8-2024

Defining Engineering Leadership and Engineering Leadership Skills From the Perspectives of ABET Leaders and Professional Engineers

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DEFINING ENGINEERING LEADERSHIP AND ENGINEERING LEADERSHIP SKILLS FROM THE PERSPECTIVES OF ABET LEADERS AND PROFESSIONAL ENGINEERS

by

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A dissertation proposal submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Engineering Education

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Utah State University
Logan, Utah

2024

ABSTRACT

Defining Engineering Leadership and Engineering Leadership Skills from the Perspectives of ABET Leaders and Professional Engineers

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Engineering leadership has been widely recognized as pivotal to the success of engineering projects and overall success in the engineering profession in the modern work environment. Engineering institutions have responded to the calls from industry and engineering regulating bodies to incorporate engineering leadership training into the engineering curricula using a variety of approaches such as stand-alone courses and programs, integrated curricula, and experiential learning. However, there is a lack of consensus on the definition of engineering leadership and the specific engineering leadership skills that should be emphasized in training. This study contributes to the discourse on achieving a consensus on the definition by proposing a definition of engineering leadership from the perspectives of engineering leaders in industry and the Accreditation Board for Engineering and Technology (ABET). The study also highlights the engineering leadership skills identified as essential in engineering leadership training by these participating engineering leaders.

In order to gain insights into how these leaders conceptualize engineering leadership and its associated skills, a qualitative research methodology using phenomenology research design was used to describe the common meaning of the lived experiences of a phenomenon by a group of individuals. The phenomenon of interest in this study is engineering leadership. The specific phenomenological approach used in this study is the interpretive phenomenological analysis (IPA). Six ABET leaders and seven industry leaders participated in this study through in-depth interviews where they defined engineering leadership based on their experience as engineering leaders and highlighted the skills that should be emphasized in engineering training.

The subsequent data analysis resulted in a proposed definition of engineering leadership, a proposed definition of engineering leadership skills, and an identification of eighteen engineering leadership skills that are considered essential in the teaching of engineering leadership. In addition, this study 1) proposed a taxonomy of engineering leadership skills as consisting of technical skills, interpersonal skills, and personal professional skills, 2) found that the main difference between engineering leadership and general leadership is the technical expertise component, and supported the dichotomous view of engineering leadership as consisting of technical expertise and interpersonal skills, and 3) indicated that engineering is a leadership profession starting from self-leadership to managerial leadership.

(228 pages)

PUBLIC ABSTRACT

Defining Engineering Leadership and Engineering Leadership Skills from the Perspectives of ABET Leaders and Professional Engineers

Yemisi Victoria Oyewola

Leadership within the engineering domain has gained significant recognition in recent years due to calls from the literature, industry, and engineering professional bodies to incorporate leadership training into the engineering curriculum. In response to these calls and despite various approaches that have been implemented by engineering institutions to teach engineering leadership, research indicates that there remains a lack of consensus on the definition of engineering leadership and the specific skills that should be emphasized in the teaching of engineering leadership. Also, there is evidence in the literature that there exists a debate regarding the nature of engineering leadership, with some contending that it is indistinguishable from leadership in general, and others asserting that it incorporates engineering design principles.

This lack of consensus indicates varying interpretations and priorities among engineering leadership educators, and this could impede the formation of a cohesive understanding of engineering leadership and impact the quality of leadership education in engineering programs. This study contributes to ongoing efforts by researchers to embark on empirical studies on engineering leadership to bridge the conceptual gap and arrive at a generally accepted definition. In addition, this research aims to understand the nature of engineering leadership and to highlight the leadership skills that should be emphasized in engineering leadership training.

Six ABET leaders and seven engineering leaders from the industry participated in this study. Their perspectives on engineering leadership definition and the skills that should be emphasized in engineering leadership training were explored through in-depth interviews. The

outcome of analyzing their data resulted in a proposed definition of engineering leadership and the identification of eighteen engineering leadership skills that should be emphasized in engineering leadership training. Also, other outcomes from the study include 1) the indication that the main difference between engineering leadership and general leadership is the technical expertise component, resulting in a dichotomous view of engineering leadership as consisting of technical expertise and interpersonal skills, 2) the indication that engineering is a leadership profession starting from self-leadership and progressing to managerial leadership based on the 3-stages of engineering leadership model, and 3) a proposed a taxonomy of engineering leadership skills as consisting of technical skills, interpersonal skills, and personal professional skills.

ACKNOWLEDGMENTS

I give all praises and adoration to my Lord Jesus Christ for His Love and Grace unto me, and for giving me the strength to complete my doctoral studies and research against all odds. May His name be praised forever.

I would like to sincerely thank my advisor, Dr. Kurt Becker, for his incredible mentoring and professional guidance throughout my doctoral studies. He was always a constant source of inspiration who believed in me, supported me, and pushed me to become a better researcher and a better communicator. He would always patiently listen to me and guide me through whatever challenges I was facing. I am truly fortunate to have had him as my advisor. I would also like to express my heartfelt gratitude to my esteemed dissertation committee members, Drs. Angela Minichiello, Oenardi Lawanto, Cassandra McCall, and Thomas Fronk. Their insightful feedback and constructive suggestions have greatly enriched this work. I am grateful for their expertise and the time they dedicated to reviewing and evaluating my work. My heartfelt appreciation goes to Dr. Marissa Tsugawa for her invaluable input and guidance regarding the IPA method used in this dissertation. I also would like to thank my friend and colleague Rifatul Himel for his timely help in coding the qualitative data.

In addition, I would like to extend my deepest gratitude and appreciation to my loving family members and friends, especially my mom, my siblings, and my relatives. They all helped nurture me back to health when I was sick, and their unwavering support, prayers, words of encouragement, listening ears, and understanding were much appreciated throughout this academic journey. Extra special thanks go out to my loving husband, Olanrewaju Oyewola. His unwavering support and encouragement throughout my doctoral studies have been immeasurable. His willingness to listen during moments of stress, his selflessness, patience, and understanding have all been invaluable. I would also like to thank my friend, Denise, for her genuine care, and the countless ways she has gone above and beyond to support me throughout this academic journey. In addition, I would like to extend my gratitude to my colleagues, and research participants. Their contributions through insightful discussions and sharing their valuable experiences greatly contributed to the successful completion of this dissertation.

Lastly, I would like to extend my heartfelt gratitude to my church family at Grace Baptist Church, Logan, and all those who have supported me in various ways, both seen and unseen. Their kind gestures, words of encouragement, and belief in my potential have significantly contributed to my academic success.

Yemisi Victoria Oyewola

CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Leadership is a key element for achieving success as an engineering professional in a highly competitive global economy. The National Academy of Engineering (NAE) emphasized the importance of leadership skills for engineers 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). With respect to the need for engineers to have leadership capability, NAE stated that;

> "… there will be an increasing number of opportunities for engineers to exercise their potential as leaders, not only in business but also in the nonprofit and government sectors. ′ (NAE, 2004, p. 55)
>
> " …. Engineers must understand the principles of leadership and be able to practice them in growing proportions as their careers advance (NAE, 2004, p. 55)."
>
> "… it is necessary to educate technically proficient engineers who are broadly educated, see themselves as global citizens, who can be leaders in business and public service, and who are ethically grounded (NAE, 2005, p. 51)."

Although many attributes were discussed in these two reports, they emphasized leadership as one of the important acumens that modern engineers must possess (NAE, 2005; NAE, 2004) and they also urged engineering institutions to reform engineering curricula to prepare present-day engineering students for future careers. (NAE, 2005; NAE, 2004)

Similarly, industry has called for engineers to have broad skills including leadership skills beyond their technical expertise. (Beder, 1998; Bowman & Farr, 2000; Duderstadt, 2008; Felder, 2006; Kaushal, 2011; Kumar & Hsiao 2007; Lamancusa et al., 2008; Mills & Treagust, 2003; Rottmann et al., 2016; Samavedham & Ragupathi, 2012; Sheppard et al., 2008). Authors have noted that the industry's dependency on the ability to hire graduates with deep technical and broad professional skills, especially, leadership, cannot be overemphasized (Crumpton-Young et al., 2010; Kumar & Hsiao, 2007; Passow, 2012; Russell & Yao, 1996; Schuhmann, 2010). Thus, incorporating leadership development into engineering curricula has been advocated to better prepare engineering graduates for the workforce. (Athreya &Kalkhoff, 2010; Crumpton-Young et al., 2010; Duderstadt, 2008; Farr & Brazil, 2009; Gordon & Silevitch, 2009; Schuhmann, 2010; Cox et al., 2009).

1.1 Problem

In response to the calls from the literature, industry, and other engineering regulating bodies like NAE, several engineering institutions rose to the challenge and incorporated leadership development training into their engineering programs using a variety of approaches, including integrated curricula, stand-alone courses and programs, and experiential learning (Athreya & Kalkhoff, 2010; Cox et al., 2009; Crumpton-Young et al., 2010; Kumar and Hsiao, 2007; Schuhmann, 2010). However, there is a lack of consensus on the definition of engineering leadership and the specific skills and competencies that should be taught (Hartmann & Jahren, 2015; Passow, 2007; Paul et. al., 2018; Rottmann et al., 2016; Reeve et al., 2015, Rottmann et al., 2015; Schuhmann, 2010). For instance, Paul et al., (2018) posited that there is still a lack of clarity on the definition of engineering leadership despite the widespread recognition that engineering graduates must possess leadership attributes. The authors also stated that there seems to be confusion in articulating the key differences between general leadership and engineering leadership.

Rottmann et al., (2016) noted that leadership concepts are frequently derived from management literature as a standard for measuring engineers. However, to be able to develop engineering students into leaders more coherently or systematically, the authors believed that engineering educators must first define what leadership means from an engineering perspective. Reeve et al., (2015) found that most empirical studies on engineering leadership evaluated engineers against leadership frameworks borrowed from the management and psychology literature. In addition, Hartmann & Jahren (2015) noted that while both industry and academia acknowledged the importance of leadership skills for engineering graduates, a consensus has yet to be reached regarding a unified definition of engineering leadership. Thus, there exists a debate regarding the nature of engineering leadership, with some contending that it is indistinguishable from leadership in general, and others asserting that engineering leadership necessitates the incorporation of engineering design principles.

In addition to this, researchers also pointed out a lack of consensus regarding engineering leadership skills that should be emphasized in engineering leadership training and discussions. Rottmann et al., (2016) opined that it is unclear how some authors who have provided a list of leadership skills relevant to engineers methodologically arrived at their lists or how they have factored engineering into their research. While Hartmann et al., (2017) noted that despite an increase in engineering leadership programs and scholarly work, there remains a need to understand what leadership competencies companies are looking for in graduate engineering students.

The lack of consensus on the definition of engineering leadership and the specific skills and competencies that engineering leadership training programs should emphasize has a major implication which is that the quality of leadership education in engineering programs is impacted by this knowledge gap. There are inherent inconsistencies in engineering leadership curricula because educators may prioritize different competencies based on their interpretation of engineering leadership (Rottmann et al., 2015). These inherent inconsistencies which also translate to having no standardized engineering leadership curricula can lead to varying levels of preparedness among engineering graduates entering the workforce. Also, developing leadership programs based on individual educators' subjective interpretation of engineering leadership may result in fragmented approaches to teaching engineering leadership, which may hinder the formation of a cohesive understanding of engineering leadership among the students.

Furthermore, the lack of consensus is an indication that there is no unified voice on the specific learning outcomes that engineering leadership curricula should target. Thus, the development of effective assessment methods for engineering leadership education is hampered. Without a clear understanding of the desired outcomes, evaluating the effectiveness of different educational approaches and making evidence-based improvements becomes challenging (Mumford et al., 2007). Finally, a lack of consensus on the definition of engineering leadership and engineering leadership skills that should be taught may contribute to a gap between industry expectations and engineering education. Employers may have specific expectations regarding the skills and competencies that engineering leaders must possess, but these may not align with engineering educators' expectations and priorities (Passow, 2007).

