE meets approximately twice a year, rotating locations to member universities and other locations.

COMPLETE members helped in the formation of the Leadership Development (LEAD) Division of the American Society for Engineering Education (ASEE) in 2013, and continue to advance the area of engineering leadership education by working to understand industry requirements for leadership from graduates of engineering programs.

Purpose

The purpose of this research project was to determine the importance of specific leadership themes that are associated with the competencies that companies are seeking from applicants of full-time, entry-level positions. In an earlier qualitative study, the first author interviewed personnel from engineering companies involved with hiring entry-level engineers and found they are most interested in five leadership themes from applicants: initiative/confidence, communication, interpersonal interactions, teamwork, and engagement. These leadership themes were defined in the earlier study as shown in Table 4.1 (Hartmann, Stephens & Jahren, 2015, p. 6). This study will seek to validate the quantitative survey instrument used and to rank the importance of these themes.

Table 4.1. Leadership Themes with Definitions

Theme	Definition
Initiative/confidence	Stepping up, going the extra step, asking questions, having confidence and/or self-confidence.
Communication	Possess excellent written, oral, non-verbal, and listening skills.
Interpersonal Interactions	Having people skills and the ability to build relationships and resolve conflicts.
Teamwork	Being a team player, collaborative, and a consensus builder.
Engagement	Involved in extracurricular and volunteer activities.

The study was conducted at a large land-grant institution in the Midwest, which serves over 35,000 students and employs 6,300 faculty and staff members. The College

of Engineering is the home to eight academic departments and twelve majors. The college also hosts a large indoor career fair, which attracts approximately 300 companies and 3,000 to 6,000 students and alumni each semester.

Research Methodology

A web-based survey was developed and distributed to professionals recruiting engineering undergraduates for full-time positions using Qualtrics Survey Software (version 2015). The survey consisted of sixty Likert-scale questions to determine the importance of five leadership themes across three dimensions, as well as four user questions: job title, number of years with the company, engineering majors hired, and last time company attended the career fair. Further details regarding survey development and distribution will follow.

Question Development

A number of researchers have devised methods to classify leadership competencies (Dugan & Haber, 2007; Hemphill & Coons, 1957; Kouzes & Posner, 1998; Posner 2010; Rost 1991; Seemiller, 2013; Seemiller & Murray, 2013; Tyree, 1998). Seemiller and Murray (2013) determined 61 competencies and 4 dimensions: knowledge, values, abilities, and behaviors for a total of 244 competencies. These dimensions represent levels of understanding and practice required for students to possess, as indicated by the diverse accreditation materials reviewed. For the purposes of survey question development, the authors of this paper found the classification of competencies and dimensions (Seemiller, 2013; Seemiller & Murray 2013) to be compelling.

To aid in the further development of questions, the research team created a matrix to provide a framework of the five themes across the four dimensions of knowledge, values, abilities (or skills), and behaviors, which were described by Seemiller (2013) and Seemiller & Murray (2013). Utilizing key words and phrases from the in-depth interviews conducted in the prior study, the first author drafted Likert-scale survey questions to capture the needs of engineering companies seeking applicants with leadership skills. During the question-writing phase, limitations for the "values" questions were noted, as it would likely be difficult for the survey respondents to have knowledge about applicants' values. The first author focused on the five themes across the remaining three dimensions. Sixty questions, four per each cell of the matrix and twelve per theme (see Figure 4.1), were written and tagged with the alphanumeric codes. The survey questions can be found in Appendix D. This coding provided a structure by which to analyze and evaluate the validity and reliability of the instrument.

		LEADERSHIP THEMES				
		Initiative/ Confidence	**Communication**	**Interpersonal Interactions**	**Teamwork**	**Engagement**
DIMENSIONS	**Knowledge**	4 questions	4 questions	4 questions	4 questions	4 questions
	Abilities	4 questions	4 questions	4 questions	4 questions	4 questions
	Behaviors	4 questions	4 questions	4 questions	4 questions	4 questions
		12 questions	***12 questions***	***12 questions***	***12 questions***	***12 questions***

Figure 4.1. Question Matrix

Cognitive Interviews

Two college recruiters were contacted to assist with improving the survey instrument. A project manager from a large heavy-construction contractor and a project engineer from a national building contractor agreed to perform cognitive interviews. The project manager and project engineer had over ten years and five years of experience as a recruiter for their respective companies.

The participants agreed to be audiotaped and each completed a "think-aloud" interview while taking the survey in the online survey tool, Qualtrics. These cognitive interviews are recommended as best practices in survey development (Groves, Fowler, Couper, Lepowski, Singer & Tourangeau, 2004; Tourangeau, 1984; Tourangeau, Rips & Rasinski, 2000; Willis, 1999). Upon completion of the first interview and prior to the second interview, enhancements were made to the survey. Both participants verbalized their thoughts while taking the electronic survey. Each interviewee was observed during their 30- to 40-minute interview. The first author focused on verbal feedback, facial expressions, and other non-verbal cues to identify questions that were problematic. During this process, improvements to the instrument were identified and appropriate changes were made to create a better survey instrument for release.

Company Contact Acquisition

Working with the university's engineering career services office, the researchers obtained two reports from the campus online recruiting and hiring tool used by employers and students – one with a listing of hires, the other a listing of company contacts. The first report included a listing of 3,485 engineering students hired for full-time, entry-level

positions, known as *placements*, during the years of 2008 to 2014. The 3,485 placements were attributed to 1,099 companies, with one company claiming 158 hires.

The team reviewed the data to obtain valid email addresses for contacts using a three-step approach. The first step involved a thorough review of the report. This evaluation revealed 476 companies with a contact and email address and 245 companies with some contact information – name of contact, phone number for some, but no email address. Additionally, there were 263 companies with no contact information, as well as 115 placements listed as "Employer Unknown."

The second step of the process involved performing a crosswalk of data from the second report, which included primary points of contact for each company in the hiring system. Company recruiter information included name, and/or phone number, and/or email. By comparing data from both reports, the research team found an additional email addresses for 326 companies (699 placements), which increased the email addresses to a total of 802 companies (3,044 placements).

Finally, the research team was granted administrator access to the online hiring system to assist in finding the remaining company contacts and email addresses. Team members looked up individual companies and contacts, as well as made phone calls to various companies. This effort yielded 38 additional email addresses. In the end, the team obtained 840 email addresses, which corresponded to 3,089 placements. The information obtained during each step is highlighted in Table 4.2.

Table 4.2. Company Contact Information Available by Steps Performed

Step Performed	Name and Email Address	Some Contact Info, but no Email Address	No contact information	Employer Unknown
Reviewed First Report	476	245	263	115
Performed Crosswalk	802	50	132	115
Reviewed Online System and Made Phone Calls	840	15	129	115

Survey Details and Launch

The survey was launched to 840 recruiting contacts in the spring of 2015. Utilizing advanced functions of the survey distribution application, the research team randomized the 60 questions so each respondent's survey was unique in the order that questions appeared. This function helped to remove any influence one question may have on another if answered in sequence.

Respondents were asked to rate various knowledge, abilities and behaviors on a six-point Likert scale from "Extremely Important" to "Not Important at All" (Likert, 1932). The values were coded such that selection of "Extremely Important" received a numerical score of 6, while "Not Important at All" received a score of 1. The researchers elected a 6-point scale to eliminate the "neutral" response. Matell and Jacoby (1972) discovered as the number of choices increase, the selection of the "neutral" option decreases. They suggest that using an even-numbered scale depends on the purpose of the research. Green and Rao (1970) found that 6- or 7-point scales appear to be optimal.

Validity and Reliability Testing

This pilot study was done to determine the validity and reliability of the 60-question instrument. Cronbach's alpha reliability was estimated from the data and

confirmatory factor analyses (CFA) were conducted to examine validity and reliability. All analyses were performed using the most recent available version of the statistical analysis software application R, which was version 3.2.3 at the time of analysis. CFA estimates were also computed using the most recent available version of the Lavaan package, 0.5, at the time of analysis.

To determine the reliability of the instrument's scale, a commonly-used metric of inter-item consistency and reliability, Cronbach's coefficient alpha (α), was applied (Cronbach, 1984). Bell (2005) described that reliability refers to how consistently a test generates analogous results when performed under the exact same conditions multiple times. A reliability value is between 0 and 1 with values closer to 1 indicating a higher degree of reliability. In this study, a reliability value of at least 0.7 was used (Hair, Tatham & Anderson, 2002).

To test the factorial validity of the category scales, CFA was performed using maximum likelihood to ensure that scale items loaded on the same factors that had been identified by Hartmann and Jahren (2015). The CFA model (see Figure 4.2) was constructed and estimated to measure goodness of fit. Before estimating the model in this study, factors were validated by choosing factors with Eigenvalues higher than 1 and omitting items with a loading of 0.3 or lower. This ensured that the findings generated by factor analysis were as meaningful as possible.

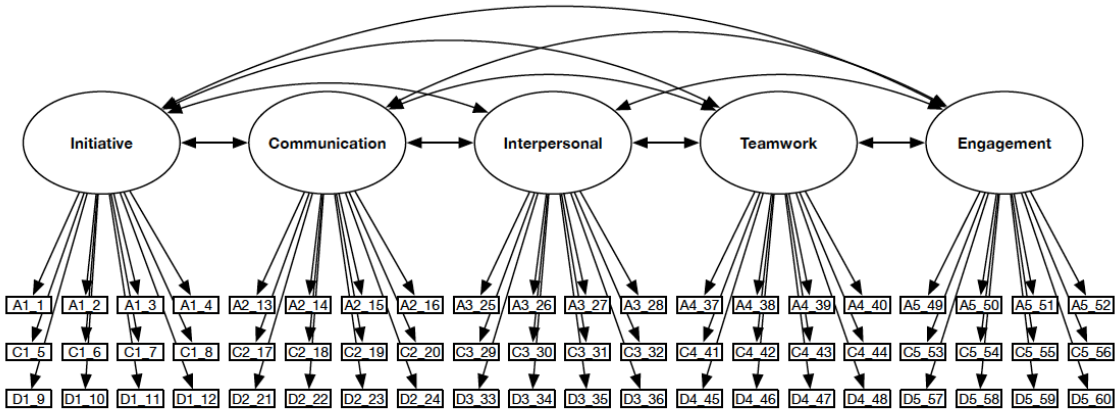


Figure 4.2 Factor Analyses Model

Validity and Reliability Results

Several statistical analyses were conducted to study the instruments' properties in measuring the five categories, Initiative, Communication, Interpersonal, Teamwork, and Engagement. Together, for all 60 questions, the value of Cronbach's alpha was estimated at 0.97. The CFA consisted of a five-factor model with 12 questions per factor. Using the 172 complete-case observations, the CFA model converged after 120 iterations and demonstrated adequate fit with the Root Mean Square Error of Approximation (RMSEA) estimated at 0.081 ($p < 0.01$). The RMSEA had a 90% confidence intervals of 0.077 - 0.084. Hu & Bentler (1999) described RMSEA values 0.05 to 0.10 as a moderate fit, supporting the goodness of fit for this model.

A careful introspection of each factor individually by the research team provided strong evidence of reliability and validity. All coefficients were estimated with *p*-values below 0.001. The estimated Cronbach's alpha for the Engagement factor was the highest alpha score at .94, with the other four factors highly similar between .85 and .88. For the Initiative factor, Cronbach's alpha was 0.85 for the 12 questions. The CFA coefficients ranged 1.01 to 1.69. For the Communication factor, Cronbach's alpha was 0.88 and the

coefficients ranged 0.73 to 1.03. On Interpersonal, Cronbach's alpha was 0.87 and the coefficients ranged 0.92 to 2.27. In Teamwork, Cronbach's alpha was 0.87 and the coefficients ranged 0.67 to 1.33. For Engagement, the Cronbach's alpha was 0.94 with the coefficients ranged 0.72 to 0.91. These values are shown in Table 4.3. Taken together, these five factors demonstrated support for the survey's construction. Both the RMSEA and the individual questions' factor loadings indicate the survey instrument is measuring the hypothesized latent constructs reliably and with validity.