1.2 Purpose and Objectives

This study aims to contribute to achieving a consensus on engineering leadership by proposing a definition of engineering leadership from the perspectives of the Accreditation Board for Engineering and Technology (ABET) leaders and engineering leaders in the industry. The study further seeks to expound on engineering leadership skills that these leaders considered crucial in engineering leadership training based on their experience as engineering leaders. Authors have noted that it would be beneficial to engage engineers in leadership positions in defining engineering leadership and in specifying skills that should be emphasized (Hartmann et al., 2017, Hartmann & Jahren, 2015; Reeves et al., 2015; Rottmann et al., 2016). This is because leadership is a phenomenon that is embedded in experience (Block, 2014). Also, considering the theory of experiential learning as posited by Kolb (1984) which states that learning is a process where knowledge is created through the transformation of experience, that is, people with experience in a specific domain can contribute more to explaining or defining the phenomenon because they have encountered and reflected upon the subject matter. Although a few studies have attempted to define engineering leadership and the skills that should be emphasized from the standpoint of engineering professionals in the industry (Hartmann et al, 2017; Hartmann & Jahren, 2015; Rottmann et al., 2016; Rottmann et al., 2015, Reeve et al., 2015), none have considered defining engineering leadership from the perspectives of engineering leaders in engineering regulating bodies like ABET.

Since ABET establishes engineering guidelines that give direction to the curriculum for engineering institutions, knowing how ABET leaders would define engineering leadership and important engineering leadership skills, along with the perspectives of engineering professionals in the industry, can contribute to achieving a consensus and guide engineering institutions to improve their teaching of engineering leadership and engineering leadership skills. The following objectives were the focus of this study in an effort to answer the research questions:

1. Investigate how ABET leaders would define engineering leadership and engineering leadership skills based on their experience.

2. Investigate how engineering professionals in industry would define engineering leadership and engineering leadership skills based on their experience.
3. Verify if there are alignments or differences in the definitions of ABET leaders and engineering professionals in industry.

1.3 Research Questions

The study is guided by the following research questions:

1. How do ABET leaders define engineering leadership and engineering leadership skills based on their experience as engineering leaders?
2. How do engineering professionals in the industry define engineering leadership and engineering leadership skills based on their experience as engineering leaders?
3. How do what ABET leaders define as engineering leadership and engineering leadership skills align with the definitions of engineering professionals in the industry?

1.4 Positionality

The researcher's interest in this topic started from a mandatory online certification training she took as a research assistant during her graduate studies. The training focused on the social and behavioral responsible conduct of research and there were discussions on a range of topics such as ethics, conflict of interest, authorship, and so on. This got her fascinated to learn more about the soft skills necessary for engineering graduates in the workplace. Then, the semester following the period of this training, she took a course in Foundations of Engineering Education, and one of the topics brought to light was that the debate to foster soft skills in engineering graduates has been going on for more than seven decades. This further increased her curiosity to learn more about soft skills for engineering graduates, and during one of her discussions with a faculty member in the department centered on how to best define engineering leadership and what skills would be considered engineering leadership skills. Through the discussion, they couldn't reach a consensus on what the definition should be, based on what was in the literature. So, she decided to comb the literature and found that the definition of engineering leadership and the skills needed were not well established. Especially, in the areas of defining engineering leadership skills from the perspectives of leaders in engineering regulating bodies like ABET. Then she decided to investigate how engineering leaders in ABET and engineering professionals who are leaders in the respective organizations would define engineering leadership and the skills that should be emphasized. Also, this research took the insider/outsider perspective with respect to considering positionality in terms of the relationship with the group being studied. In this study, the researcher has an engineering background (insider) but does not have ABET membership or work in the industry (outsider).

1.5 Methodology

The research methodology used for this study is qualitative research methodology. Qualitative research is a research approach that seeks to understand and interpret human experiences and social phenomena by focusing on the meanings, perspectives, and understandings of the people involved (Johnson & Christensen, 2017). It typically involves the collection of data through methods such as interviews, focus groups, and observations, and uses interpretive procedures to understand participants' perspectives and experiences (Creswell, 2014; Johnson & Christensen, 2017). The qualitative research design used in this study is the Phenomenology research design. According to Creswell (2013), a phenomenological study describes the common meaning for several individuals of their lived experiences of a phenomenon, that is, the focus of the methodology is describing what all participants have in common as they experience a phenomenon.

The specific phenomenological approach employed in the study is the interpretive phenomenological analysis (IPA). IPA is a qualitative research approach that is used to examine and interpret the 'lived experiences' of research participants with respect to a phenomenon (Alase, 2017). That is, IPA is best suited to all forms of data collection which invite participants to articulate stories, thoughts, and feelings about their experiences of a target phenomenon (Smith, 2004). Block (2014) posited that leadership is a phenomenon that is embedded in experience. Hence, the phenomenon of interest in this study is engineering leadership. Therefore, this study investigates how engineering leaders in ABET and industry define engineering leadership and the skills that should be emphasized based on their experience as leaders in the engineering profession.

The method of data collection employed in this study is the interview. The interview is a widely recognized method of data collection in qualitative research methodology which helps the researcher to explore participants' perspectives, opinions, and experiences by engaging with them in a dialogue using various methods such as structured, semi-structured, or unstructured based on the objectives of the research (Denzin and Lincoln, 2011). It is a conversation with a purpose, where the researcher seeks to obtain descriptions of the lived experiences of the interviewee in order to interpret the meaning of the described phenomena (Kvale & Brinkmann, 2009). In this study, data was collected using semi-structured interviews in order to unearth how engineering leadership would be defined from the perspectives of the engineering leaders who participated in the study. The collected data was analyzed using the MAXQDA software.

1.6 Limitations of the Study

The limitations of this study are:

1. The research participants were selected using pre-established criteria (leadership position in ABET and industry, size of the industry, etc.), however, the companies from which the participants were selected are companies that are based in the state of Utah. This coupled with the fact that qualitative studies typically involve smaller sample sizes may limit the generalizability of the findings.
2. Research participants in this study were required to have at least two years of experience in a leadership position in addition to several years of experience as an engineering professional. Participants might have different perspectives on engineering leadership definition and leadership skills that should be emphasized due to the variability in the years of experience.
3. Although purposeful sampling was used in this study, the voluntary nature of participation in the study may limit the diversity of the participants in terms of gender, ethnicity, industrial sector, and experience.
4. All the industry leaders in this study are located in the state of Utah and all the ABET leaders in this study are in academia.

1.7 Assumptions of the Study

This study was conducted with the following assumptions:

1. Participants have held leadership positions in an engineering organization or establishment.

2. Participants in the study do so voluntarily and give their candid opinions of how engineering leadership and engineering leadership skills should be defined based on their experience as leaders.
3. The qualitative data collection was administered in the same way by the researcher for all interviews.

1.8 Definition of Terms

- *Phenomenon*: An observable occurrence in any aspect of experience, consciousness, psychology, or science.
- *Accreditation Board for Engineering and Technology (ABET)*: ABET is a nonprofit organization that accredits college and university programs in applied and natural science, computing, engineering, and engineering technology. ABET strives to ensure that Engineering programs meet the quality standards that produce graduates prepared to enter a global workforce (ABET, n.d.).
- *National Academy of Engineering (NAE)*: NAE is a private, independent, nonprofit institution with a mission to advance the welfare and prosperity of the nation by providing independent advice on matters involving engineering and technology, and by promoting a vibrant engineering profession and public appreciation of engineering (National Academy of Engineering, n.d.)
- *ABET Leaders:* ABET leaders are individuals with a strong background in engineering, technology, or education who play a significant role in the accreditation process, policymaking, or administration of the organization. They collaborate with educational institutions, professional societies, and industry partners to maintain and enhance the

accreditation process and uphold the highest standards for engineering and technology education. An ABET leader may have experience in academia, industry, or both

- *MAXQDA software*: a software program used for analyzing qualitative and mixed methods data, text, and multimedia in academic, scientific, and business institutions.

CHAPTER 2

LITERATURE REVIEW

The definition of leadership and what constitutes a leader have long been debated in the literature. Researchers have noted that there are as many definitions of leadership and there are authors who have tried to define the concept due to what has been referred to as its elusive nature (Bargau, 2015; Hunt & Fedynich, 2019; Shepard et al., 1997). In their bid to use definitions to explore the deep nature of leadership, Raffo & Clark (2018) looked at the definitions of leadership constructed by prominent leadership scholars and concluded that how we define leadership reflects what we value as individuals or a group of people, and the message we want to convey to others as we articulate our views on leadership.

2.1 Leadership Approaches

Despite the myriads of definitions of leadership, common themes have emerged, and these involve defining leadership in terms of traits, behavior, influence, interaction patterns, role relationships, and occupation of an administrative position (Yukl, 2013). This further led to classifying some of the prominent theories and empirical research in the leadership literature into five major approaches including *the trait approach, the behavior approach, the power-influence approach, the situational approach, and the integrative approach* (Jackson et al., 2015; Yukl, 2013). As such, it is believed that each constructed definition of leadership will fall under one of these classifications.

The major highlight of the trait approach is that it looked to define leadership based on the attributes of the leader such as personality traits, motives, values, and skills that enabled them to lead others successfully and it emerged from the great man theory which assumed that leaders were born with innate characteristics that destined them to lead. The major measures used in traits approach studies are leader self-ratings, tests, coded critical incidents, and ratings by other people which are correlated with measures of leadership effectiveness like unit performance or ratings of leader effectiveness by bosses (Yulk, 2013). This approach has been criticized for the assumption that some people are natural leaders and endowed with certain traits not possessed by other people. However, over the years, there has been a shift in the assumption of being a natural leader to identifying the traits, skills, and values that classified someone as a successful leader, that is, attributes developed and possessed by an individual that resulted in leadership effectiveness (Hunt & Fedynich, 2019; Yukl 2013, Zaccaro, 2007).

The behavior approach explores leadership in terms of the actions of the individual as opposed to their personality traits. It defines leadership as the ability of the leader to overcome constraints, recognize opportunities, handle demands, and resolve role conflicts while carrying out his or her duties. Hundreds of survey studies and field experiments were carried out to investigate how effective leaders differ in behavior from ineffective leaders in terms of their actions and decision-making. As such, it is closely related to the trait approach (Hess, 2018; Hunt & Fedynich, 2019; Jackson et al., 2015; Northouse, 2019; Yukl 2013)

The power-influence approach also defines leadership from the perspective of highlighting the different influence tactics explored by the leaders for getting their followers to do what they want and comparing it with their relative effectiveness. This includes the amount and type of power possessed by a leader and how the power is exercised. A key component that researchers looked at in this approach is participative leadership which deals with power-sharing and empowerment of followers. Most of the studies that followed this approach used the survey questionnaires’ correlation method to measure the correlation between subordinate perceptions of participative leadership with leadership effectiveness criteria such as subordinate satisfaction and performance in terms of achieving the organizational goals (Hess, 2018; Shepard et al., 1997; Winston & Patterson, 2006; Yulk, 2013).

The situational approach seeks to define leadership in terms of situational variables such as the type of organization, the characteristics of followers, the nature of the work performed by the leader's unit, and the nature of the external environment. This line of research attempts to discover the extent to which leadership processes are unique or the same across different types of organizations, levels of management, and cultures using a comparative study of two or more situations. Also, some of the studies focused on aspects of the situation that demanded leadership effectiveness with respect to the skills, traits, and behavior of the leader (Hunt & Fedynich, 2019; Yukl, 2013).

The integrative approach is that which uses two or more combinations of these approaches in defining leadership. The integrated approach examined leadership from the perspective of the skills and behaviors or actions that enhanced consistent leadership effectiveness across diverse groups and organizational situations and enabled the leader to influence the follower in achieving common organizational goals (Yukl, 2013). The approach has been investigated through measures such as developing and testing integrated leadership frameworks and models that combine existing knowledge about leadership effectiveness (Shaikh, 2018).