The survey instrument was developed in anticipation that the questions would measure the five factors that had been identified through the cognitive interviews. After analyzing these results, the findings demonstrated empirically that the survey does accurately measure these factors among engineering recruiters.

Table 4.3. CFA Estimates

Category	Question	Estimate (Standard Error)	Cronbach alpha	Mean (Standard Dev.)
Initiative			0.85	5.09 (0.46)
	A1_2	1.02*** (0.27)		
	A1_3	1.42*** (0.32)		
	A1_4	1.69*** (0.38)		
	C1_5	1.05*** (0.25)		
	C1_6	1.11*** (0.25)		
	C1_7	1.06*** (0.24)		
	C1_8	1.07*** (0.24)		
	D1_9	1.008*** (0.24)		
	D1_10	1.15*** (0.26)		
	D1_11	1.16*** (0.25)		
	D1_12	1.26*** (0.28)		
Communication			0.88	4.90 (0.54)
	A2_14	0.98*** (0.14)		
	A2_15	0.87*** (0.13)		
	A2_16	0.79*** (0.13)		
	C2_17	0.95*** (0.13)		
	C2_18	0.91*** (0.13)		
	C2_19	0.91*** (0.14)		
	C2_20	0.78*** (0.13)		
	D2_21	0.73*** (0.12)		
	D2_22	0.82*** (0.13)		
	D2_23	1.03*** (0.15)		
	D2_24	0.89*** (0.13)		

Table 4.3. (Continued)

Category	Question	Estimate (Standard Error)	Cronbach alpha	Mean (Standard Dev.)
Interpersonal			0.87	4.90 (0.51)
	A3_26	1.56*** (0.17)		
	A3_27	0.95*** (0.11)		
	A3_28	0.92*** (0.11)		
	C3_29	2.27*** (0.24)		
	C3_30	1.58*** (0.17)		
	C3_31	1.44*** (0.16)		
	C3_32	1.27*** (0.14)		
	D3_33	1.07*** (0.12)		
	D3_34	1.17*** (0.13)		
	D3_35	1.69*** (0.18)		
	D3_36	1.18*** (0.13)		
Teamwork			0.87	4.75 (0.54)
	A4_38	0.68*** (0.13)		
	A4_39	1.12*** (0.17)		
	A4_40	1.15*** (0.20)		
	C4_41	1.25*** (0.20)		
	C4_42	0.98*** (0.16)		
	C4_43	0.67*** (0.12)		
	C4_44	1.05*** (0.16)		
	D4_45	0.78*** (0.13)		
	D4_46	1.33*** (0.22)		
	D4_47	0.82*** (0.14)		

Table 4.3. (Continued)

Category	Question	Estimate (Standard Error)	Cronbach alpha	Mean (Standard Dev.)
Engagement	D4_48	0.91*** (0.16)	0.94	3.90 (0.77)
	A5_50	0.75*** (0.07)		
	A5_51	0.78*** (0.08)		
	A5_52	0.73*** (0.08)		
	C5_53	0.90*** (0.08)		
	C5_54	0.91*** (0.08)		
	C5_55	0.91*** (0.07)		
	C5_56	0.85*** (0.07)		
	D5_57	0.72*** (0.08)		
	D5_58	0.89*** (0.07)		
	D5_59	0.85*** (0.08)		
	D5_60	0.91*** (0.08)		

Note: *** $p \leq 0.001$

Survey Findings

The survey was distributed to answer the following research question:

RQ1: What is the order of importance of the five leadership themes?

H1: The order of importance will be: initiative/confidence, communication, interpersonal interactions, teamwork, and engagement.

The hypothesis was based on the work from the earlier qualitative study. The first author identified this as the order of importance by noting the frequency that interviewees

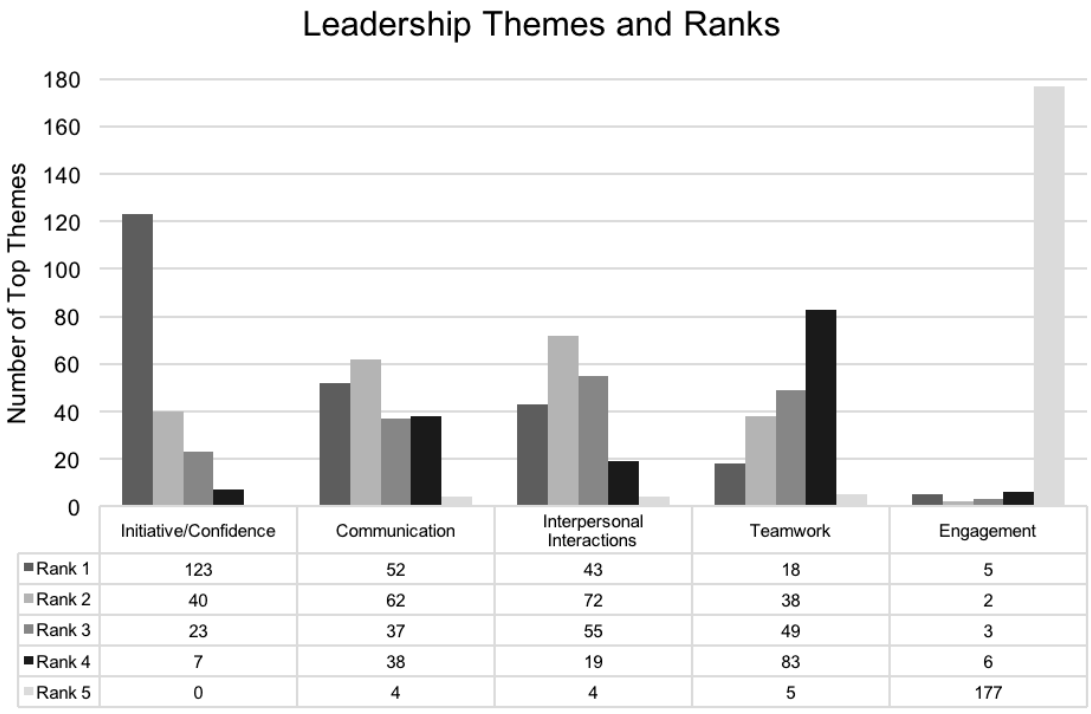
discussed the themes. Additionally, it was noted that participants mentioned the themes in this particular order when asked the question: "What does your company mean by the word *leadership* when used in a job description?"

These results of the data from the survey are displayed in Table 4.4. In addition to calculating the means of the responses for each of the five themes, the research team identified the top ranking theme(s) for each respondent. In some cases, more than one theme received the highest mean, which resulted in two or more themes as the "high mean theme" for that respondent. The data represented here is for the entire 193 respondents, not just the complete-case observations utilized in the CFA.

Table 4.4. Survey response information

Leadership Theme	Mean	Standard Deviation	Number of Respondents With High Mean in this Theme
Initiative/Confidence	5.09	0.46	123
Communication	4.90	0.54	52
Interpersonal Interactions	4.90	0.51	43
Teamwork	4.75	0.54	18
Engagement	3.90	0.77	5

As noted earlier, 36 of the 193 respondents answered the questions in such a way to create a tie for the top ranked theme. The ties were between two, three, four or all five categories resulting in 241 top rankings. The breakdown of the rankings is provided in Figure 4.3. The analysis of data asserts that initiative/confidence is the most important leadership theme. Conversely, engagement is clearly the least important of the five competencies measured. Although engagement is the least important of the five themes, it is still one of the five most important identified by the qualitative survey, making it fairly important in general.



	Initiative/Confidence	Communication	Interpersonal Interactions	Teamwork	Engagement
Rank 1	123	52	43	18	5
Rank 2	40	62	72	38	2
Rank 3	23	37	55	49	3
Rank 4	7	38	19	83	6
Rank 5	0	4	4	5	177

Figure 4.3. Leadership themes and ranks

These findings support the hypothesis and align with those made in the earlier qualitative study (Hartmann & Jahren, 2015) that during interviews the first theme discussed by interviewees was initiative/confidence and the last was engagement in all the interviews. During the qualitative phase of the study it was observed that based on the conversations that the order that interviewees discussed leadership themes might suggest their relative importance. Interestingly, the order noted in the qualitative study matches the relative rankings in this study.

Discussion of Rankings of Themes

Overall, the rankings of the competencies matched those observed during the earlier qualitative study. Each participant when asked the main survey question began with discussing initiative and/or confidence. Through the review of transcripts, the order in which each of these themes was listed correlated with the frequency that those themes

appeared. Initiative/confidence was determined to be the most important of the five categories with a mean score of 5.09 and 123 top rankings, over twice as many as the next category. Many authors highlighted "initiative" as a leadership competency or skill required for a successful career in engineering (Athreya & Kalkhoff, 2010; Bernard M. Gordon, 2011; Brumm et al., 2006; NSPE, 2010; Seemiller & Murray, 2013). Additionally, initiative and confidence were identified by Reeve, Rottmann, and Sacks (2015) as two of the top five traits of "engineering leadership exemplars."

The mean score of 4.90 for the communication questions tied with those for the interpersonal interactions questions. While communication had more rankings of 1 than interpersonal interactions (52 versus 43), interpersonal interactions had more rankings of 2 and 3 than communication. These two leadership competencies were so closely ranked, but due to the slightly higher number of top rankings, the authors place communication as second most important and interpersonal interactions as third.

Communication – written and oral – was found in all the literature reviewed and can be directly tied to ABET outcome (g), an ability to communicate effectively. Interpersonal interactions represent a group of competencies, including people skills and the ability to work with others, and conflict resolution. Many other authors used the term "interpersonal interaction(s)," although their definitions differed slightly (Bernard M. Gordon, 2011; Crumpton-Young et al., 2010; Martin et al., 2005; Meier, Williams, & Humphreys, 2000; NSPE, 2010; Rover et al., 2013; Seemiller, 2013; Yaacoub et al., 2011). It was noted that other authors may have captured similar competencies but used different terminology altogether.

Teamwork and engagement are ranked fourth and fifth of the leadership competencies, with mean scores of 4.75 and 3.90, respectively. Teamwork had the most (83) rankings of 4; engagement had the most (177) rankings of 5. The soft skills and leadership literature reviewed identified teamwork, like communication, as an important competency. While ABET outcome (d) requires "an ability to function on multidisciplinary teams," many equate this outcome to teamwork in general. ASCE (2008), Brumm et al. (2006), Cox et al. (2010), Itani and Srour (2015), and Seemiller and Murray (2013) also discussed engagement, which the authors of this paper defined as being involved in extracurricular activities and volunteer service. ASCE (2008) suggested students get involved with extracurricular activities as a way to gain experience in the other ASCE BOK2 outcomes, such as communication (Outcome 16), Leadership (Outcome 20), and Teamwork (Outcome 21). Additionally, Brumm et al. (2006) identified participation in professional student organizations related to engineering have a greater impact on success in the workplace than other student organizations.

Limitations and Future Work

This paper contributes to the field of engineering leadership education by exploring the five most prominent leadership themes identified by engineering recruiters to determine their relative importance, as well as creating a valid and reliable survey instrument.