2.2. Definitions of Engineering Leadership

There has not been a unified definition of engineering leadership in the literature, just as it was for general leadership definition. However, most of the definitions of engineering leadership have leaned towards the integrated approach of leadership definition by using a combination of trait, influence, and situational approaches in defining engineering leadership. There is a school of thought that believes in including elements of engineering in the definition with the belief that the nature of the work performed by engineers is distinct compared to other disciplines and thus, the definition of engineering leadership needs to emphasize the technical skills. Another school of thought believes the definition should be constructed based on the general definition of leadership by emphasizing human and organizational dimensions as well as the ability to influence others. The majority of the definitions encountered in the literature seem to follow the school of thought that believed in including elements of engineering in the definition. An example of such is the definition of engineering leadership by Crumpton-Young et al. (2010), *"Engineering leadership is the ability to lead a group of engineers and technical personnel responsible for creating, designing, developing, and implementing and evaluating products, systems, or services (p.10)".* In addition, Paul et al. (2018) noted that one of the definitions of engineering leadership in the literature is: "*Engineering leadership is a 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 (p.4)".*

All of these definitions are great attempts to define engineering leadership, but they appear to be too focused on the technical side of engineering. It should be noted that the origin of calling for leadership in engineering stemmed from making a case that engineers needed to know how to work with and lead people from other professions that are different from theirs (Belilove, 1947; NAE, 2004, NAE, 2005). For instance, in his article on how to educate our engineers, Belilove (1947) advocated that engineers be broadly trained to ensure that the modern engineer is not just a servant of civilization, who is extremely successful in the area of production efficiency but unfamiliar with the subject matter of human relationships, rather a leader who is fully prepared to utilize his engineering expertise to solve intricate societal problems. Hess (2018) also noted that less than 20% of an engineer's time in high-level leadership or management positions will generally be spent on engineering-focused tasks in the workplace while much of their day-to-day time will generally involve interactions with other people and groups of people within and outside the organization. The author further stated that much of such an engineer's time will be spent giving directions, setting goals, discussing performance, and making decisions, which means more than his technical prowess, he would need to have exceptional people management skills. In addition, Russell & Yao (1996) noted that an engineer is hired for her or his technical skills, fired for poor people skills, and promoted for leadership and management skills.

Thus, while it has been argued that engineering leadership should be rooted in the technical competence identity of the engineer (Paul et al., 2018; Rottmann et al., 2015), research has shown that technical mastery is not a sufficient skill set for leadership success (Hess, 2018; Samavedham & Ragupathi, 2012). As such, authors have proposed that it is also very necessary that a broad view of engineering leadership that takes into consideration everyone in the organization, both engineering professionals and non-professionals, including the customers or clients that do business with the organization, are taken into consideration in the discussions of engineering leadership. Worthy of note is the fact that all of these notions and arguments contributed to the lack of consensus in the definition of engineering leadership.

In one such attempt to deviate from the norms of technically focused engineering leadership definition to a broader view of defining engineering leadership, Paul et al. (2018) proposed a definition of engineering leadership as follows:

> *"Engineering leadership is an approach that influences others to effectively collaborate and solve problems. Engineering leadership requires technical expertise, authenticity, personal effectiveness, and the ability to synthesize diverse expertise and skillsets.*

> *Through engineering leadership, individuals and groups implement transformative change and innovation to positively influence technologies, organizations, communities, society, and the world at large (p.10)".*

The authors noted that leadership is a process, and by defining it as a process, it ceases to be about the person `in charge but involves a transactional, continuous social process between the leader and the followers as they both work together in mutual understanding towards fulfilling the organizational goals. They reinstated that the leader's ability to influence the followers is regarded as a key factor in effective leadership while influence refers to the tactics or actions employed by the leader to motivate, inspire, empower, and engage the followers toward achieving a common goal. Most authors that emphasized the human and organizational management skills more than the technical skills in the definition of engineering leadership tend to lean towards the traits and influence approach of defining engineering leadership because according to them, the term "influence" rather than control or dictatorship is the hallmark of effective leadership, and that "influence" connotes fostering trust through a mutual partnership as the leader shows respect and fairness to those being led (Hess, 2018; Paul et al., 2018; Yulk, 2019).

It is very important to note that engineering leadership requires technical expertise, authenticity, personal effectiveness, and the ability to synthesize diverse expertise and skillsets (Paul et al., 2018). The need for technical expertise in effective leadership cannot be overemphasized. According to Hess (2018), engineers are often promoted to management or leadership positions because of the successes they have had in technical positions. As such, leaders must be experts in their field so that they can be in control of the operations that are necessary for achieving success and quickly identify moves that could be detrimental to achieving their goals. However, for leadership effectiveness, this technical expertise must be combined with appropriate soft skills.

Soft skills can be defined as a broad set of skills, work habits, and character traits that enhance someone's competence in working or relating well with other individuals and are believed to be critically important to success in today's contemporary careers and workplaces (Ariratanaet al., 2015; Binkley et al., 2012; Voogt & Robin, 2012). Soft skills are also referred to as people skills, social skills, or human skills and they include communication skills, creativity skills, teamwork, problem-solving skills, conflict resolution and negotiation skills, ethics, critical thinking skills, information processing skills, intercultural relations, integrity and emotional intelligence amongst others. A lot of these soft skills have been identified in the literature by authors as engineering leadership skills. (Athreya & Kalkhof, 2010; Cox et al., 2012; Farr & Brazil, 2009; Hess, 2018;)

2.3 Engineering Leadership Skills

Engineering leadership skills have been approached in two distinct ways in the literature, one of which was including engineering leadership skills among professional skills that should be mastered by engineering graduates while the other was designating engineering leadership skills as a stand-alone professional skill with its own separate set of broad skills (Gruber et al, 2022; Hartmann, 2016). The first approach is usually employed by studies that focus on the call for engineering graduates to be proficient in soft skills (ABET, 2023; Hartmann & Jahren, 2015; Itani & Srour, 2016) while the second approach is often employed by engineering leadership educators, engineering leadership researchers, and other engineering stakeholders who choose to put all the broad or non-technical skills that are necessary for engineering graduates to survive in the workplace under the umbrella of engineering leadership skills (Athreya & Kalkhof, 2010;

Crumpton-Young et al., 2010; Cox et al., 2010; Farr & Brazil, 2009; Kumar & Hsiao, 2007; Passow, 2012). Although the list is not exhaustive, some of the identified engineering leadership skills in past literature are highlighted in Table 2.1 below:

Table 2.1

Engineering Leadership skills identified by past studies

Engineering Leadership skills	**Authors**
Excellent written and oral communication, Teamwork, Interpersonal and conflict resolution skills, Confidence, and Engagement in extracurricular activities.	Hartmann et al. (2017, p. 2)
Effective Communication, Courage, Fairness, Accountability, Integrity, Visionary, People Skills, Willingness to be wrong, Outcomes driven, Delegating, Technical competence, Good Reasoning, intelligence, Seeing the big picture, Thinking outside the box, Good listening skills.	Cox et al. (2012, p.66)
Effective communication, Teamwork, Professional and ethical responsibility, Global and societal understanding, Life-long learning, Visionary, Innovation, Embracing diversity and inclusion.	Athreya & Kalkhoff (2010, p.71).
Communication skills, Teamwork, Lifelong learning, Strategic Thinking, Customer Service, Business Management.	Crumpton-Young et al. (2010 p.12)
Effective written and oral communication, Teamwork, Creativity and Innovation, Ethical awareness, Economics, and marketing skills, Enhanced technological savviness, Project planning, Enhanced global awareness, and Cultural diversity.	Schuhmann, (2010, p.63-4)
Communication skills, Teamwork, Decision-making skills, Adaptability (master change), Ethics and Courage, Big Thinking, Risk management skills, Using Power Wisely, Mission that Matters.	Farr & Brazil (2009, p.4)
Effective written and oral communication, Good listening skills, Empathy, Teamwork, Respect for others, Risk Taking, Technical expertise, Visionary, and Strategic planning, Integrity, and Good Customer service.	Kumar & Hsiao (2007, p.19).

2.3.1 NAE on Engineering Leadership Skills

The National Academy of Engineering (NAE) in their 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) emphasize in both reports the need to train engineers of today in varieties of broad skills that will enable them to become effective leaders in the society (NAE, 2005; NAE, 2004). They also reinstated that the modern workplace demands the social interaction of engineers with customers, defying the prevailing image of the engineer as the "techie nerd" and necessitating that engineers have well-developed people skills in addition to their technical expertise (NAE, 2005; NAE, 2004). NAE envisioned engineers without boundaries, who would embrace the potentialities offered by creativity, and invention while also accommodating new fields of endeavor, including those that require openness to interdisciplinary efforts with non-engineering disciplines such as social science, and business. It should be noted that the focus of these two reports is on engineering leadership skills in terms of why and how to ensure that today's engineers are fully trained to possess these skills to help them become successful engineering leaders and professionals. As such, NAE emphasized the flowing skills in their reports;

1. Communication skills
2. Creativity and innovation:
3. Ethics and Social responsibility
4. Collaboration and teamwork
5. Practical ingenuity
6. Global and societal skills
7. Lifelong learning
8. Strong analytical skills
9. Adaptability
10. Business and management

2.3.2 ABET on Engineering Leadership Skills

The Accreditation Board for Engineering and Technology (ABET) board of directors approved the Engineering Criteria 2000 (EC2000) as the new criteria for evaluating engineering programs and the criteria became fully implemented in 2001 (Engineering Criteria 2000,1997; Prados et al., 2005). A critical component of this criteria is the student outcomes which according to ABET, are what students are expected to know and be able to do by the time of graduation (ABET, 2023). Listed under the student outcomes are 11 criteria (a) through (k), 6 out of which ABET called for an increased emphasis on a broader range of knowledge, skills, and attributes referred to as professional skills in addition to technical expertise from engineering graduates (Engineering Criteria 2000, 1997). The student outcomes criteria which were effective from the inception of the EC2000 criteria until it was reviewed in the year 2018 are:

(a) an ability to apply knowledge of mathematics, science, and engineering

(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs

(d) an ability to function on multi-disciplinary teams

(e) an ability to identify, formulate, and solve engineering problems

(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively

(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context

(i) a recognition of the need for, and an ability to engage in lifelong learning

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The ABET criteria were reviewed in 2018 and mapped to include what is now known as student outcomes (1) through (7) as presented in Table 2.2 below:

Table 2.2

ABET Mapping Criteria

Former Engineering Accreditation Commission Criteria (1997-2018)	**Current Engineering Accreditation Commission Criteria (2018-2023)**
Criterion 3. Student outcomes The program must have documented student outcomes that prepare graduates to attain the program's educational objectives. Student outcomes are outcomes (a) through (k), plus any additional outcomes that may be articulated by the program.	**Criterion 3. Student outcomes** The program must have documented student outcomes that support the program's educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.
(a) an ability to apply knowledge of mathematics, science, and engineering (e) an ability to identify, formulate, and solve engineering problems	1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturing, and sustainability.	2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
(d) an ability to function on multi-disciplinary teams	5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

Table 2.2 (continued)

Former Engineering Accreditation Commission Criteria (1997-2018)	**Current Engineering Accreditation Commission Criteria (2018-2023)**
(f) an understanding of professional and ethical responsibility (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context (j) a knowledge of contemporary issues	4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
(g) an ability to communicate effectively	3. an ability to communicate effectively with a range of audiences.
(i) a recognition of the need for, and an ability to engage in lifelong learning	7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	Implied in 1, 2, and 6.

Source: ABET Mapping Criteria https://www.abet.org/wp-content/uploads/2018/03/C3_C5_mapping_SEC_1-13-2018.pdf

Therefore, the ABET professional skills, otherwise known as soft skills which match some of the engineering leadership skills earlier highlighted can be summarized as follows:

1. Communication skill (from 3)
2. Collaboration / Teamwork (from 5)
3. Ethics and Professional responsibilities (from 4)
4. Problem-solving skills (from 2)
5. Decision-making (from 4)
6. Social and cultural awareness (from 4)
7. Lifelong learning skill (from7)

In addition, the current ABET's student outcomes (ABET, 2023) in which it was stated that engineering graduates at the time of graduation should have, "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives" *(Outcome no. 5),* is proof that ABET recognized the importance of leadership skills for today's engineering graduates. It can be inferred from this stated outcome that ABET expected every graduate of engineering to have the necessary leadership acumen and skills at the time of graduation.

2. 3. 3. Summary of the Engineering Leadership skills in the literature

This section summarizes the most common engineering leadership skills as highlighted by the authors in the literature. It can be deduced from the skills identified by authors as engineering leadership skills in this study (see Table 2.1.) that there is truly a lack of consensus on what skills engineering leadership educators should emphasize in their teaching of the engineering leadership program. However, Figure 2.1 shows a summary of the common engineering leadership skills that are discussed by the participants in this study;

Figure 2.1. A summary of the common engineering leadership skills identified by participants.

2.4 Implications of Employing the Trait Approach to Engineering Leadership

Leadership is often conceptualized using behavioral and trait approaches, and engineering leadership also follows this pattern of conceptualization. The behavior approach is that which primarily explores leadership in terms of the actions of the individual rather than their personality traits (Hess, 2018; Jackson et al., 2015; Yukl 2013). It defines leadership as the ability of the leader to overcome constraints, recognize opportunities, handle demands, and resolve role conflicts while carrying out his or her duties (Yukl 2013). A good example of this is ABET's stance on leadership skills acquisition as expressed in the current student outcome where it was stated that engineering graduates should have, "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives." *(Outcome no. 5)*

It can be inferred from this statement that ABET expected engineering students to have acquired leadership acumen by the time of graduation. The statement particularly focuses on the things they should be able to do as leaders by virtue of the experience garnered during their training rather than the leadership skills they should have acquired. However, there is evidence in the literature that explicit instruction and modeling enhance social skills development (Durlak et. al, 2011; MacCann et al., 2011; Spence, 2003). This could be the motive why most engineering institutions teaching engineering leadership employed the trait approach of explicitly teaching and modeling leadership skills in their programs. Some of these institutions used the ABET professional skills as a framework for the development of the learning instructions for their engineering leadership programs (Athreya & Kalkhof, 2010; Bowman & Farr, 2000; Kumar & Hsiao, 2007; Schuhmann, 2010) while others used the leadership skills in the management literature as a basis for the skills included in their learning instructions (Rottmann et. al., 2016).

The implication of employing the trait approach in the teaching of engineering leadership is that it helps in fulfilling the calls for engineering graduates to acquire soft skills in addition to their technical expertise to be relevant in today's workplace. Authors have bemoaned the fact that the engineering curriculum is too technically oriented and focused with little or no incorporation of any managerial, leadership, or life skills into their curriculum (Duderstadt, 2010; Sheppard et al., 2008; Felder, 2006). In addition, several authors have indicated that there is a significant gap between what undergraduate engineering students are taught and assessed and what professional engineers and industry practitioners expect them to be capable of (Radermacher et al., 2014; Samavedham & Ragupathi, 2012; Scardamalia et al., 2012).

It should be noted that the competency gap reported in the literature between what engineering graduates can do and what the industry employers expected them to be capable of has often been on the professional skills not their technical skills. In fact, there is evidence from the literature that employers value the technical capabilities of engineering students but lament their lack of communication skills, ability to work in teams, and other social skills (Nair et al., 2009; Schipper & van der Stappen, 2018; Williams, 2001). Although engineering student's technical expertise is not being questioned, however, several authors have asserted that, in today's workplace, technical skills without soft skills are of declining importance (Duderstadt, 2008; Felder, 2006; Samavedham & Ragupathi, 2012;).

The reason cannot be farfetched. According to Kaipa et al. (2005), when the focus is too much on hard or technical skills, the dynamics in the workplace become difficult to manage and many companies never see their first anniversary because they lack soft skills. This is because, without soft skills, poor decisions are made, negotiations go poorly, communication lacks passion, and leadership withers away quickly. The authors also noted that most project failures can be attributed to breakdowns in communication between executives and the talent, teams, and project managers. They concluded by asserting that companies sink, or swim based on soft skills regardless of whether their technologies keep them afloat temporarily. The authors also affirmed that great technology and mediocre management lead to sure failure. All these sentiments point to one fact, today's engineering graduates need to be specifically trained in soft skills and the trait approach of teaching engineering leadership can sufficiently meet this need.

Also, considering the 21st-century skills framework which was introduced in the recent times, the framework was developed by educators, education specialists, and business leaders to identify and describe the skills, knowledge, and expertise that students need to succeed in the contemporary workplace, life, and citizenship (Griffin & Care, 2014; Voogt & Robin, 2012; Beers, 2011; Partnership for 21st Century Skills, 2007). The 21st-century skills include communication, collaboration, critical thinking, creativity, digital and information literacy, leadership, flexibility, adaptability, emotional intelligence, and social skills amongst others as shown in Figure 2.2 below:

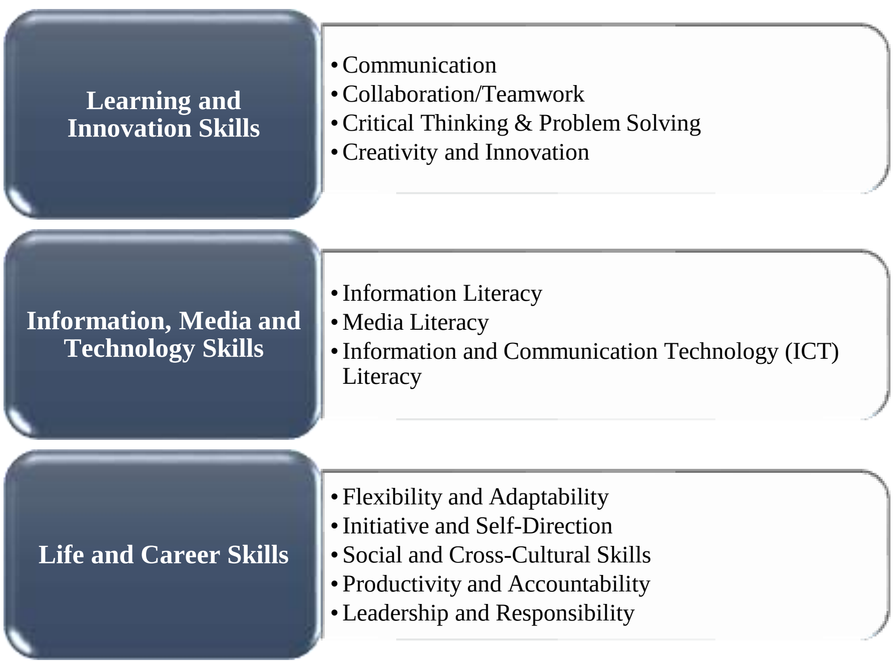

Figure 2.2. 21st-century Framework and Skills

The 21st-century skills have been introduced into the K-12 curriculum but they are beginning to find their way into the higher education curriculum because discussions have started on bringing the skills to higher education classrooms (Bakay, 2022; CERI, 2022; Toczauer, 2023;) although there is relatively no scholarly work on this yet. It is believed that integrating 21st-century skills into college education will better prepare students for the opportunities and problems they will encounter in the contemporary workplace and personal lives. It should be noted that even though the commonly identified skills by authors as highlighted in this study (see Figure 1) do not totally match with the skills highlighted in the 21st-century framework (refer to Figure 2), however, to a large extent it can be seen that the majority of the skills in the learning and innovation as well as career and life category are inclusive of the skills identified engineering leadership skills by the authors. It would be interesting to know how many of the skills that will be identified by engineering leaders in this study will match the skills highlighted in the 21^{st}-century framework.

CHAPTER 3

METHODOLOGY

This chapter presents the research methodology used in this study consisting of an introduction to the research, research purpose, research questions, the research method, research design, positionality, participants' selection, participants' recruitment, ethical consideration, and IRB process, data collection, the role of researcher and data analysis.

3.1. Introduction

Leadership has emerged as a critical component for success for engineering graduates because of the need to adapt to the ever-changing economic landscape in the contemporary global economy, characterized by rapid technological advancements, increasing interconnectivity, and heightened competition (Bowman & Farr, 2000; Cox et. al, 2012; Hartmann & Jahren, 2015; Hess, 2018; Paul & Falls, 2018; Rottmann et. al, 2015; Yousefdehi et. al, 2017). Thus, engineering institutions are called upon to include leadership training and development in the engineering curriculum to ensure that engineering graduates have the leadership acumen necessary to survive in the modern workplace (Crumpton-Young et al., 2010; Duderstadt, 2008; Kumar & Hsiao, 2007; Russell & Yao, 1996; Samavedham & Ragupathi, 2012). Engineering institutions have responded to this call by using a wide range of instructional strategies to train engineering students on leadership including direct instruction of leadership skills and traits, problem-based learning, case studies, experiential education, formative peer assessment, and team effectiveness inventories (Rottmann et al., 2016). However, authors have noted that although there has been advocacy, implementation, and evaluation of engineering leadership in academic institutions, as well as a growing body of literature on the subject, a notable conceptual gap persists in terms of defining leadership from an engineering standpoint (Rothmann et al., 2015). Also, Hartmann et al. (2017) noted that despite an increase in engineering leadership programs and scholarly work, there remains a need to understand what leadership competencies companies are looking for in entry-level engineers. This lack of consensus about the definition of engineering leadership and leadership skills that should be emphasized could lead to confusion and inconsistency in the teaching and assessment of engineering leadership.

3.2. Purpose of the Study

The purpose of this study was to investigate how engineering leaders in the Accreditation Board for Engineering and Technology (ABET) and engineering leaders in industry would define engineering leadership based on their experience as leaders, as well as investigate the engineering leadership skills that these leaders considered crucial for emphasis in the teaching of engineering leadership. This is aimed at contributing to bridging the conceptual gap in the definition of engineering leadership and engineering leadership skills as identified in the literature (Hartmann et al., 2017; Rothmann et al., 2015).

3.3. Research Questions

The research questions that guided this study are:

1. How do ABET leaders define engineering leadership and engineering leadership skills based on their experience as engineering leaders?

2. How do engineering professionals in the industry define engineering leadership and engineering leadership skills based on their experience as engineering leaders?

3. How do what ABET leaders define as engineering leadership and engineering leadership skills align with the definitions of engineering professionals in the industry?

3.4 Research Method

The research method used in this study was the qualitative research method. The qualitative research method is that which relies on the collection of non-numeric data such as interviews, observations, focus group discussions, or pictorial, textual, or conversational analysis which researchers use to explore and understand individual experiences, perceptions, social interaction, and human behaviors (Borrego et al., 2009; Creswell, 2014; Johnson & Christensen, 2017). The qualitative approach is suitable when there has not been a lot of research done on a topic, when the phenomenon needs to be investigated and comprehended in greater detail, or when a researcher seeks to determine the meaning of a phenomenon from the perspectives of participants (Creswell, 2014). According to Block (2014), leadership is a phenomenon that is embedded in experience. Thus, the phenomenon of interest investigated in this research is engineering leadership and this study sought to explore this phenomenon to understand how it will be defined from the perspective of ABET and engineering leaders in industry based on their experience as leaders.

3.5. Phenomenological Research Methodology

The research methodology used in this study was phenomenology. Phenomenology is a qualitative research method that describes the common meaning for several individuals of their lived experiences of a phenomenon (Creswell, 2013). The phenomenological research methodology has three main approaches; IPA, hermeneutical phenomenology, and transcendental phenomenology (Alase, 2017; Groenewald, 2004; Neubauer et. al, 2019). Table 3.1. shows a description of these approaches. The particular phenomenological approach used in this study was the interpretive phenomenological analysis (IPA). IPA is a qualitative research approach that is used to examine and interpret the 'lived experiences' of a phenomenon (Alase, 2017; Kirn et.

al, 2019; Neubauer et al., 2019). That is, IPA is best suited to all forms of data collection which invite participants to articulate stories, thoughts, and feelings about their experiences of a target phenomenon (Smith, 2004).