Limitations

While the results are promising, they should be considered within several limitations. The sample size was modest, respondent self-selection is possible, and variance between institutions was not measured. Our sample size was appropriate for

estimating statistically significant results to test the reliability and validity of the instrument. However, a larger sample would enable detection of moderate and low effect sizes; the sample used could be used to measure only high effect size. Further, the respondents may have self selected themselves and not have been representative of non-respondents. To address this concern the authors reviewed the position titles, affiliations, years recruiting at institution, and recruiting field or fields. The authors did not identify any differences between respondents and non-respondents on these known demographics. Finally, the sample of recruiters were in contact with the one institution chosen for the study. The researchers selected to do this pilot study at a large, public institution with 12 (or twelve) academic majors in engineering and this enabled us to reach a wide breadth of engineering recruiters. Recruiters frequently engage with multiple higher education institutions to identify potential hires. But it is possible that a single institution may attract engineering recruiters who differ from the larger population of engineering recruiters in ways not measured by this study.

Further Research

While continuing this work on understanding leadership is needed in the field of engineering among entry-level hires, several veins of research stand out as ready for exploration. These areas include survey duration, sampling frame, and engineering leadership education.

The length of the survey used could be reduced. This would increase response rate and decrease respondent break off. In this pilot study we observed a 23% response rate, which may be improved by lowering the length of time asked of respondents. Further, of the 193 participants we had 172 complete-case responses. This rate of survey break-off is

acceptable in social science research (Fowler, 2014), but could still be reduced by question item reduction. Reducing the survey length should be done only in ways that maintain the validity and reliability of the instrument to measure the latent factors.

Expanding the sampling frame will help future studies. As discussed in limitations, the 193 respondents here may not represent all the recruiters of engineers at all higher education institutions. Broadening the sample frame beyond one institution's recent engineering recruiters will improve the generalizability of the results and better represent the expectations for leadership in engineering graduates. To help inform the inclusion of leadership into engineering programs, data in future extensions of this study will be analyzed to determine any differences by engineering discipline and/or respondent demographics.

While outside the scope of this study, additional work is also needed regarding how to improve the engineering education curriculum to address the findings from this survey. Integrating these leadership skills into both coursework and co-curricular experiences will improve student learning and the effectiveness such efforts are ripe for further research. Based on the literature review conducted (e.g., Brumm et al., 2006; NAE, 2012; Walters & Sirotiak, 2011), recommendations can be made to encourage students to gain skills through involvement in experiential education (co-op and internship experiences), capstone courses, problem-based learning, student organizations and volunteer service

Conclusion

With an increase in the engineering leadership programs and scholarly work, there remains a need to understand what companies are looking for in applicants for full-time,

entry-level engineering positions. This study highlighted the order of importance of the five leadership themes recruiters are seeking when hiring new engineering graduates.

One important outcome of this survey is that the five leadership themes identified are all important (all with means equal to or greater than 3.90) for undergraduates to possess when seeking full-time employment. This helps to validate the findings of the earlier study and to highlight that qualitative work may be a valuable precursor to create a quantitative survey, as suggested by Creswell (2013).

The final conclusions were that the most highly rated theme was initiative/confidence (mean 5.09), followed by communication, interpersonal interactions, teamwork, and engagement. While the respondents clearly rated the five leadership competencies as important, there were distinct preferences in the order of importance. Understanding the ranking of importance will be beneficial for engineering leadership educators in their quest to best prepare students for industry.

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CHAPTER 5. ENGINEERING RECRUITERS SURVEY: LEADERSHIP THEMES FOR FULL-TIME, ENTRY-LEVEL EMPLOYMENT

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A paper for submission to the *Journal of Engineering Education*

Abstract

Background Studies have underscored the importance for introducing leadership into engineering curricula. Limited studies compared leadership requirements across engineering disciplines, while no studies were found that surveyed engineering recruiters.

Purpose The goals of this research were to identify leadership requirements from the standpoint of perspective employers for full-time, entry-level positions and create an instrument to evaluate them.

Design/Method In the first phase of the study, six engineering recruiters were interviewed. The transcripts were analyzed to identify emerging themes. In the second phase of the study, survey items were developed and refined through cognitive interviews. A confirmatory factor analysis determined validity and reliability of the instrument.

Results The mixed methods approach resulted in the development of a survey with 60 items mapped to five leadership themes companies are seeking: initiative/confidence, communication, interpersonal interactions, teamwork, and engagement. Twelve questions for each theme were also written across the three dimensions of knowledge, abilities, and behaviors. The quantitative results were analyzed by engineering major and job title category of recruiter.

Conclusion The study validated the importance of the leadership themes and revealed no substantial differences in the requirements for leadership based on engineering major of job applicant or on the job title category of the recruiter. These findings will help engineering educators in developing curricular and co-curricular programs in their pursuit to develop engineering leaders for the twenty-first century.

Keywords. Leadership; professional skills; ABET

Introduction

This study, informed by the perspectives of engineering recruiters, uses a mixed methods approach to understand how to best prepare students for full-time, entry-level engineering positions. Toward that aim, this article addresses the comparison of survey data to measure the importance of five leadership themes identified in the qualitative portion of this study: initiative/confidence, communication, interpersonal interactions, teamwork, and engagement.

The themes emerged through semi-structured interviews with six engineering recruiters. The results of the analysis of the interviews were the basis of a 60-item survey that was distributed to engineering recruiters. The survey instrument was shown to be valid and reliable, and the relative importance of the five themes was determined. Here, the data are analyzed to ascertain if recruiters rank the leadership themes differently based upon the engineering major of the job applicant, as well as the job title category of the engineering recruiter. The findings of this study will help to guide engineering educators in creating and assessing curricular and non-curricular experiences to best prepare students to become twenty-first century engineering leaders.

Background

The need for engineers to possess leadership skills (and professional skills) has been a topic of discussion for many years. Reviewing the progression of requirements of engineering undergraduate curricula, this effort has been ongoing for more than twenty years. While the Grinter Report (1955) laid the foundation for the technical requirements for undergraduate engineering programs, The Green Report (1994) among other efforts helped to identify necessary non-technical skills. Green (1994) urged engineering programs to include leadership, team skills, communication skills, and many other skills and abilities to "prepare their students for the broadened world of engineering work." Since then, a number of authors have highlighted the need for engineering disciplines to include non-technical topics into their programs (Bowman & Farr, 2000; Dudman & Weane, 2003; *Educating,* 1995; Farr, Walesh & Forsythe, 1997; Goleman, 1999; Hilton, 2007; Hinkle, 2007; Meier, Williams & Humphreys, 2000; Newport & Elms, 1997; Russell & Yao, 1996, Sageev & Romanowski, 2001; Schulz, 2008; Toor & Ofori, 2008; Zaharim et al., 2010). Whiles some recommend creating stand-alone courses to address leadership and/or professional skills, Bowman & Farr (2000), Schulz (2008), along with many others, recommended embedding soft skills content into hard skills courses.

The list of skills and abilities identified by Green (1994) served as one of the predecessors of today's ABET General Criterion 3 (a) through (k) student outcomes, which were developed as a part of the Engineering Criteria 2000 (EC2000). These student outcomes include five technical and six non-technical skills. Many would argue that "engineers at all levels are often naïve about the optimum mixture of technical and on-technical skills needed to be a success" (Farr & Brazil, 2009, p. 8). According to

Shuhman, Besterfield-Sacre, and McGourty (2005), the non-technical skills, also called "professional skills," can be taught and assessed, but require an approach that differs from the traditional lectures, problem solving demonstrations, homework assignments, and exams that are commonly provided as part of many engineering courses. They offered several examples how these skills have been introduced into classrooms across the United States through active and cooperative learning. Even with the efforts noted, industry representatives report engineering undergraduates are well-prepared technically, but lack soft skills (McMasters, 2004; Schulz, 2008). Furthermore, Sageev and Romanowksi (2001) stated, "Technical abilities are a given, communication and leadership differentiate" (p. 690).

A plethora of work has been conducted regarding the assessment of competencies and soft skills. Three studies (Passow, 2012; Sageev & Romanowksi, 2001; Scott & Yates, 2002) focused specifically on the perceptions of new graduates. Passow (2012) explored the history of "competency studies" and sought to discover which ABET competencies engineering graduates perceive most important in their careers. All eleven of the (a) through (k) outcomes were found to be important, with communication, data analysis, teamwork, and problem solving identified as the most important across this seven-year study (Passow, 2012). Consistent with those findings, Sageev and Romanowksi (2001) surveyed engineers with 3-5 years of experience and found they spent 64% of their work hours communicating and 32% of their time working on teams. Yaacoub, Husseini & Choueiki (2011) utilized content analysis to review job descriptions. Using a list of 60 soft skills developed by Phani (2007), their review identified which softs skills are most cited, comparing their findings with the ABET

outcomes. Team skills and communication skills were noted as the most prevalent soft skills identified in engineering job descriptions. Riemer (2007) noted, “An insufficient level of communication skills instruction in engineering education generally only serves to undermine the whole profile of the professional engineer” (p. 89). This was confirmed by Seemiller and Murray (2013) who found that engineering programs had the fewest number of “student leadership competencies” of the eighteen career fields they studied.

Working with 212 “stakeholders,” Brumm, Hanneman, and Mickelson (2006) identified fourteen specific workplace competencies and measured them against the ABET Outcomes. Of note, Brumm et al. (2006) provided a listing of the opportunities that students (and graduates) will have to develop and demonstrate these competencies. They highlighted the importance of work experience and experiential education, followed by capstone design courses, engineering profession extracurricular activities, laboratory classes, non-engineering extracurricular activities, and finally, traditional classroom experiences. These findings were supported by Toor and Ofori (2008), and expanded by Litchfield, Javernick-Will, and Maul (2016) who found that students involved in engineering service organizations reported much higher competency in professional skills than those in non-service organizations.

In many of the soft skills and professional skills studies, leadership is not mentioned. However, the need for engineering undergraduates to have leadership skills was emphasized by in national reports (NAE, 2004, 2005). While “leadership” is not explicitly included in the the ABET student outcomes, some (Bowman & Farr, 2000; Brumm et al., 2006; Kumar & Hsiao, 2007; Passow, 2012; Schuhmann, 2010) suggested that is leadership may be embedded in these Criterion 3 non-technical outcomes. That

said, three (Civil Engineering, Construction Engineering, and Engineering Management and Similarly Named Programs) of the twenty-eight ABET programs explicitly cite leadership in their Program Level Criteria. As the Lead Society for Civil Engineering and Construction Engineering, the American Society of Civil Engineers (ASCE) has highlighted the need for leadership in their own publications (ASCE, 2007, 2008). The 2nd edition of the text, *Civil engineering body of knowledge for the 21st century: Preparing the civil engineer for the future* (ASCE, 2008), also known as BOK2, specifically identified leadership as an outcome separate and distinct from communications and teamwork and outlines ways for undergraduates to develop these skills. Similarly, the National Society of Professional Engineers (NSPE) through a formal policy statement recommended an additional six education outcomes above and beyond the ABET criteria. The first outcome identified was, "apply principles of leadership." (NSPE, 2010).

Numerous engineering academic programs have worked to identify specific needs from their industrial advisory boards and others, yet there exists no consensus on the definition of engineering leadership (Ahn, Cox, London, Cekic, & Zhu, 2014; Schuhmann, 2010). AlSagheer and Al-Sagheer (2011) noted that, "Although the importance for leadership skills has been recognized, this area still has not been traditionally part of the curriculum for engineering students" (p. 58). Cox, Cekic, Ahn, and Zhu (2012) found that engineering professionals identified technical competence as a requirement of an engineering leader. This may be the only distinguishing feature between leadership and engineering leadership.