Table 3.1

Attributes of the Phenomenological Approaches

	IPA	**Hermeneutical Phenomenology**	**Transcendental Phenomenology**
Focus	Individual experiences	Meanings within a broader context	Essence of experiences
Research Goals	Understand subjective experiences and meaning-making.	Interpret meanings within cultural, historical, and social contexts	Describe the essential structure of experiences
Role of the Researcher	Interpretation influenced by the researcher's background	Interpretation within the context of language, culture, history	Bracketing or suspending the researcher's biases
Idiography	It is highly idiographic. It considers the uniqueness of individual experiences.	It is somewhat idiographic. It moves towards more general themes across experiences.	It is less idiographic. It prioritizes a universal essence over variations in individual experiences.
Double Hermeneutics	It is integral to the approach.	It is integral to the approach but with a different focus.	It is not a primary concern.
Treatment of biases	Reflexivity; being aware of and considering biases during the research process	Recognizing the influence of context on biases; part of the hermeneutic circle.	Bracketing; suspending biases to achieve a pure description of experiences
Analytical process	Close examination of participant accounts; iterative analysis	Hermeneutic circle; interpret parts and whole within broader context	Epoche; focuses on essential components and shared structure

The Philosophical Foundations of IPA

The philosophical foundations of IPA are phenomenology, idiography, and hermeneutics (Alase, 2017; Kirn et. al, 2019; Neubauer et al., 2019; Smith et al., 2009) and they are described as:

- ***Phenomenology:*** IPA focuses on exploring and understanding the lived experiences of individuals. It seeks to uncover the underlying meaning and essence of experiences and emphasizes the description, interpretation, and analysis of individual experiences.
- ***Hermeneutics:*** IPA emphasizes the researcher's interpretation of participants' experiences using the concepts of double hermeneutics. Double hermeneutics, according to Smith & Osborn (2008), is a process by which the researcher seeks to interpret the participants' interpretations of their experiences.
- ***Idiography:*** Idiography is a process by which the researcher engages in an in-depth exploration or understanding of individual experiences before making any generalizations (Smith et al., 2009).

The reason for choosing IPA for this study is that, out of the three approaches, IPA is more suited to answer the research questions which are focused on the inquiry into how engineering leaders would define the engineering leadership phenomenon based on their experience. Borrego et al., (2009) have suggested that the choice of methodology should be determined by the nature of the research question. In addition, Creswell (2013) noted qualitative researchers carry out the task of reducing individual experiences concerning a phenomenon to a description of the universal essence by identifying an "object" of human experience (i.e., the phenomenon), collecting data from people who have experienced it, and developing a composite description of "what" was experienced and "how" it was experienced for all of the participants.

The transcendental approach is not suited for this research because its focus is on the essence of experiences and seeking to understand the fundamental structures and conditions that enable experiences to occur with emphasis on identifying the necessary conditions for the phenomenon to exist and providing a more generalized perspective of the phenomenon. The hermeneutic approach is not suited for this research because its main focus is exploring the meaning of a phenomenon within a broader context, that is, it seeks to uncover the historical, cultural, and social dimensions that shape people's experience of a phenomenon. Also, the IPA goes beyond the description of the essence of the experience by incorporating the interpretation element in which the researcher actively participates in understanding and making sense of the participant's experiences (Alase, 2017). The essence of an experience can be described as the fundamental characteristics and unchanging structure or the core meaning of the experience. The essence of an experience paints the picture of what makes that experience what it is regardless of the specific details or circumstances surrounding the experience. For instance, consider a study exploring "friendship" as a phenomenon, the essence of friendship might include qualities such as shared interest, trust, mutual respect, a desire to spend time together, and acts of giving or generosity. Also, consider a study exploring the experience of drinking coffee as a phenomenon, the essence of this experience might be features such as the aroma of the coffee, the way it provides alertness and energy boost, the taste and texture of the drink, the warmth of the coffee and so on. The essence, that is, the qualities or features would remain constant regardless of the circumstances surrounding the individual's experience. It should be noted that, although both hermeneutical and transcendental phenomenology also focus on describing the essence of the phenomenon as foretold by the research participants, however, the emphasis of their focus is different from that of IPA (Alase, 2017; Neubauer et al., 2019).

It should also be noted that hermeneutical, and transcendental phenomenology underscore the importance of achieving a shared understanding between the researcher and the participant even though they recognize the impact of the researcher's perspective on the interpretation of data (Alase, 2017). Also, the idiographic focus is less pronounced in both hermeneutical phenomenology and transcendental phenomenology (Smith et al., 2009).

3.6. Positionality

Positionality, according to Hampton et al. (2021), is described as a statement that captures how the researcher is positioned, personally, socially, and politically to the study's context. Creswell (2013) asserted that the position adopted by a researcher will influence every stage of the research process. According to Herr (2004), three broad positionality perspectives exist between the researcher and the participants, and they include insider, outsider, and insider/outsider perspectives. He further noted that it is essential that researchers have a good mastery of their relative positioning as insiders or outsiders when conducting research, as this will govern how they formulate their methodology, axiology, and epistemology.

The insider's positionality can be described as a situation in which the researcher is part of the group being studied. The outsider positionality can be conceptualized as a situation where the researcher is not part of the group being studied and has minimal or no interaction with participants to avoid bias. The insider/outsider perspective has to do with situations in which the researcher has a substantial degree of relationship or partial interaction with the group being studied. This study employed the insider/outsider perspective. As an outsider, the researcher sought to investigate how the participants would define engineering leadership and the skills that should be emphasized from their perspectives as engineering leaders using the interview data collection procedure. Thus, there was a collaboration to co-construct knowledge between the researcher and the participants as the researcher tried to understand and interpret the data from the perspective of the participants. As an insider, the researcher has an engineering background. She is currently undertaking her Ph.D. studies in Engineering Education at Utah State University, and she has a bachelor's degree in computer engineering from Obafemi Awolowo University, Nigeria.

Personally, the researcher's interest in this study emerged from an Institutional Review Board (IRB) mandated certification training on the social and behavioral responsible conduct of research that she took as a research assistant during her graduate studies. The range of topics learned during the training such as ethics, conflict of interest, authorship, and so on, got her fascinated to learn more about the soft skills necessary for engineering graduates in the workplace. This desire further increased when she took a course in Foundations of Engineering Education in the semester following the period of this training where one of the topics discussed in the class revealed that the debate to foster soft skills in engineering graduates has been ongoing for more than seven decades. This further intensified her desire to learn more about soft skills for engineering graduates. Hence, during one of her discussions with a faculty in the department which centered on how to best define engineering leadership and what skills would be considered engineering leadership skills, she took up the challenge to comb the literature more and found out that the definition of engineering leadership and the skills that should be specified varies greatly. She thus decided to investigate how engineering leaders in engineering regulating bodies like ABET and engineering professionals who are leaders in the industry would define engineering leadership and the skills that should be emphasized based on their experience.

3.7. Research Design

Research design, according to Creswell (2014), refers to the types of inquiry within qualitative, quantitative, and mixed methods approaches that provide specific direction for procedures in research. The research design used in an IPA study according to Smith et al., (2009) is described in three major processes, including participants' selection and recruitment, data collection, and data analysis (see Figure 3.1). This was employed in this study.

Figure 3.1. The IPA Research Design

3.7.1 Participants' Selection and Recruitment

This section describes the processes used to select the participants while keeping the IPA philosophical underpinning of phenomenology in mind. That is, it is the process of selecting those who have lived experience of the phenomenon, which is engineering leadership. Also, this explored the process it took to recruit engineering leaders to participate in this study.

3.7.1.1. Engineering Leaders' Selection

This study collected data from engineering professional leaders in ABET and industry professionals. In a phenomenological study, the foremost criteria for the selection of the participants are that they must have lived the experience of the phenomenon being studied and that the sample be fairly homogenous (Alase, 2017; Creswell, 2013). The criteria for selecting the engineering leader recruited to participate in this study is that they have been practicing in the field of engineering for at least 5 years in addition to occupying a leadership position in ABET or industry for a minimum of two years. Hess (2018) has stated that:

> *"Engineers and scientists are generally promoted into or aspire toward formal leadership or management opportunities because of the success(es) they have had in technical positions (p.17)".*

Also, Rottmann et al., (2015) posited that most engineers' normal career paths involve five to ten years of technical work before moving into project or process management which kick starts their leadership responsibilities where they now have to manage others to accomplish goals or meet up with deadlines. It can be inferred from these assertions that anyone who holds a leadership position in engineering must have had a minimum of 5 years prior technical experience in the engineering field before becoming a leader. This study therefore suggests that having a minimum of five years of experience in the engineering field in addition to a minimum of two years of leadership experience in the organization should be sufficient for the research participants to be able to conceptualize the definition of engineering leadership and the leadership skills that should be emphasized as depicted in Figure 3.1.

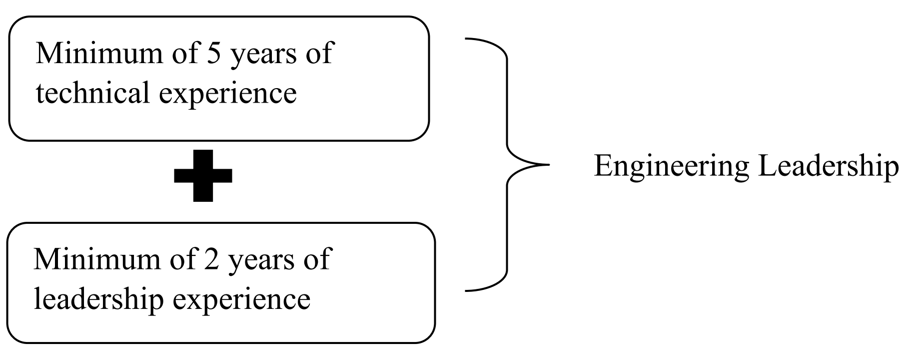

Figure 3.2. Criteria for the Choice of Engineering Leaders in the Study

Other selection criteria considered for this study are the participants' availability and their willingness to provide accurate information regarding the definition of engineering leadership and the skills that should be emphasized in engineering leadership training.

Concerning the sample size, Smith et al., (2009) noted that it is essential that IPA studies are conducted on relatively small sample sizes in order to find a reasonably homogeneous sample, so that, within the sample, the convergence and divergence can be extensively examined in detail. Smith & Osborn (2008) also stated that IPA studies have been published with sample sizes of one, four, nine, fifteen, and more participants, as such, there is no right answer to the question of the sample size, noting that it partly depends on several factors such as the degree of commitment to the case study, level of analysis and reporting, the richness of the individual cases, and the constraints one is operating under. However, the authors did suggest that for students doing IPA for the first time, three is an extremely useful number. In this study, six participants were recruited from ABET, and seven participants were recruited from the industry, making a total of thirteen participants to allow for a deep exploration of the engineering leadership phenomenon, especially engineering leadership skills. A higher frequency of emergence of certain themes in an open-ended, unstructured, or semi-structured interview could be an indication of their relative importance or relevance to the participants (Smith et. al, 2009). It would be more credible to have certain skills identified by ten participants than by four participants.

The purposive sampling technique also referred to as purposeful sampling was used in this study. Purposive sampling requires the identification and selection of individuals or groups of individuals who are proficient and well-informed about a phenomenon of interest, who are available, and are also willing to participate in the research (Palinkas et al., 2015). Hence, purposive sampling is often used whenever there is a need to recruit participants who meet certain criteria that fit the objective and purpose of the study. The targeted participant in this study has to meet the criteria of being an engineering professional who in addition to years of experience as a professional in the engineering field must have held a leadership position in an engineering organization for a minimum of one year. Therefore, this sampling was employed because participants in this study must meet the stated criteria to be considered appropriate for participation.

3.7.1.2. Engineering Leaders' Recruitment

This describes how engineering leaders in ABET and the industry were recruited for participation in this study.