Graham, Crawley, and Mendelsohn (2009) reviewed leadership programs to gauge the current state of engineering leadership education worldwide. They identified over 40 programs teaching leadership to engineering students in a number of different ways. Graham et al. (2009) were perceptive in using the word "snapshot" in their identification of these programs, since some of the programs in their report no longer exist while many others have emerged. Excellent strides have been made in recent years to understand this new field and highlight how universities are responding to this call for engineers to possess leadership skills. Athreya and Kalkhoff (2010), Bernard M. Gordon Leadership Program (2011), Cox, Cekic and Adams (2010), Crumpton-Young, McCauley-Bush, Rabelo, Meza, Ferreras, et al. (2010), Rover et al., (2013), and Schuhmann (2010) each highlighted efforts that have taken place at their respective universities. These programs represent a small sample of the ongoing effort to bring leadership to the forefront of undergraduate engineering education.

The Graham et al. (2009) white paper also prompted the regular meetings of several academic institutions with "explicit" and "non-explicit" engineering leadership programs. This body of engineering educators, known as the Community of Practice for Engineering Leadership Education for 21st Century Engineers (COMPLETE), held their first meeting in October of 2010. Meeting approximately every six months to share best practices and discuss ways to advance engineering leadership education, COMPLETE has held eight subsequent meetings to date.

In addition to the discussions taking place within COMPLETE, the engineering education community has recently seen an increase in the conversation regarding leadership development for engineering undergraduates. With a surge in engineering

leadership minors, certificates, programs, and other curricula, this topic is taking center stage. This current interest served as the catalyst for the formation of new division in the American Society for Engineering Education (ASEE) in 2013, the Leadership Development Division (LEAD). The ASEE LEAD Division has seen an increase in membership from no members in 2012 to almost 750 members in 2016 (R. Bennett, personal communication, February 20, 2016).

Even with this emphasis and the renewed interest in leadership, gaps still exist between the preparation engineering undergraduates receive and the needs of industry. Closing these gaps is of great interest to those in academia and industry. According to Russell and Yao (1996), "an engineer is hired for his or her technical skills, fired for poor people skills, and promoted for leadership and management skills" (p. 18). While there is recognition of industry needs, challenges exist in integrating leadership into engineering programs. Toor and Ofori (2008) offered that, "the technical coursework should be complemented with elements of flexible education, and emphasis on soft-skills development" (p. 285). However, embedding leadership into engineering programs is not any easy task. Meier et al. (2000) highlighted three main weaknesses in engineering curricula and programs that contribute to the current gaps between undergraduate preparation and industry needs: (1) engineering programs do not have enough room for general education requirements; (2) faculty members resist making course changes, using accreditation requirements as an excuse; and (3) faculty members are not able to integrate non-technical content into curricular and co-curricular experiences for students. These reasons were echoed by faculty members who were interviewed by Cox et al. (2010).

Ahn et al. (2014) recently focused on the identifying the abilities needed by engineering undergraduates by interviewing academic and engineering professionals for "leadership, change and synthesis." Through a mixed methods approach, the researchers interviewed engineering professionals and engineering faculty members to create a survey instrument for engineering undergraduates. Through this study, a tool was created to measure leadership, change, and synthesis in engineering undergraduates. Studies such as this one are helping to add to the body of knowledge in the area of engineering leadership.

Many of the studies reviewed surveyed students, academics, and industry professionals from two or more engineering majors or disciplines, but few (Dudman & Weane, 2003; Passow, 2012) performed comparisons across those disciplines. While AlSagheer and Al-Sagheer (2011) focused on teaching ethics and leadership to engineering, they cited a more focused effort needed to compare if different (leadership) skills are more important depending on the field of engineering. The need to understand if different engineering disciplines require different skills is central to this study. Additionally, although Yaacoub, Husseini, and Choueiki (2011) did review job descriptions, no study was found to focus specifically on the perceptions of engineering recruiters. This study will address these perspectives.

Methods and Results

We used a mixed methods approach called "sequential exploratory" to identify and rank prominent leadership themes noted by engineering recruiters. Creswell (2013) suggested this method is helpful when developing and testing a new instrument. In the qualitative portion of our study, we interviewed six engineering recruiters about the

meaning of *leadership* when used in a job description. In the quantitative portion of our study, we developed a survey instrument for distribution to engineering recruiters. Our methodology and process are outlined in the following sections.

Step 1: Leadership Theme Identification

We reviewed job postings in our engineering career services database to recognize the incidences and meanings of the word *leadership* in job descriptions posted for engineering undergraduates from 2006-2013 at large Midwestern university with twelve engineering majors. Identifying that 13.6% of the job postings included the word leadership, we further reviewed the job postings to locate those job postings targeted from undergraduates in construction engineering (ConE) and electrical engineering (EE). Through semi-structured interviews with three engineering recruiters for each of these majors, we identified five emerging leadership themes, and qualitatively compared the leadership requirements from companies hiring only those students in ConE and EE to see if there were any differences between industry needs for graduates from a program with leadership explicitly stated in the ABET program criteria and one without.

The five emerging themes from this phase are described briefly as follows. Initiative/Confidence**:** stepping up, asking questions, and having confidence to perform tasks. Communication: skills in oral, non-verbal, and listening skills. Interpersonal Interactions: people skills, relationship building, and conflict resolution. Teamwork: being a team player, working well with others, collaboration, and consensus building. Engagement: being active in extracurricular activities and volunteer service. More detailed discussions and example quotes from interviews for these themes are provided in Hartmann and Jahren (2015).

Step 2: Survey Instrument Development and Validation Phase

Using the five themes identified in the qualitative phase of the study (initiative/confidence, communication, interpersonal interactions, teamwork, and engagement), sixty Likert-scale questions, twelve for each theme, were created. The questions were written to also measure three of the four dimensions identified in Seemiller (2013) and Seemiller and Murray (2103). The dimensions of knowledge, abilities, and behaviors were used; the "values" dimension was not included as we deemed it challenging for survey respondents who were corporate recruiters to determine students' values. Removing "values" from the survey is also supported by Shuman et al. (2005) who state "students should be evaluated on knowledge and skills, not values or beliefs." In each grouping of twelve questions, four questions were written to address each dimension, resulting in twenty questions tagged to knowledge, abilities, and behaviors. A matrix (see Figure 5.1) was developed to assist during the question-writing phase.

Using cognitive interviews, two engineering professionals who recruit students from our university agreed to participate in "think-aloud" interviews while taking the draft survey instrument. These cognitive interviews are recommended as best practices in survey development (Groves, Fowler, Couper, Lepowski, Singer & Tourangeau, 2004; Tourangeau, 1984; Tourangeau, Rips & Rasinski, 2000; Willis, 1999). The survey and questions were refined prior to release to engineering recruiters. Using a web-based survey (Qualtrics Survey Software, version 2015), we distributed the quantitative survey to 840 recruiters and hiring managers from 840 different companies who hire engineering undergraduates from our university.

		LEADERSHIP THEMES					
		Initiative/ Confidence	Communication	Interpersonal Interactions	Teamwork	Engagement	
DIMENSIONS	Knowledge	4 questions	4 questions	4 questions	4 questions	4 questions	20 questions
	Abilities	4 questions	4 questions	4 questions	4 questions	4 questions	20 questions
	Behaviors	4 questions	4 questions	4 questions	4 questions	4 questions	20 questions
		12 questions	12 questions	12 questions	12 questions	12 questions	**60 questions**

Figure 5.1. Question Matrix

The survey response rate was 23% with 193 responses, including 172 complete-case observations. The response rate and break-off are acceptable in social science research (Fowler, 2014). Previously, the survey instrument was assessed for validity and reliability. Validity and reliability tests were performed on the 172 complete-case observations. The Cronbach's alpha for the 60 questions was estimated at 0.97 and the Root Mean Square Error of Approximation (RMSEA) was estimated at 0.081 ($p < 0.01$). This analysis also examined each themes individually; Cronbach's alpha for the themes ranged from 0.85 to 0.94. This analysis empirically demonstrated the survey is valid and reliable (Hartmann, Stephens & Jahren, 2016).

The themes were ranked in this order: initiative/confidence, communication, interpersonal interactions, teamwork, and engagement. The means and standard deviations for the themes, are shown in Table 5.1 and Figure 5.2 (Hartmann, Stephens & Jahren, 2016).

Table 5.1. Leadership Theme Data

Leadership Themes	Mean	S.D.
Initiative/ Confidence	5.09	0.46
Communication	4.90	0.54
Interpersonal Interactions	4.90	0.51
Teamwork	4.75	0.54
Engagement	3.90	0.77

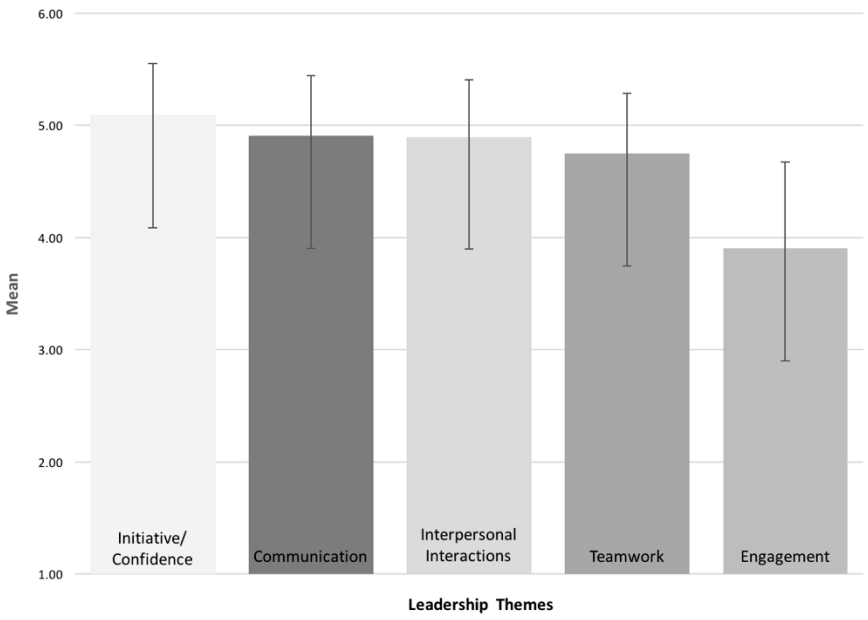


Figure 5.2. Respondents' View of Importance of Five Leadership Themes

Step 3: Quantitative Analysis Phase

In this paper, we will answer the following two research questions:

RQ1 What is the order of importance of the five leadership themes based on major being hired?

RQ2 What is the order of importance of the five leadership themes based on job title category?

Observations from the qualitative interviews indicated a strong preference for initiative and confidence from engineering undergraduates. Participants also indicated the importance of communication, interpersonal interactions, and teamwork. Finally, although important, engagement was presented as the least critical of the five themes. Two hypotheses were developed based on the interviews conducted by Hartmann and Jahren (2015):

H1 The order of importance of leadership themes will not differ based on the major of applicant being hired.

H2 The order of importance of leadership themes will not differ based on the job title category of the recruiter.

Results by Major(s) Hired (RQ1)

We analyzed the data by engineering major hired. The 193 respondents represented 193 different companies. The majority of these companies hire two or more of the twelve majors at this university, while thirty-six (36) companies focus their hiring on only one major from this university. Table 5.2 and Figure 5.3 outline the complete breakdown of number of majors hired by the respondents' companies.