ABET Leaders

The ABET leaders were recruited in this study through indirect recruitment, as well as through the ABET website. For indirect recruitment, the researcher was introduced by a member of the research committee to an ABET evaluator who knows a lot about ABET leadership. This person assisted the researcher in indirect recruitment by giving the researcher the email contacts of potential participants. The researcher contacted the professionals by letting them know she got their email contact from one of their professional colleagues and invited them to participate in the study. A copy of the electronic letter used to invite the ABET leaders can be found in Appendix A. A total number of five participants were recruited through this method, but a closer look at the criteria shows that three out of the five participants did not sufficiently meet the criteria. This is because although they have held the position of program evaluator for a couple of years, investigation shows that program evaluation is the entry-level position in ABET and real leadership in ABET starts from a team leadership position. Also, because the number of participants obtained from the indirect recruitment was not sufficient, the remaining participants were recruited by looking at the ABET website for people in leadership roles and checking out their profiles on LinkedIn and other sources to ensure they have the required experience. The potential participants were sent emails to ask for their participation in the study. Figure 3.3. shows the participant ABET leader's recruitment summary, while Table 3.2 shows their data summary.

Figure. 3.3. ABET Leaders Recruitment Summary

Table 3.2

ABET Leaders' Data Summary

Engineering Leader Pseudonym	**Economic Sector**	**Job Title**	**No. of years of experience in the Engineering Field**	**No. of years of experience in a Leadership Position**
Lilly	Academia	EAC Executive Commissioner	38	7
Allison	Industry / Academia	At-Large Director	45	9
Kate	Academia	EAC Executive Commissioner	14	2
Sawyer	Academia	President	35	8
Fredrick	Academia	EAC Executive Commissioner and Team Chair	30	5
Maxwell	Academia	EAC Executive Commissioner and Team Chair	40	8

Industry Leaders

This study sought to recruit two engineering professionals from a small, medium-sized, and large engineering company, for a total of six, based on company size classification criteria (see Table 3.3) to explore if there might be variability in their perspectives as they define engineering leadership and the skills that should be emphasized. Seven industry leaders were, however, recruited. Table 3.4 shows the data summary of the participant's companies.

Table 3.3

Engineering Company Classification

Classification	**Employee Size**
Small	Greater than 10 but not more than 99 employees
Medium-sized	Between 100 and 499 employees
Large	Greater than 500 employees

Adapted from "*Measuring the small business economy*", by Highfill et al., 2020, p.15. Copyright 2020 by Bureau of Economic Analysis, US Department of Commerce.

Table 3.4

Company Data Summary of Industry Leaders

Participant's Pseudonym	**Company**	**Industry**	**Employee Size**	**Classification**
Aaron	Company 1	Transportation	Locally ~ 5000	Large
Alex	Company 2	High-Tech	Locally ~ 6000 Globally ~161,000	Large
Norah	Company 3	Aerospace	Locally ~ 4500 Globally ~ 100,000	Large
George	Company 4	Manufacturing	Locally ~ 200	Medium
Justin	Company 5	Civil Engineering	Locally ~ 200	Medium
Henry	Company 6	Industrial Automation	Locally ~ 50	Small
Raymond	Company 7	Civil Engineering	Locally ~ 25	Small

The engineering professionals who participated in this study were recruited through the Director of Industry Relations at Utah State University and direct contact. The criteria for the participants were discussed with the Director of Industry Relations, and the email addresses of potential participants who were on the College of Engineering advisory board who met the criteria were sent to the researcher to be used for research invitations. Two participants were recruited using this method. Another four participants were recruited through direct contact by visiting the websites of engineering companies in the state of Utah to get contact information of the people in leadership positions who met the criteria for participation. This was then used to send them the research invitation. Four participants were recruited using this method. The remainder of the participants were recruited during the STEM week at Utah State University. The researcher visited a few of the booths set up by the engineering companies and explained the purpose of the research and the criteria for participation. This yielded several contacts, and one participant was recruited using this method. The electronic letter used to invite the industry leaders can be found in Appendix B. Figure 3.5 shows the breakdown of the industry leaders' recruitment. Table 3.5 shows the data summary of industry leaders.

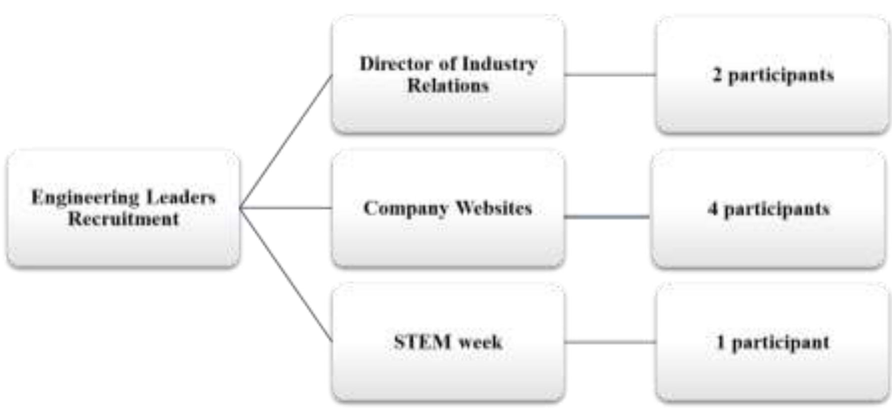

Figure. 3.5. Recruitment of the Industry Leaders

Table 3.5

Industry Leaders' Data Summary

Engineering Leader Pseudonym	**Economic Sector**	**Job Title**	**No. of years of experience in the Engineering Field**	**No. of years of experience in a Leadership Position**
Aaron	Transportation	Director of Transportation	22	16
Alex	High-Tech	Lead Electronics Engineer	8	3
Norah	Aerospace	Design Engineering Director	14	8
George	Manufacturing	Engineering Design Leader	32	25
Justin	Civil Engineering	Director of Construction and Materials	27	16
Henry	Industrial Automation	Founder	17	14
Raymond	Civil Engineering	CEO	46	34

With regards to the ethical consideration and Institutional Review Board (IRB) Process, using the IRB online Kuali process, a proposal outlining the details of the procedures to be carried out in this study was submitted to the (IRB) for approval. In the informed consent form, the research goal and objectives were communicated to the participants. They were assured of the anonymity and confidentiality of their responses, the benefits versus risks of the research, the type of required data to be collected, that the research has minimal risk and is not different from those usually encountered in daily life events, and their right to withdraw at any time. The informed consent form is located in Appendix C. Participants were offered an incentive of an Amazon gift card valued at $50.

3.7.2. Data Collection

The data collection method used in this study was the interview method, and the interview approach used was the semi-structured interview. Semi-structured interview allows a researcher to use predetermined open-ended questions to collect data from research participants and also allow other questions to be asked by the researcher that were not included in the questions earlier formulated, for a detailed exploration of the phenomenon being studied (Smith et al., 2009). According to Smith & Osborn (2008), semi-structured interviews are likely the best method for gathering data for IPA investigations, and this method has been used to perform the majority of IPA studies. The questions used in a semi-structured interview are usually constructed in a way that would allow the respondent to be able to elicit a more detailed and free-form response, however, rather than sticking closely to the interview schedule, the constructed questions are modified in light of the participants' responses. This allows the investigator to probe into interesting and important areas that come up during the interview (Smith and Osborn, 2008). Hence, rather than the interview protocol dictating the interview schedule, it is guided by it. The constructed questions are usually referred to as interview protocol. In this study, the interview protocol was developed with the assistance of a qualitative research expert in IPA in the Department of Engineering Education at Utah State University. Smith & Osborn, (2008) suggest that a researcher using the semi-structured interview should try and establish rapport with the respondent to put them at ease, should know that the ordering of questions is less important, and that the researcher is free to probe interesting areas that arise based on the respondent's interests or concerns were used during the interview for this study.

In this study, the semi-structured interview lasted between 45 and 60 minutes as suggested by Alase (2017), that the interview duration of an IPA study should be approximately sixty to ninety minutes. The interview protocol is located in Appendix D. In addition to the researcher taking notes during the interviewing process, the interview was audio recorded as suggested by Creswell (2013). The interviews were stored in a secure box folder and the recorded interviews were transcribed into text format by using professional transcribers from the company SpeechPad and Descript speech-to-text software. Once the interview transcription was completed, the transcription was thoroughly read, de-identified to remove sensitive information, and sent to the participants. This was in accordance with the promise made to the participants before the interview that after the interview they would be sent a copy of their de-identified transcript for perusal and approval before using their data for analysis. All the transcripts used for analysis in this study were approved transcripts by the participants. The transcribed interviews were then imported into the qualitative data analysis software, MAXQDA 2020 for subsequent data analysis. MAXQDA is a software program that relies on various methods for systematizing, organizing, and analyzing non-numeric data and it is designed for computer-assisted qualitative and mixed methods data.

3.7.3. Data Analysis

The data analysis steps used in this study were adapted from Smith et al., (2009)'s IPA data analysis method. The authors said that IPA data analysis is an iterative and inductive cycle that is characterized by a variety of common processes such as moving from the particular to the shared and moving from the descriptive to the interpretative. They also prescribed guiding principles like focusing on individual meaning-making within a specific context and being committed to an understanding of the participant's point of view. They noted that it is customary to start the process of the IPA data analysis with a single case due to the idiographic commitment of the IPA method. The idiographic commitment of the IPA requires that the researcher analyzes the first case in detail, then goes ahead to analyze the second case in detail, and on and on before engaging in finding patterns among cases. However, they stated that their suggested IPA data analysis steps are open to change and should be adapted when and where the researchers feel comfortable doing so, especially when working with larger samples. According to the authors:

> *"If one has a larger corpus, ..., the emphasis may shift more to assessing what were the key emergent themes for the whole group. Here, it may even be the case that one identifies emergent themes at the case level but holds off the search for patterns and connections until one is examining all the cases together (Smith et al., 2009, p.106)"*

The suggested approach was used in conducting the data analysis in this study as the number of participants was thirteen. Figure 3.6. shows the steps involved in the IPA data analysis process used in this study. An illustration of how this procedure was implemented in the MAXQDA data analysis software can also be found in Appendix F.

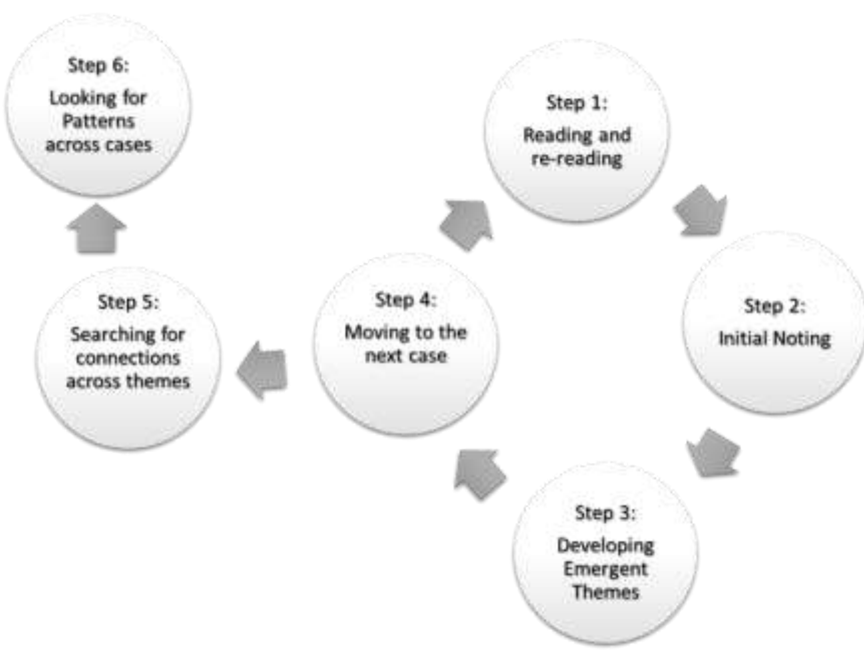

Figure 3.6. IPA data analysis Procedure. Adapted from "Interpretative Phenomenological Analysis: Theory, Method, and Research.", by Smith et al., 2009. Copyright 2009 by Sage Publications.

The description of the data analysis procedure is given below:

Step 1: Reading and re-reading phase

Here, the researcher first becomes familiar with the transcripts by reading and re-reading to enter into the world of the participants. That is, the researcher delays the habitual inclination to summarize while reading through the transcript but instead engages in repeated reading to understand how the narration binds certain sections of the interview together. Since, repeated reading allows a model of the overall interview to develop, and the researcher is able to spot the locations of richer and more detailed sections as well as sections that contain discrepancies or unexpected findings. In this study, the transcripts were read more than twice to get familiarized with the transcripts.

Step 2: Initial Noting

This stage is where the researcher further grows in familiarity with the transcript by identifying specific ways by which the participants think or talk about an issue and make a note of anything of interest within the transcript. It is a step that examines the narratives and the use of the language of the participants on a very exploratory level. The aim here is to produce a comprehensive set of comments or notes on the data and there are no rules about what is commented upon. In this study, the first initial noting started at the third time of reading the transcripts (see Appendix F). The types of exploratory comments that the researcher engages in during this stage of data analysis are:

- <u>Descriptive comments</u>: these are comments that describe which things matter to the participants or which things are key objects of concern to them. For example, it could be values, interest, events, places, relationships, process, emotional responses, etc.

Descriptive comments have a phenomenological focus because they highlight the objects or phenomena that structure participants' thoughts and experiences. The purpose of a descriptive comment is to analyze the transcript with the aim of describing the content. In this study, one of the descriptive comments made by researcher while making a note about a participant's views on rationale articulation was, "*being ready to explain 'the whys' and encouraging your followers to ask 'the whys' is one of the hallmarks of successful leaders*". That is, this was not a quote from the participant, but the researcher's descriptive comment to capture the narratives of the participant concerning the importance of articulating the whys in the workplace.

- <u>Linguistic comment</u>: This is a comment that helps the researcher to understand how and why the participants have certain concerns by looking at their use of language. This could be pronoun use, pauses, laughter, tone, repetition, degree of fluency, etc. In this study, one of the examples of linguistic comment was when the participants were asked to differentiate between engineering leadership and general leadership, and one of the participants said, "*You know, yeah, it's hard for me to tell. Is there any difference? Leadership is leadership".* The linguistic comment that the researcher made concerning this was *"hesitation"* as it could be seen that this study participant hesitated to share his views on the difference between the two domains of engineering leadership. Also, another participant when sharing his views on communication skills said *"Communication in general is super important"*. The linguistic comment here is "*emphasis*" that is, the participant's use of the language "super important" shows the degree of importance he attributed to communication skills.

- Conceptual comments: These refer to comments that deal with the transcript data at a conceptual level and are more interpretive in nature. Here, the researcher engages in reflection that could even take on an interrogative form, discussion, and refinement of ideas. The interpretation here inevitably draws on the researcher's experiential and/or professional knowledge, or the researcher's perception and understanding in order to make sense of and sound out the meaning of the participant's major experience. The main aim of conceptual comment according to the authors is that, when making a conceptual comment, one is using oneself to make sense of the participant and not the other way round. In this study, one of the examples of conceptual comment was, "*technical knowledge as a guide to knowing the feasibility of a proposed solution to an engineering problem*." This was a comment made when one of the study participants narrated how he would have wasted a lot of resources and time on a proposed solution by a subordinate who was considered an expert if he had not had the technical background to ask insightful questions that led to the discovery of the long-term impracticability of the solution.

Step 3: Developing the emergent themes

This is the stage where the researcher engages in turning the notes generated in stage 2 into themes to produce a concise statement of the major points in the various comments attached to a piece of transcript. Themes, according to the authors, are phrases that capture the psychological essence of a piece of information that contains enough particularity to be grounded or foundational, and enough abstraction to be conceptual. It should be noted that the emergent themes in this situation reflect not only the participants' original words but also the researcher's interpretation due to the phenomenological underpinning. The authors noted that the most important thing in this stage is that the emergent themes should feel like they have captured the necessary points and reflect an understanding. In this study, some of the themes that emerged at this stage are, "*why technical skill is important*", "*leadership evolvement*", "*Not afraid to fail*" "*people are not things*", "*big-picture oriented*", "*why soft skills are necessary*" "*explaining the whys*", "*provide mentorship*", "*everyone on your team matters*", "e*ngineering leadership definition*", "*communication skills*", and so on.

Step 4: Moving to the next case.

This step involves moving to the next participant's transcript and repeating the earlier steps. The authors noted that while it is important to treat the next case on its terms to do justice to its individuality, the researcher will inevitably be influenced by what he has already found. However, they noted that it is an important skill in IPA to allow new themes to emerge with each case.

Step 5: Searching for connections among the themes.

This is the step where the researcher engages in looking for connections between themes and grouping them based on how they fit together. That is, themes that relate to the same aspect of the studied experience are grouped while some may be discarded. This step is dynamic and iterative and necessitates the researcher moving back and forth between the entire data set and the consolidated themes. Some of the specific ways of finding connections among themes as suggested by the authors used in this study are:

- <u>Abstraction</u>: This involves clustering related themes together and giving the cluster a new name or thematic label that is representative of the whole cluster. The new theme is called the super-ordinate theme. Abstraction is a way of synthesizing and integrating the emergent themes to show the relationships between them. In this study, emergent themes like, "*people are not things*", "*provide mentorship*", and "*everyone on your team matters*" were abstracted to become "teamwork" (see Appendix F).

- Subsumption: This is a situation in which an emergent theme is broad enough to acquire the super-ordinate status. That is, it is broad enough to subsume or absorb other emergent themes as part of itself. A good example of a subsumption theme in this study is, "communication skills". Emerging themes like, "*knowing your audience and what they value*" and "*customizing your communication to the audience*" were all absorbed into communication skills (see Appendix F).
- Numeration: This refers to the frequency with which a theme is supported. That is, numeration is the art of noting the frequency of certain themes across different cases. According to the authors, it made sense to think of the frequency with which emergent themes appear as one indicator of their relative importance and relevance to the participant especially in situations where the interview style was open-ended and unstructured. In this study, the interview questions were open-ended, and the interview protocol was semi-structured. Numeration was used to derive the core essences of engineering leadership which translated to the identified engineering leadership skills in this study.
- Comparison: Comparison is an attempt to identify themes that relate to shared experiences or divergent views of the participants, especially across cases. It is somehow similar to numeration but unlike numeration which quantifies the frequency of themes, comparison delves deeper into the essence of the participant's experience by exploring the depth and nuances of their shared and individual perceptions of their experience. For

instance, in this study, a comparison was used to identify the commonality and differences in the views of the participants on engineering leadership and general leadership, and it was used throughout the data analysis to explore the shared views of the participants on the identified engineering leadership skills.

It should be noted that a codebook was created during this step and its use extended to the next step which has to do with looking for patterns across cases. The codebook can be found in Appendix E.

Step 6: Looking for patterns across cases.

This step involves cross-case analysis that is aimed at identifying shared themes among different participants while still preserving the unique aspects of each individual's experience. According to the authors, this step is particularly a creative task as it usually leads to reconfiguring and relabeling of themes which helps the analysis to move to a more theoretical level. In this study, during this step, patterns that led to identifying the conceptualization and articulation of engineering leadership by the study participants emerged. So, the core essences of engineering leadership that translate to the identified engineering leadership skills emerged (see Appendix F). These two themes were used to answer research questions 1 and 2. In addition, the theme, contextual differences in engineering leadership definition and skills, which was used to answer research question 3 emerged at this stage, as well as the role of training and experience in engineering leadership success.

Inter-coder reliability was conducted in step 3, which was the stage for developing emergent themes, to ensure that the identified themes were not solely influenced by the researcher’s subjective interpretation but were grounded in the data. A graduate Ph.D. student who is knowledgeable in qualitative phenomenological study was invited by the researcher to work as the second coder and 30% of the codes were discussed. The second coder was exposed to two interviews from ABET professionals and two interviews from industry leaders, making a total of four interviews. The transcriptions were segmented, and both the researcher and the second coder assigned their codes to each of the segments separately. The codes assigned by the researcher and the second coder were then compared, and the differences were discussed at an arbitration session until at least 80% of the agreement was reached as suggested by Saldaña (2013).

3.8. The Role of the Researcher

The researcher led the data collection procedure and the qualitative analysis for this study. The researcher, having had experience in both engineering education and information science, used the expertise acquired from the experience to conduct the interview and analyze the data. Also, in data analysis, it is customary in an IPA study for the researcher to actively engage in double hermeneutics, which has to do with being able to interpret the participant's interpretation of their experience (Alase, 2017; Smith & Osborn, 2015). In addition, the authors noted that it is very important that the IPA researcher comply with the idiography approach to data analysis by going over one interview's transcript in great detail before moving on to look at other cases. That is, starting with “particular” instances and only slowly working up to more general categorizations or claims. The idiographic mode of inquiry is opposite to the nomothetic approach in which analysis is at the level of groups and populations and only makes probabilistic claims about individuals. The idiographic approach takes into consideration the particular experience of the individual concerning the phenomenon under study. Therefore, the researcher engaged in the process of idiography during the data analysis as well as double hermeneutics in interpreting the findings from this research.

CHAPTER 4

FINDINGS

Introduction

This study aimed to investigate how engineering leaders in ABET and leaders in industry would define engineering leadership and engineering leadership skills based on their experience. Thus, adhering to the principles of phenomenological research, this chapter presents findings deeply rooted in the participants' lived experiences. Four major themes emerged from the interpretive phenomenological analysis as shown in Figure 4.1, and a brief description of the themes is given in Table 4.1. The subsequent paragraphs address each of these themes and their corresponding sub-themes.

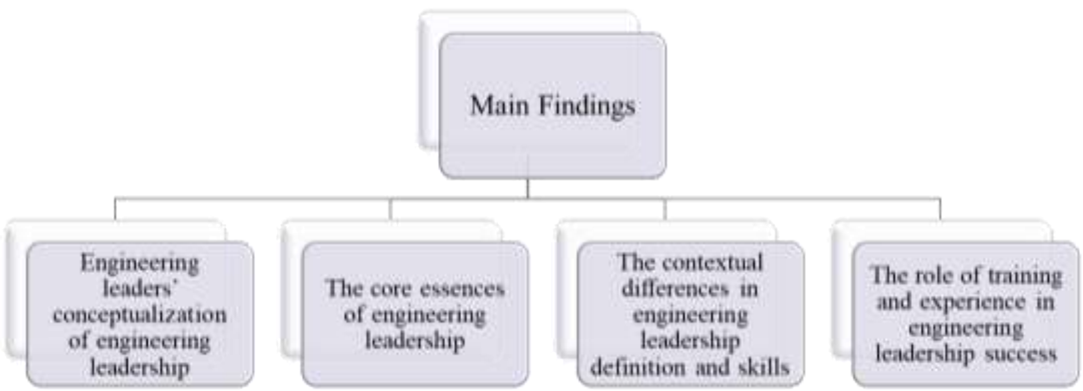

Figure 4.1. The main themes from the findings.

Table 4.1

A Description of the Identified Themes in this study

SN	Theme	Meaning
1.	Engineering Leaders Conceptualization of Engineering Leadership	This theme sheds light on the diverse perspectives of the engineering leaders in this study about what they believed to be the fundamental leadership principles within the engineering context and how they defined engineering leadership based on their experiences as leaders.
2.	The core essences of engineering leadership skills	This theme highlights the personal and professional characteristics exhibited by engineering leaders and those they articulated as essential for engineering leadership success. This provided insights into the identified engineering leadership skills in this study.
3.	Contextual Differences in the Definition of Engineering Leadership and Classification of Engineering Leadership Skills	This theme revealed contextual variations in the definition of engineering leadership and engineering leadership skills by offering valuable insights into how situational factors influence the perception and identification of engineering leadership skills by the engineering leaders in this study.
4.	The Role of Training and Experience in Engineering Leadership Success	This theme explores the impact of formal training on engineering leadership success based on the perspectives of engineering leaders in this study. It emphasizes the significance of experiential learning in leadership development.