Table 5.2. Number of Majors Hired

Number of Majors Hired	Number of Companies	%
No response	9	4.7%
One Major	36	18.7%
Two Majors	44	22.8%
Three Majors	32	16.6%
Four Majors	28	14.5%
Five Majors	21	10.9%
Six Majors	10	5.2%
Seven Majors	2	1.0%
Eight Majors	7	3.6%
Nine Majors	2	1.0%
Ten Majors	1	0.5%
Eleven Majors	1	0.5%
Total	**193**	**100.0%**

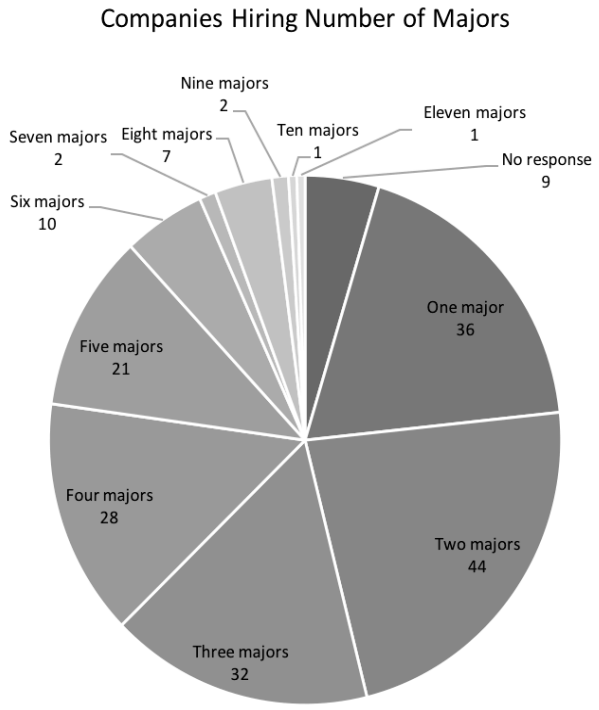


Figure 5.3. Number of Companies by Number of Different Majors from which they Hired Students

We analyzed the responses further to determine how many of the companies hire each of the twelve majors. Of the 193 responses, the number of companies hiring each major ranged from 10 (5.2%) for Biological Systems Engineering (BSE) to 106 (54.9%) for Mechanical Engineering (ME). Nine respondents did not complete this section of the survey. Table 5.3 provides the twelve engineering majors identified in the survey and how many of the 193 companies hire each major. Respondents hiring multiple majors are counted in multiple rows.

Table 5.3. Number of Companies Hiring by Major

Engineering Major	Abbreviation	Number of Companies hiring	%
Aerospace	AeroE	20	10.4%
Agricultural	AgE	41	21.2%
Biological Systems	BSE	10	5.2%
Chemical & Biological	CBE	36	18.7%
Civil & Environmental	CE	73	37.8%
Computer	CompE	49	25.4%
Construction	ConE	68	35.2%
Electrical	EE	90	46.6%
Industrial & Manufacturing Systems	IMSE	54	28.0%
Materials	MatE	20	10.4%
Mechanical	ME	106	54.9%
Software	SE	39	20.2%

Themes analysis – major(s) being hired. We evaluated the data by major being hired to ascertain similarities and/or differences in the importance of the five leadership themes. There was a clear preference for initiative/confidence as the most important of the five themes and engagement for the least preferred. Teamwork was ranked fourth by all but one group, receiving a tie for third from those hiring Aerospace Engineers. As seen in the previous study, communication and interpersonal interactions are very similar in

scores with six groups ranking each of these themes as the second most important. The detailed analysis in this study proved that H1 is true; the theme ranking does not differ based on major being hired. Overall, these themes were ranked in the following order: (1) initiative/confidence, (2) communication, (3) interpersonal interactions, (4) teamwork, and (5) engagement. The mean and ranking of each theme by respondents hiring each of the twelve majors is presented in Table 5.4. Data from respondents hiring multiple majors are included in each row of this table, as applicable.

Table 5.4. Mean and Rank of Themes by Major Being Hired

Major(s) Being Hired	Initiative/ Confidence		Communication		Interpersonal Interactions		Teamwork		Engagement	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
AeroE	5.24	1	4.97	3	4.99	2	4.97	3	4.11	5
AgE	5.01	1	4.78	3	4.79	2	4.64	4	3.72	5
BSE	5.04	1	4.85	3	4.91	2	4.84	4	4.13	5
CBE	5.15	1	5.03	2	4.99	3	4.90	4	4.23	5
CE	5.17	1	5.06	2	5.03	3	4.86	4	4.00	5
CompE	5.09	1	4.85	2	4.84	3	4.72	4	3.91	5
ConE	5.16	1	4.96	3	4.98	2	4.82	4	3.99	5
EE	5.13	1	4.97	2	4.94	3	4.84	4	3.99	5
IMSE	5.16	1	4.94	3	4.99	2	4.83	4	4.08	5
MatE	5.18	1	4.98	3	5.01	2	4.95	4	4.24	5
ME	5.12	1	4.92	2	4.90	3	4.78	4	3.90	5
SE	5.07	1	4.88	2	4.84	3	4.73	4	3.96	5

The survey information was further analyzed to determine top theme(s) for each respondent. The top theme(s) is/are the leadership theme(s) with the highest mean of the twelve associated questions tagged to that theme. The percentage of top themes for each of the twelve engineering majors can be seen in Table 5.4. In 36 cases (18.6%), respondents' answers resulted in two or more of the five themes receiving the high mean score. In other words, the means for the twelve questions associated to those leadership themes were the same. Those respondents' results are included in the "multiple" column in Table 5.5.

Table 5.5. Percentage of Respondents' Top Themes by Major Hired

Major Hired	n	Initiative/ Confidence	Communication	Interpersonal Interactions	Teamwork	Engagement	Multiple
AeroE	20	60%	10%	5%	5%	5%	15%
AgE	41	49%	17%	7%	5%	0%	22%
BSE	10	40%	0%	20%	20%	0%	20%
CBE	36	41%	14%	14%	3%	0%	28%
CE	73	43%	15%	12%	4%	0%	26%
CompE	49	57%	12%	6%	8%	2%	15%
ConE	68	48%	10%	15%	6%	0%	21%
EE	90	47%	15%	9%	8%	1%	20%
ISME	54	56%	7%	15%	5%	0%	17%
MatE	20	45%	10%	5%	10%	0%	30%
ME	106	52%	14%	9%	6%	0%	19%
SE	39	51%	13%	5%	5%	3%	23%

To illustrate the multiple category and its impact, we will look at one engineering major in detail. At first glance, it appears that none of the ten respondents hiring BSE students ranked communication as a top theme. However, looking at the data in more detail, we see that two respondents did rank communication in a high manner. The means and rankings for the ten BSE respondents are presented in Table 5.6 and show that the answers from Respondent 8 and Respondent 10 resulted in multiple themes receiving a top ranking. In the case of Respondent 8, all questions for all themes were answered by providing a score of six (Extremely Important), resulting in a five-way tie for the top theme. Respondent 10 answered the 12 questions tagged to initiative/confidence, communication, and teamwork in such a way to create a three-way tie for the top theme. Both of these respondents' top theme is reported as "multiple" in Table 5.5.

Table 5.6. BSE Respondents' Data – Mean and Rank

BSE Respondent	Initiative/ Confidence		Communication		Interpersonal Interactions		Teamwork		Engagement	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
1	5.17	2	4.58	4	5.17	2	5.58	1	4.42	5
2	4.92	2	4.75	3	5.00	1	4.75	3	4.00	4
3	4.67	2	4.50	3	4.75	1	4.33	4	3.17	5
4	4.92	1	4.75	4	4.83	2	4.83	2	4.00	5
5	4.83	2	4.50	4	4.67	3	5.00	1	3.83	5
6	4.83	1	4.75	2	4.67	3	4.42	4	3.92	5
7	5.33	1	5.00	2	4.75	3	4.50	4	3.83	5
8	6.00	1	6.00	1	6.00	1	6.00	1	6.00	1
9	4.92	1	4.83	2	4.50	3	4.17	4	3.67	5
10	4.83	1	4.83	1	4.75	4	4.83	1	4.42	5
All	**5.04**	**1**	**4.85**	**3**	**4.91**	**2**	**4.84**	**4**	**3.13**	**5**

Of the 36 respondents with multiple high mean themes, there were 84 choices of top themes identified: initiative/confidence (28), communication (21), interpersonal interactions (23), teamwork (9), and engagement (3). The prevalence of respondents scoring questions in such a manner for multiple high means underscores the importance of those themes. It should be noted that the number of themes receiving high means in this multiple category emulate the stand-alone top theme rankings indicated earlier.

Shown another way, we reviewed all high mean themes by total count. In this review, we included the 84 choices identified above and found that overall, there are 241 top themes: initiative/confidence (123), communication (52), interpersonal interactions (43), teamwork (18) and engagement (5). In three of the five cases respondents ranked engagement as the top theme, with the mean for the twelve questions tagged to engagement equal to the means for three or four other themes. Table 5.7 presents the total count of top themes by major being hired, including those that were shown in the "multiple" column in Table 5.4.

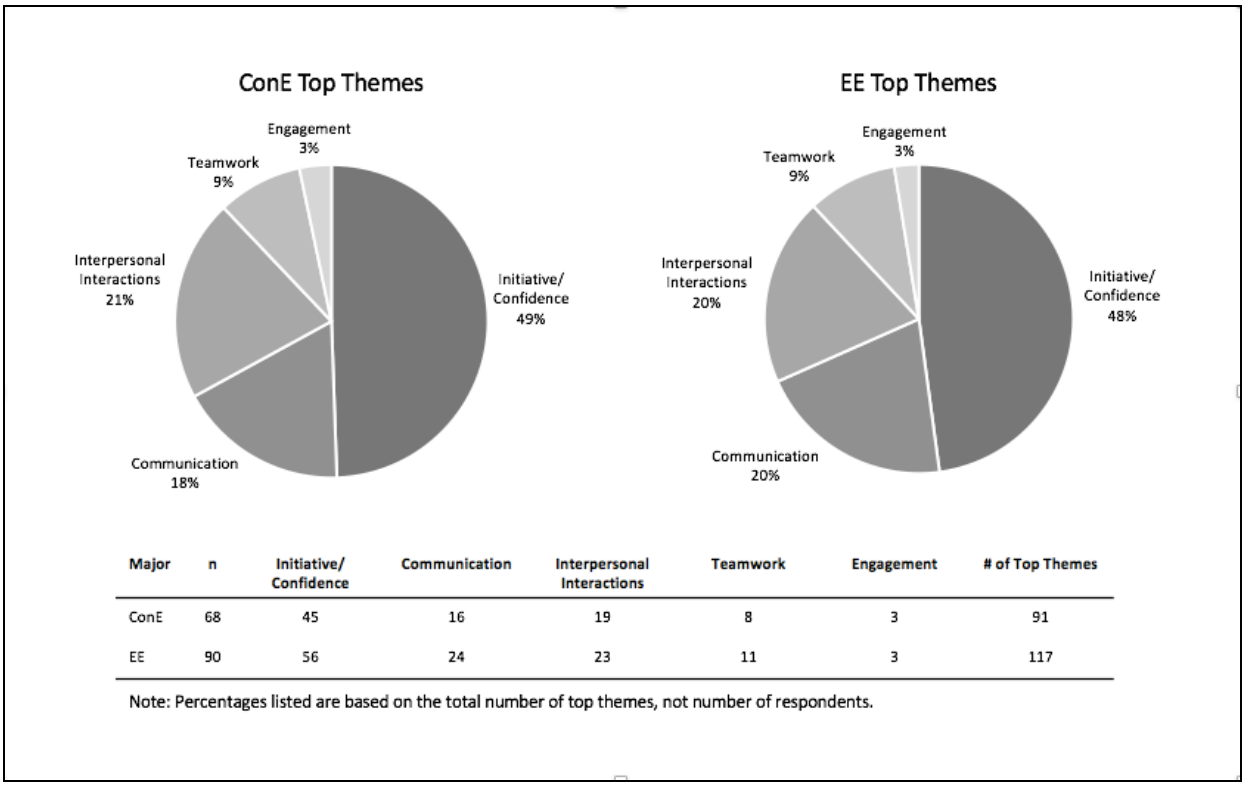
Table 5.7. Count of Top Themes by Major Hired

Major	n	Initiative/ Confidence		Communication		Interpersonal Interactions		Teamwork		Engagement	
		Count	%	Count	%	Count	%	Count	%	Count	%
AeroE	20	14	70%	5	25%	4	20%	2	10%	2	10%
AgE	41	28	68%	11	27%	8	20%	3	7%	0	0%
BSE	10	6	60%	2	20%	3	30%	4	40%	1	10%
CBE	36	23	64%	12	33%	11	31%	4	11%	2	6%
CE	73	46	63%	25	34%	22	30%	7	10%	2	3%
CompE	49	33	67%	11	22%	8	16%	6	12%	3	6%
ConE	68	45	66%	16	24%	19	28%	8	12%	3	4%
EE	90	56	62%	24	27%	23	26%	11	12%	3	3%
ISME	54	37	69%	10	19%	13	24%	5	9%	1	2%
MatE	20	14	70%	7	35%	5	25%	4	20%	1	5%
ME	106	71	67%	27	25%	26	25%	9	8%	2	2%
SE	39	27	69%	12	31%	8	21%	4	10%	3	8%

As shown in previous tables (Tables 5.3, 5.4 and 5.5), data from respondents hiring multiple majors are counted in multiple rows. As can be seen, initiative/confidence is highly rated by all recruiters with 62% to 70% of respondents in each category of major being hired ranking this as the top theme. Communication received 19% to 35% of the top themes by major; interpersonal interactions received 16% to 31%; teamwork received 7% to 40%; and engagement received 0% to 10%.

Construction engineering and electrical engineering comparisons. In the earlier qualitative study, we interviewed recruiters hiring students in two majors, construction engineering (ConE) and electrical engineering (EE). This study showed one slight difference between the two groups: recruiters hiring ConE students all mentioned "conflict resolution" as being an important leadership skill while those hiring EE students did not (Hartmann & Jahren, 2015). To validate the qualitative findings, we present the

analysis of quantitative data for these two majors (see Figure 5.3). For the 68 ConE recruiters, 91 top themes were identified; for the 90 EE recruiters, 117 top themes were identified. We confirmed recruiters hiring applicants from both majors rank the themes in a very similar manner with only one slight difference. ConE recruiters



Major	n	Initiative/ Confidence	Communication	Interpersonal Interactions	Teamwork	Engagement	# of Top Themes
ConE	68	45	16	19	8	3	91
EE	90	56	24	23	11	3	117

Note: Percentages listed are based on the total number of top themes, not number of respondents.

Figure 5.3. Comparison of ConE and EE Top Leadership Themes

value interpersonal interactions slightly more than communication; EE recruiters value communication slightly more than interpersonal interactions. If conflict resolution is thought to be an important part of interpersonal interactions, this result would tend to confirm this previous results of the qualitative survey. It should also be noted that there are 21 common respondents in these data sets.

Realizing that the majority of the respondents hire multiple majors, it comes as no surprise that the data for all majors is similar due to the impact of common respondents.

Therefore, we performed further analysis to review the responses of those respondents (companies) that target only one major from the university.

Targeted construction engineering and civil engineering comparisons. In our analysis of the 36 respondents who identified hiring only one major, we discovered that there were only two majors with more than four respondents: civil engineering (CE) and construction engineering (ConE). Eleven respondents indicated they hired CE students only; eleven respondents specified they hire ConE students only. It should be noted that at the university studied, an ABET-accredited ConE program exists. Most universities do not have ConE as a separate major, rather, it is part of the CE program. Since these two majors are so closely related, we did not expect to see any differences between the results from the two groups.

The ranking of themes for the eleven respondents who hire only students in CE is consistent with the earlier findings of the aggregated data: (1) initiative/confidence, (2) communication, (3) interpersonal interactions, (4) teamwork, and (5) engagement. However, the respondents targeting only ConE students favored interpersonal interactions over communication. A side-by-side comparison of the means and standard deviations of the respondents targetings only CE and ConE students is presented in Table 5.8 and Figure 5.4. Responses for these two groups were highly similar and consistent. With the means being essentially equal, the data analzyed indicated the recruiters for these two majors seek very similar leadership qualities.

Table 5.8. Targeted CE and ConE Recruiter Data

	CE		ConE	
Theme	Mean	S.D.	Mean	S.D.
Initiative/Confidence	4.84	0.52	5.10	0.43
Communication	4.74	0.46	4.81	0.50
Interpersonal Interactions	4.68	0.61	4.87	0.40
Teamwork	4.38	0.73	4.71	0.49
Engagement	3.52	1.07	4.11	0.75

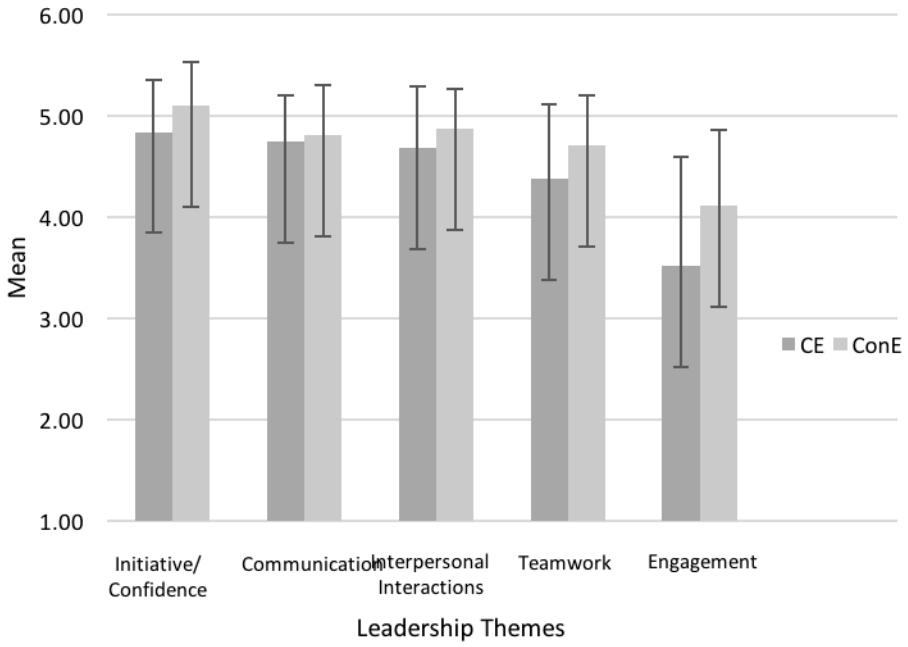


Figure 5.4. Leadership Theme Means for Targeted CE and ConE Positions

Results by Job Title Category (RQ2)

The results were also examined by the job title category of the respondents. Respondents were placed into one of four categories based on their job title: (1) engineering hiring manager, (2) human resources professional, (3) executive, and (4) other/unknown. The majority (42.0%) of the respondents were human resources personnel, with engineering hiring managers making up 23.3% of the respondents.

Executives represented 19.2% of respondents. The final category comprises job titles that were classified as operations, finance, or administrative.

Themes analysis – job title category. Overall, the respondents in the executive and other/unknown categories rated the themes in the same order as: (1) initiative, (2) communication, (3) interpersonal interactions, (4) teamwork, and (5) engagement. Respondents in the engineering hiring managers and human resources categories rated initiative/confidence as the top theme, teamwork as the fourth, and engagement as the fifth theme. However, respondents in these two job title categories reversed the order of communication and interpersonal interactions; the means for these two themes are essentially the same. The mean and rank of the leadership themes by job title category are shown in Table 5.6 and indicate no major differences in responses based on job title category, thereby supporting the claim in H2.

Table 5.6. Mean and Rank of Leadership Themes by Job Title Category

Job Title Category	n	Initiative / Confidence		Communication		Interpersonal Interactions		Teamwork		Engagement	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Engineering Hiring Manager	45	4.95	1	4.74	3	4.76	2	4.63	4	3.67	5
HR	81	5.16	1	5.01	3	5.01	2	4.86	4	4.13	5
Executive	37	5.12	1	4.88	2	4.84	3	4.64	4	3.68	5
Other/Unknown	30	5.07	1	4.90	2	4.86	3	4.74	4	3.91	5
All	**193**	**5.09**	**1**	**4.90**	**2**	**4.90**	**3**	**4.75**	**4**	**3.90**	**5**

Discussion

Using a mixed methods approach (see Figure 5.5), we used our qualitative findings to develop a valid and reliable quantitative survey instrument. The goals of this study were to determine if the leadership skills recruiters hiring engineering

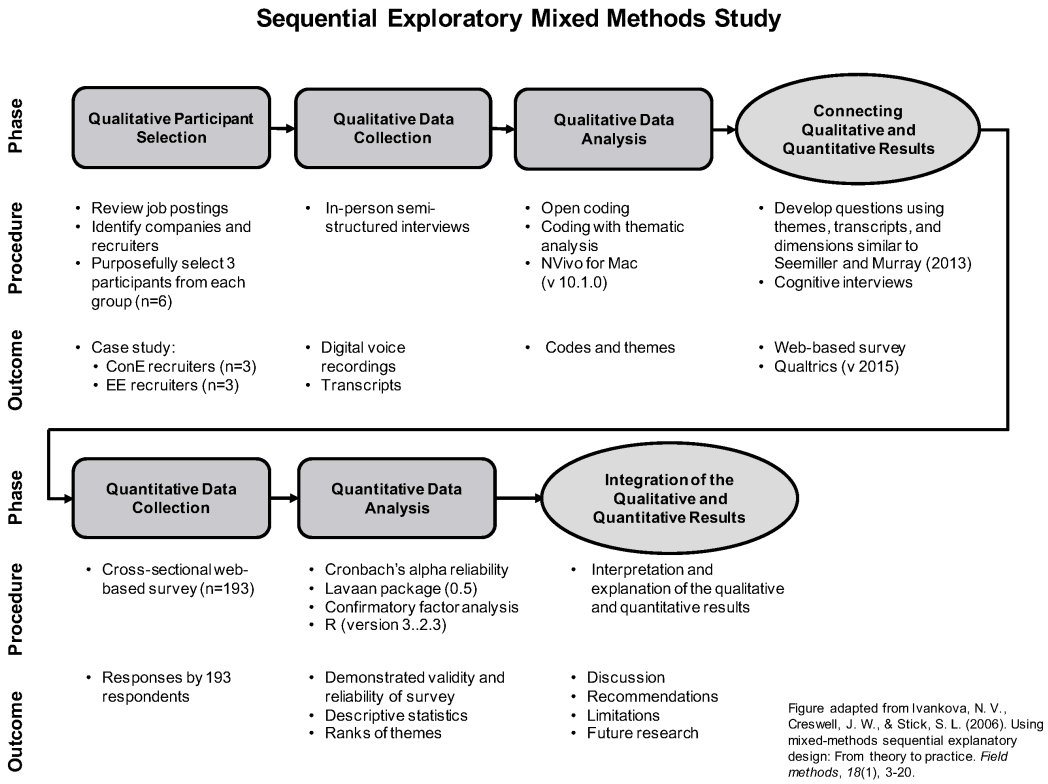


Figure 5.5. Sequential Exploratory Mixed Methods Study Flowchart

undergraduates for full-time, entry-level positions were the same or different based on major being hired, as well as by job title of the recruiter. We achieved our goals.

The findings regarding major hired show that in the aggregate there are no noticeable differences in leadership themes for which recruiters are looking depending on the engineering major of a job applicant. The means of the twelve questions associated with each theme also indicate that all five leadership themes are important for students in all twelve majors. This is critical to engineering leadership educators, as it highlights that leadership development education and training should be focused on the same main themes, regardless of engineering major. While there may be different ways to teach the

knowledge, abilities, and behaviors needed, this finding helps to focus engineering leadership education efforts in a meaningful way.

The findings regarding job title category of recruiter showed that the type of position of the respondent did not have a great impact on the relative importance of the five themes. This is important to note for students seeking employment. While some may argue that an engineering hiring manager is focused on more technical competencies, this study shows that they value non-technical skills as much as the other recruiters. Knowing the information can help develop and shape engineering leadership curricula and programs.

Summary and Recommendations

Existing studies have been carried out by surveying industry members, but no study had focused on recruiters. Our research provides an empirical study to identify and measure leadership themes from the perspective of the engineering recruiter. This study identified leadership themes through qualitative interviews and ranked their importance through a quantitative survey instrument. The theme rankings were largely the same regardless of major being hired or job title of the respondent. All five themes were also determined to be important. These findings are generalizable in the U.S. based on the fact that most recruiters hire at multiple academic institutions. These findings may have a cultural aspect; therefore, work with international institutions is still needed.

Based on the conclusions of this study and the results of the literature review, the recommendations are made. From these findings, first and foremost, engineering educators must develop curricular and non-curricular opportunities to assist undergraduate students to develop initiative and confidence. This was also recently

supported by Reeve, Rottmann and Sacks (2015) who identified initiative and confidence as two of the top five traits of "engineering leadership exemplars." Programs should also prepare students by offering courses and experiences to practice and develop effective communication skills, competency in interpersonal interactions and teamwork. Communication skills recognized in the study include written, oral, and listening skills. In the area of Interpersonal Interactions, competency in "people skills," relationship building, and conflict resolution are needed. Teamwork was defined as having the knowledge, skills, and abilities to work effectively on a team through collaboration and consensus building. Finally, throughout their academic career students should be encouraged to be engaged in student organizations and volunteer and service activities.

While outside of the scope of this study, a body of knowledge exists which suggests promising methods to assist students in acquiring the non-technical and leadership knowledge, abilities, and behaviors identified by recruiters in this study. Brumm, Hanneman, and Mickelson (2006) cite work experience, experiential education (co-ops and internships), capstone courses, and extracurricular activities as ways develop competencies. Others suggest problem based learning (PBL) as an excellent way to teach and develop leadership abilities and communication skills (Kumar & Hsiao, 2007; Walters & Sirotiak, 2011). Active involvement in student organizations is also cited in the research literature as a way to develop leadership skills (ASCE, 2008; Dugan, & Haber, 2007).

Limitations and Future Research

One limitation of this research is that is was administered to recruiters hiring engineering students from this university. However, it is generally understood that most

recruiters do recruit from multiple universities, thus suggesting that this is not a severe limitation. For future surveys, this information should be requested. Additionally, a multi-institutional study could provide the details needed to compare hiring desires for companies.

Another limitation is the relatively small sample size, especially when reviewing the data for those hiring only one major from the university. This could be improved in future studies by targeting hiring managers with job announcements for a specific major only. More research devoted to hiring managers targeting one specific engineering major may reveal some differences. This may prove difficult since many engineering jobs cross boundaries of skill sets required and recruiters typically recruit multiple majors.

Finally, the study does not provide details on what engineering educators should do to ensure students are equipped with the leadership knowledge, abilities, and behaviors identified. While it is beyond the scope of this study, identification of important leadership themes that should be included is the first step to assessing what changes or additions should be made to engineering undergraduate programs to better prepare students for industry.

Taking into consideration these limitations, future work to aid in the generalizability of this study should be considered. While most of the respondents completed the survey, the number of survey questions could be reduced through an exploratory factor analysis. More demographic information may be requested to better understand the background of respondents. Additionally, more may be learned by performing a multi-institutional and international study. We also believe there may be some benefit to include recruiters who recruit students outside of engineering. Finally, we

may also directly ask if recruiters have different leadership expectations for different majors, including those outside of engineering. By working to improve this study and understand the needs of industry, our goal is to best prepare engineering undergraduates for careers as twenty-first century engineers.

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CHAPTER 6. GENERAL CONCLUSIONS

For over twenty years, there has been an effort to introduce leadership development curricula into engineering undergraduate programs. With no consensus on the definition of engineering leadership or which skills to teach, this has precipitated several articles and studies to capture the state of engineering leadership education, what is currently being done, and recommendations to implement. The purpose of this study was to identify the most important leadership knowledge, abilities, and behaviors as needed for entry-level, engineering positions. In this study, recruiters indicated that when they are hiring engineering undergraduates, their desires can be classified into five main themes, initiative/confidence, communication, interpersonal interactions, teamwork, and engagement. It was also revealed that these themes are ranked in essentially the same order regardless of engineering discipline and job position of the recruiter.

The findings were revealed through a mixed methods approach called the "sequential exploratory" method. This systematic approach was presented in three journal papers. The first article contributed to the field of engineering leadership education by identifying and classifying five emerging leadership themes through semi-structured interviews with engineering recruiters. Through this qualitative approach, initiative/confidence, communication, interpersonal interactions, teamwork, and engagement were found to be the prominent themes discussed by personnel hiring engineering undergraduates for entry-level positions.

While these five themes are not exclusive to individuals identified as leaders, many leadership studies have identified the same or similar themes or competencies. For example, each of the five themes are represented by the work of Seemiller and Murray

(2013) to identify and classify "Student Leadership Competencies" in various accreditation documentation. Discussions regarding initiative and/or confidence are found in many sources, including those by Athreya and Kalkhoff (2010), Bernard M. Gordon-MIT Engineering Leadership Program (2011), Brumm, et al (2006), Newport and Elms (1997), and Reeve, Rottmann and Sacks (2015).

Communication(s) was pervasive in the literature reviewed. Authors who identified the importance of communication in their studies include: Crumpton-Young et al (2010), Grant and Dickson (2006), Özgen et al (2013), and many others. Similarly, teamwork was acknowledged by several researchers, including Baytiyeh and Naja (2010), Itani and Srour (2015), Newport and Elms (1997).

Finally, the value of being engaged in student organizations and volunteer/service activities was previously identified by many. Involvement in extracurricular activities was highlighted by ASCE (2008), Brumm et al (2006), Itani and Srour (2015), and Martin et al (2005). The usefulness of service learning projects in leadership development was discussed by Athreya and Kalkhoff (2010), Athreya et al (2007), Graham et al (2009), Kumar and Hsiao (2007), Rover et al. (2013), Shuman et al (2005), and Warnick and Schmidt (2014). The presence of the five emerging themes throughout the literature reviewed indicate the definition of leadership may be rooted in these themes.

The second article documented the development of a reliable and valid quantitative survey instrument, as well as findings regarding the relative importance of the five leadership themes: (1) initiative/confidence, (2) communication, (3) interpersonal interactions, (4) communication, and (5) engagement. Additionally, the finding of initiative/confidence as the most important theme aligns with the Reeve, Rottmann and

Sacks (2015) survey of 175 Canadian engineers, in which "takes initiative" and/or "confident" appear as one or two of the top five traits of "engineering leadership exemplars."

Finally, the third article provided insight on the relative importance of the five leadership themes by engineering major being hired and by job title category of the respondents who were recruiters. The findings demonstrate that engineering recruiters rank the order of the leadership themes in essentially the same order (except for interchanging communication and interpersonal interactions) regardless of engineering major being hired and job title category of the recruiter. The finding that "no differences were noted by the twelve majors being hired" supports the outcomes of Dudman and Wearne (2003) in their comparison of ten engineering disciplines.

Limitations

The themes identified in this study are not necessarily exclusive to leaders or engineering leaders. In fact, some could argue that these themes are good traits (or practices) for any person or employee to possess. However, the themes of initiative/confidence, communication, interpersonal interactions, teamwork, and engagement, were discussed in detail by the participating recruiters when asked the question, "When you used leadership in this (these) job descriptions, what did you mean?" The power of qualitative research is to allow data to emerge through the analysis of thick, rich descriptions. In this case, 90 pages of verbatim, member-checked transcripts were analyzed using open coding and inter-coder agreement to uncover these findings.

The author acknowledges that many leadership competencies were not included in this study. The absence of these knowledge, skills, abilities, values, and behaviors does not mean they are not important to the development of engineering leaders. Simply put, they did not emerge from the qualitative portion of this mixed methods study. The ability to perform on these themes in challenging situations also did not emerge. However, such a difference may constitute the difference between a truly great leader and one with moderate ability. This study did not address what makes great leaders – just themes that are associated with leadership.

Implications

This study was conducted at one large Midwestern university. The findings indicate that, regardless of discipline of engineering, engineering leadership educators should create student outcomes to address the same themes to best prepare undergraduates for their first full-time engineering position. The literature reviewed in Chapter 2 supports the importance of professional skills, including leadership skills, to students in all engineering disciplines. Since most recruiters hire student from multiple institutions, there is a high likelihood that the findings are generalizable across the United States.

The three articles for publication should provide value to ongoing research regarding potential additions and changes that may be made to engineering curricula to better prepare students for entry-level positions. However, the study does not address how this should be accomplished nor does it does indicate if students in all engineering disciplines can be taught in the same manner. However, the literature reviewed did reveal many suggestions to develop leadership in engineering students. These recommendations

include: involvement through experiential education (co-op and internship experiences), capstone courses, problem-based learning, student organizations and volunteer service—all of which are highlighted by NAE (2012), as well as others.

Further Research

This study provides a beginning effort to better understand what employers are seeking when hiring engineering undergraduates for full-time, entry-level positions. Throughout this process, improvements for further research were identified. First, a larger sample size for the qualitative portion of the study may reveal additional themes. Moreover, interviewing hiring officials from a broader range of engineering disciplines may shed light on differences. For the quantitative portion of the study, more user questions may be added to better understand the perspective that each recruiter brings. Finally, an exploratory factor analysis may be to reduce the number of questions in the survey.

As momentum continues to increase in the area engineering leadership education, more educators may understand the importance of integrating leadership development into their courses. Although beyond the scope of this study, there remains a need to determine how to best introduce leadership development curricula to engineering undergraduate programs, as well as assess the efficacy of those additions.

APPENDIX A. INSTITUTIONAL REVIEW BOARD (IRB) APPROVAL

IRB ID: 14-146

INSTITUTIONAL REVIEW BOARD (IRB)
Application for Approval of Research Involving Humans

Title of Project: Industry needs for leadership skills for full-time, entry-level positions in construction engineering and electrical engineering

Principal Investigator (PI): Beth Lin Hartmann			Degrees: BA Arch, MSCE
University ID: [redacted]	Phone: 515-294-8190	Email Address: bethlin@iastate.edu	
Correspondence Address: 450 Town Engineering			
Department: Civil, Construction & Environmental Engineering		College/Center/Institute: Engineering	

RECEIVED
FEB 27 2014
By IRB

PI Level: ☐ Tenured, Tenure-Eligible, & NTER Faculty ☐ Adjunct/Affiliate Faculty ☐ Collaborator Faculty ☐ Emeritus Faculty
☐ Visiting Faculty/Scientist ☐ Senior Lecturer/Clinician ☐ Lecturer/Clinician, w/Ph.D. or DVM ☐ P&S Employee, P37 & above
☐ Extension to Families/Youth Specialist ☐ Field Specialist III ☐ Postdoctoral Associate ☒ Graduate/Undergrad Student ☐ Other (specify:)

FOR STUDENT PROJECTS *(Required when the principal investigator is a student)*			
Name of Major Professor/Supervising Faculty: Charles T. Jahren			
University ID: [redacted]	Phone: 515-294-3829	Email Address: cjahren@iastate.edu	
Campus Address: 428 Town Engineering		Department: Civil, Construction & Environmental Engineering	
Type of Project (check all that apply): ☒ Thesis/Dissertation		☐ Class Project	☐ Other (specify:)

Alternate Contact Person:	Email Address:
Correspondence Address:	Phone:

ASSURANCE

- I certify that the information provided in this application is complete and accurate and consistent with any proposal(s) submitted to external funding agencies. Misrepresentation of the research described in this or any other IRB application may constitute non-compliance with federal regulations and/or academic misconduct.
- I agree to provide proper surveillance of this project to ensure that the rights and welfare of the human subjects are protected. I will report any problems to the IRB. See Reporting Adverse Events and Unanticipated Problems for details.
- I agree that modifications to the approved project will not take place without prior review and approval by the IRB.
- I agree that the research will not take place without the receipt of permission from any cooperating institutions when applicable.
- I agree to obtain approval from other appropriate committees as needed for this project, such as the IACUC (if the research includes animals), the IBC (if the research involves biohazards), the Radiation Safety Committee (if the research involves x-rays or other radiation producing devices or procedures), etc., and to obtain background checks for staff when necessary.
- I understand that IRB approval of this project does not grant access to any facilities, materials, or data on which this research may depend. Such access must be granted by the unit with the relevant custodial authority.
- I agree that all activities will be performed in accordance with all applicable federal, state, local, and Iowa State University policies.

[redacted] 2/21/14
Signature of Principal Investigator Date

[redacted] 2/24/14
Signature of Major Professor/Supervising Faculty Date
(Required when the principal investigator is a student)

- I have reviewed this application and determined that departmental requirements are met, the investigator(s) has/have adequate resources to conduct the research, and the research design is scientifically sound and has scientific merit.

Terry J. Wipf
Printed Name of Department Chair/Head/Director

[redacted] 2/24/14
Signature of Department Chair/Head/Director Date

For IRB Use Only	Full Committee Review: ☐	Review Date: April 2, 2014
Approval Not Required: ☐	EXPEDITED per 45 CFR 46.110(b): Category 4,7 Letter I	Approval/Determination Date: April 2, 2014
Not Research: ☐	EXEMPT per 45 CFR 46.101(b):	Approval Expiration Date: April 1, 2016
No Human Subjects: ☐	Not Approved: ☐	Risk: Minimal ☑ More than Minimal ☐
IRB Reviewer's Signature [redacted]	April 2, 2014	

APPENDIX B. QUALITATIVE INTERVIEW QUESTIONS

Interview Questions

1. What is your name?
2. How long have you worked at [Company]?
3. What is your job title?
4. What are your main job responsibilities at [Company]?
5. When recruiting at Iowa State, what do you look for in possible hires?
    a. Follow-up questions, as required.
6. What does your company mean by "leadership" in this/these job descriptions? Provide job announcement(s).
    a. You've told me that "leadership" means. What specific skills would you expect applicants to possess?
    b. [For each skill] What acceptable evidence do you expect to see?
    c. Other follow-up questions as the conversation progresses.
7. What do you think Iowa State should do to assist ConE/EE students prepare for positions with your company?
    a. Other follow-up questions as the conversation progresses.
8. Would you like to share anything else with me regarding your company's hiring policies, views on leadership skills for engineers, or anything else that you think would help me with my research?

APPENDIX C. IRB MODIFICATION APPROVAL

Assigned IRB ID: **14-146**

INSTITUTIONAL REVIEW BOARD (IRB)
Modification Form for Non-Exempt Research

Title of Project: Industry Needs for Leadership Skills for New Hires in Full-Time, Entry Level Engineering Positions

Principal Investigator (PI): **Beth Lin Hartmann**			Degrees: BA Arch, MSCE
University ID: [redacted]	Phone: 515-294-8190	Email Address: bethlin@iastate.edu	
Department: Civil, Construction & Environmental Engineering			RECEIVED

FOR STUDENT PROJECTS *(Required when the principal investigator is a student)*			FEB 13 2015
Name of Major Professor/Supervising Faculty: Charles T. Jahren			
University ID: [redacted]	Phone: 515-294-3829	Email Address: cjahren@iastate.edu	By IRB

Alternate Contact Person:	Email Address:
Correspondence Address:	Phone:

Please notify the IRB Office if your contact information has changed since the last review.

ASSURANCE

- I certify that the information provided in this application is complete and accurate and consistent with any proposal(s) submitted to external funding agencies. Misrepresentation of the research described in this or any other IRB application may constitute non-compliance with federal regulations and/or academic misconduct.
- I agree to provide proper surveillance of this project to ensure that the rights and welfare of the human subjects are protected. I will report any problems to the IRB. See Reporting Adverse Events and Unanticipated Problems for details.
- I agree that modifications to the approved project will not take place without prior review and approval by the IRB.
- I agree that the research will not take place without the receipt of permission from any cooperating institutions when applicable.
- I agree to obtain approval from other appropriate committees as needed for this project, such as the IACUC (if the research includes animals), the IBC (if the research involves biohazards), the Radiation Safety Committee (if the research involves x-rays or other radiation producing devices or procedures), etc., and to obtain background checks for staff when necessary.
- I understand that IRB approval of this project does not grant access to any facilities, materials, or data on which this research may depend. Such access must be granted by the unit with the relevant custodial authority.
- I agree that all activities will be performed in accordance with all applicable federal, state, local, and Iowa State University policies.

[redacted] 2/8/15
Signature of Principal Investigator Date

[redacted] 2/8/15
Signature of Major Professor/Supervising Faculty Date
(Required when the principal investigator is a student)

For IRB Use Only	Full Committee Review: ☐	Review Date: 2/27/2015	
	Approval Not Required: ☐	Approval/Determination Date: 2/27/2015	
EXEMPT per 45 CFR 46.101(b):	*Not Research*: ☐	Approval Expiration Date: 4/1/2016	
EXPEDITED per 45 CFR 46.110(b): Category Letter 2	*No Human Subjects*: ☐		
	Not Approved: ☐	Risk: Minimal ☑	More than Minimal ☐
IRB Reviewer's Signature [redacted]		2/27/2015	

APPENDIX D. QUANTITATIVE SURVEY QUESTIONS

Initial Survey Questions

Introduction

Introduction Statement

Participation agreement

- o Agree
- o Disagree

Leadership Competency Questions

How important are the following for an applicant to possess when applying for a full-time, entry-level engineering position with your company?

* Some of these questions may be similar to those you have already answered.

	Extremely Important	Very Important	Somewhat Important	Somewhat Unimportant	Very Unimportant	Not at all Important
Understand my company's products and services	☐	☐	☐	☐	☐	☐
Have excellent writing skills	☐	☐	☐	☐	☐	☐
Create positive rapport with others	☐	☐	☐	☐	☐	☐
Know how to delegate	☐	☐	☐	☐	☐	☐
Participated as a member of a student organization	☐	☐	☐	☐	☐	☐
Be a self starter	☐	☐	☐	☐	☐	☐
Demonstrate participation in volunteer service	☐	☐	☐	☐	☐	☐
Interact positively with others on a team	☐	☐	☐	☐	☐	☐
Conduct an effective meeting	☐	☐	☐	☐	☐	☐
Well connected to others in the industry	☐	☐	☐	☐	☐	☐
Appreciates the benefits of being involved in extracurricular activities	☐	☐	☐	☐	☐	☐
Recognize that diversity is an asset	☐	☐	☐	☐	☐	☐
Have knowledge on how to deliver effective feedback	☐	☐	☐	☐	☐	☐
Demonstrate active listening skills	☐	☐	☐	☐	☐	☐
Display commitment to helping others in the community	☐	☐	☐	☐	☐	☐
Possess confidence	☐	☐	☐	☐	☐	☐
Have awareness about strategies to boost self confidence	☐	☐	☐	☐	☐	☐
Asks questions	☐	☐	☐	☐	☐	☐
Build relationships	☐	☐	☐	☐	☐	☐
Have knowledge about group dynamics	☐	☐	☐	☐	☐	☐
Knowledgeable about my company	☐	☐	☐	☐	☐	☐
Motivated to learn new things	☐	☐	☐	☐	☐	☐
Know how to write a professional email	☐	☐	☐	☐	☐	☐

Have knowledge about active listening techniques	☐	☐	☐	☐	☐	☐
Engage effectively in difficult conversations	☐	☐	☐	☐	☐	☐
Be cooperative with team members	☐	☐	☐	☐	☐	☐
Participated in community service activities	☐	☐	☐	☐	☐	☐
Know how to treat others with respect	☐	☐	☐	☐	☐	☐
Motivated to step up	☐	☐	☐	☐	☐	☐
Able to resolve a conflict	☐	☐	☐	☐	☐	☐

How important are the following for an applicant to possess when applying for a full-time, entry-level engineering position with your company?
* Some of these questions may be similar to those you have already answered.

	Extremely Important	Very Important	Somewhat Important	Somewhat Unimportant	Very Unimportant	Not at all Important
Provide constructive feedback to others	☐	☐	☐	☐	☐	☐
Have received training in teamwork	☐	☐	☐	☐	☐	☐
Inspire others	☐	☐	☐	☐	☐	☐
Performed community service	☐	☐	☐	☐	☐	☐
Shows commitment to the team	☐	☐	☐	☐	☐	☐
Have knowledge about “self” to enhance self confidence	☐	☐	☐	☐	☐	☐
Know how to prepare an effective presentation	☐	☐	☐	☐	☐	☐
Maintain eye contact during a conversation	☐	☐	☐	☐	☐	☐
Represent a colleagues’ position when they are not present	☐	☐	☐	☐	☐	☐
Demonstrate a successful event they have planned	☐	☐	☐	☐	☐	☐
Influence others	☐	☐	☐	☐	☐	☐
Go above and beyond what is asked	☐	☐	☐	☐	☐	☐
Communicate effectively with clients	☐	☐	☐	☐	☐	☐
Understand the roles and responsibilities of others on the team	☐	☐	☐	☐	☐	☐
Performed successfully as a cabinet member of a student organization	☐	☐	☐	☐	☐	☐
Understand they should collaborate with others	☐	☐	☐	☐	☐	☐
Able to facilitate a discussion where there are differing opinions	☐	☐	☐	☐	☐	☐
Know how to write a memo	☐	☐	☐	☐	☐	☐
Connects with others	☐	☐	☐	☐	☐	☐
Demonstrates knowledge about the benefits of participating in volunteer service	☐	☐	☐	☐	☐	☐
Motivated to understand others’ circumstances	☐	☐	☐	☐	☐	☐
Know the importance of being involved in activities outside of the classroom	☐	☐	☐	☐	☐	☐

Share an example of a time they have served on a team and delegated successfully	☐	☐	☐	☐	☐	☐
Be empathetic towards others on the team	☐	☐	☐	☐	☐	☐
Takes the initiative	☐	☐	☐	☐	☐	☐
Display success as a leader of a student organization	☐	☐	☐	☐	☐	☐
Demonstrate knowledge of the value of getting involved with professional organizations	☐	☐	☐	☐	☐	☐
Knows how to positively interact with others	☐	☐	☐	☐	☐	☐
Demonstrate excellent oral presentation skills	☐	☐	☐	☐	☐	☐
Willing to ask for help	☐	☐	☐	☐	☐	☐

User Questions

What is your job title?

How long have you worked with your current company?

- Less than 1 year
- 2-5 years
- 6-10 years
- More than 10 years

My company hires students from the following engineering programs (select all that apply):

- Aerospace
- Agricultural
- Biological Systems
- Chemical and Biological
- Civil/Environmental
- Computer
- Construction
- Electrical
- Industrial and Manufacturing Systems
- Materials
- Mechanical
- Software

The last time my company attended the [University] Engineering Career Fair was:

- Fall 2014
- Spring 2014
- Over one year ago
- Over two years ago
- Over three years ago
- Never
- I don't know (excluded from analysis)

Thank you for participation in this study.

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