4.1. Theme 1: Engineering Leaders Conceptualization of Engineering Leadership

This theme highlights the various ways in which engineering leaders who participated in this study perceived, articulated, and embodied the fundamental principles of leadership within the engineering context based on their experience as leaders. It conveys the perspective that is essential to understanding what it means to lead in the engineering domain. Theme 1 is structured around three emergent subthemes which are (1) participants' definition of engineering leadership (2) the differences and similarities between engineering and general leadership, and (3) the perceived scope of engineering leadership across organizational boundaries.

4.1.1. Sub-Theme 1: Definition of Engineering Leadership

The engineering leaders in this study sought to define engineering leadership in ways that reflected their professional conduct and technical expertise. When asked how they would define engineering leadership based on their experience, only five out of the thirteen engineering leaders were able to directly articulate the definition of engineering leadership, the remaining eight engineering leaders defined engineering leadership using illustrations or stories often backed by a statement which summarized their conceptual understanding of engineering leadership definition. For instance, Allison (ABET leader) was able to articulate and give a direct definition of engineering leadership based on the ability to motivate the group being led in fulfilling the goal and mission of the group as follows:

> *Engineering leadership is pretty much like any other kind of leadership. It's being able to manage the process flow in accordance with the mission or the goal or whatever you want to call it, to enable the things that need to be done to get done through the people because the people are your resource.*

Also, Henry (industry leader) was able to directly articulate the definition of engineering leadership, linking it with prowess to engage people in problem-solving as he said:

> *So, for me, engineering leadership means seeing the overall picture of what needs to be accomplished on the technical solution within a business unit, and understanding how to engage people in solving that technical problem is probably how I would summarize it.*

Meanwhile, Norah (industry leader) illustrated her definition of engineering leadership as that which has to do with professional conduct and technical know-how and noted this was where she found most success. In her own words, she said:

How do I define engineering leadership based on my experience? Um, that is a good question. So, I think it's important as an engineering leader to be able to understand and work with the same tools that my engineers have, to practice what you preach. Basically, I'm telling them they have to go do something. I want to be able to have at least a high-level working knowledge of how to do that too, so that I can help answer questions or understand where they may start to have any troubles. And then we can course correct together. So being an engineering leader, it's important to have that experience and that willingness to jump in and understand the problem firsthand. At least that's where I found the most success.

Similarly, George (industry leader) shared this view on engineering leadership as that which has to do with exercising sound professional ethical behavior and leading by example when he noted that:

I think that a big part of engineering leadership is leading by example. I think that a big part of it is being present to lead. I think that in order to demonstrate effective leadership, you have to be present, people have to witness it, and they have to witness your actions. Another thing is I think that you have to have a high enough level of integrity to do what you say and follow through with that. I think that integrity, not compromising when you feel like you're outside of ethical boundaries, or when you feel like there are decisions that harm others as a role, from your role as an engineer. I think that's important. I think that you need to take that engineering duty very seriously and if you have the potential to harm others, or you see that risk, you need to stand behind it and take the high ground.

Finally, Justin (industry leader) articulated his definition of engineering leadership by weaving it around a story as having the ability to seek the help needed to solve a particular problem when he said:

Engineering leadership would be, maybe not necessarily having all the answers, but to be able to know where to go to get the answers from those around you along the way. I think engineering leadership is something that people can just sense and will call you for answers. Within our company, we have lots of people who will just call each other. Okay, I'm experiencing this situation, what would you suggest I do? As an engineering leader, you are that resource that helps even if you don't have the answers.

4.1.2. Sub-Theme 2: Diversity and Commonality of Views on Engineering Leadership and General Leadership

This sub-theme seeks to provide insight into the nuances that differentiate engineering leadership from general leadership to foster an understanding of the phenomenon as posited by the engineering leaders in this study. The sub-theme lends insight into leadership principles across domains, particularly focusing on those that are essential for leaders in engineering.

Regarding the similarities between engineering leadership and general leadership, the majority of the engineering leaders noted that both are very similar and expressed a lack of inability to really ascertain whether there is a difference between engineering leadership and general leadership until when probed further to think about any characteristic that could be said to be a key difference between the two. For instance, in response to the similarities between engineering leadership and general leadership, Raymond (industry leader) expressed his views on both leadership domains as similar when he said:

I don't know that I feel that there really is a fundamental difference between engineering leadership, an engineer who's a leader, and anybody else who's a leader. Now, there could be style differences, but fundamentally, I don't know that there's a difference.

Also, Alex (industry leader) responded by sharing that he finds it hard to differentiate between the two leadership domains which means he considers them similar. He expressed this by saying:

You know, Yeah, it's hard for me to tell. Is there any difference? Leadership is leadership. I think it's just a group of people you're interacting with. Their makeup is different. With engineers, it is more of a technical environment where the questions are more fundamental, like, you have to have evidence, because people are going to challenge you. After all, engineers are curious, right?

Sawyer (ABET leader) also shared his view of the similarity between engineering leadership and general leadership by emphatically stating that there is no difference between the two domains with his response that:

Leadership in engineering is no different than any other discipline. Leadership is leadership, whether it's in a church, whether it's in ABET, or whether it's anywhere, except the military, the military is different.

When probed further as to why he thought the military is different, he responded that leadership in the military is different because they have their set or predefined way of looking at leadership. Other than that, he believed leadership in engineering is no different from leadership elsewhere. Furthermore, Lilly (ABET leader) responded to this prompt by hesitating to acknowledge that there is a difference between these two leadership domains which connotes that she considers them similar to an extent. She stated that:

I'm not so sure if engineering leadership is that much different than just leadership in general.

Finally, Maxwell (ABET leader) added philosophical underpinning to his views on the somewhat similarity of the two leadership domains. He expressed his views by stating that:

Engineering leadership is leadership in the context of goals associated with engineering, and philosophically, I don't think that's different from any other leadership.

When asked further to shed more light on the statement, he explained that leaders in both domains share similar traits which he expressed in terms of interpersonal skills as he said:

Well, look at universities. There are a lot of universities that have engineers as presidents. So, organizationally, traits of good leaders, that they listen first, they care about people, they stay focused on the goals, they respect people, those sorts of values and things of good leaders are, I don't think make a darn bit of difference if you're an engineer or not.

With regards to what differentiates engineering leadership from general leadership, the majority of engineering leaders believe that leading engineering design efforts or technical competence is the major thing that differentiates engineering leadership from general leadership. Three of the engineering leaders emphatically refuted the notion that a good leader could oversee any company. They noted that while an engineer could venture into leading a group of people outside the domain of engineering and still grasp the basic understanding required to effectively lead in that domain, the same cannot be said of someone who does not have an engineering background. For instance, Fredrick (ABET leader) disagreed with the notion as he said:

I mean, there is a philosophy that, a good project manager can manage any project, or a good dean can oversee any college, or a good CEO can oversee any company. And I *don't know that. I don't necessarily agree with that because I do think that when you're leading a technical organization or a technical project, you do need to have a deep appreciation of the technical discipline. Now you might not be a domain expert, but being a domain expert in some technical discipline gives you credibility with those technical people, but it also gives you, I'd say, just the broad scalability to assess other people's technical statements, or maybe at least know the right questions to ask. So, I think that is what differentiates engineering from other types of leadership.*

This view was also shared by Henry (industry leader) who reiterated that technical competence is a key ingredient in engineering leadership and stated that it would be nearly impossible for non-engineers to attempt to handle engineering design efforts by saying:

Yeah, I think the technical expertise does need to be there, and so I think having a leader in engineering would make it easier to have them apply their skill set in other arenas than it would be for a general leader to apply their skill set in engineering. But I think engineering, I mean, you get some value for all this trouble of trying to understand the science behind things, build up this basis, and now you can actually apply that in a whole bunch of different arenas. A leader in the other space can never, they can never even attempt to come to engineering…. It would be a lot, a lot more challenging to go in that direction.

In addition, Maxwell (ABET leader) opined that contrary to what MBA teaches that anyone could lead just about any company without understanding the product, an engineering company demands technical competence to understand what goes on there. He noted that:

Well, engineering leaders have to be technically competent. Engineers tend to respect competence. So, you need to be technically competent to understand what goes on in the project. And maybe that's one philosophical difference because, the MBA school says, if you have an MBA, you can manage anything from a McDonald's to a car company. You don't need to understand the product. Whereas I think engineering leaders do need to understand the core knowledge of their organization. So, technical competence.

In addition to this, some other salient points that other engineering leaders made in support of this perspective are that having technical expertise helps the leader to have the vocabulary that he or she can use in working with others. Also, technical expertise gives the leader credibility with those that they are leading because it connotes that their judgment can be relied on, and technical expertise helps the leader to know when someone is going overboard with their proposal of engineering solutions like Fredrick (ABET leader) said:

And so, if somebody is proposing an effort where what it sounds like is dabbling over the edges of the laws of physics, presumably you've got the expertise to write that anecdotally.

Justin (industry leader) also shared this view of the usefulness of technical knowledge as a guide in knowing the feasibility of a proposed solution to an engineering problem when he said:

I think that an engineering leader has an advantage over a non-engineering leader in an organization that is engineering because of the fact that they just have that basis of knowledge and I don't want to call it a bias, but it may be that a non-engineer would say, well, why can't you do this? And that would be great because we love being challenged, but understanding that you're not going to change the laws of physics, right? Yes. It's kind *of important. Yeah. Right? Yeah…. I think it's inherent in an engineering leader that they understand the principles, especially the knowledge of those that can't be changed would help.*

Another important view that engineering leaders in this study shared is the fact that contrary to the opinion of some schools of thought that say leadership is not for the engineer, the participants noted that leadership actually starts for the engineer right from the entry-level into the engineering field of practice and continues throughout their career. They noted that the only difference is that leadership is in stages in the engineering profession and an engineer might decide not to reach the highest stage. In talking about the first stage of leadership, which he referred to as the self-directed leadership stage, Fredrick (ABET Leader) explained that,

When somebody's hired into an entry-level position, they're still expected to show leadership. But that leadership at that level is really self-direction. They're expected to lead themselves. They may be assigned a small activity, but they should be able to do that with minimal supervision. So, at the early stages of their career, it would be self-direction.

He proceeded to explain what he called the second stage of leadership which is motivated leadership. He noted that this level of leadership is initiated when the engineering leader transitioned into a project management role by saying,

At the next stage of their career, it would be project management. So, probably no supervisory or management responsibilities beyond project management, and everyone who's done project management knows it's tough because you have responsibility but *often no authority So, the main leadership challenge at that next level is motivating others.*

Sawyer (ABET leader) also shared his views on this stage of engineering leadership and maintained that project management is a leadership position when he said,

Engineers after a while become project managers, and a project is a leadership position for an engineer. So, it's going to be working with a bunch of other engineers with less experience and managing the project.

Fredrick continued his classification of stages of engineering leadership by describing it as the managerial leadership stage. He explained this by saying that,

The next level, and I wouldn't even call it a change in level because I think it's a voluntary change in role, some engineers are then drawn to managerial leadership. And with that comes formal organizational leadership, where not only do you need to motivate yourself and motivate others, but you also have direct supervisory and personnel responsibilities that now go with that. And that's where I think, leadership, I mean, maybe a lot of those tasks, it leaves engineering leadership and goes into the generic category of managerial leadership where you need knowledge of, personnel policies and supervisory policies and a lot more. I'd say direct, again, direct managerial as opposed to leadership responsibilities.

Finally, he noted that the managerial leadership stage is the highest stage of engineering leadership and that it is the optional or less inviting stage for many engineers. However, he maintained that every engineering professional will experience the first two stages of leadership in their career. Explaining his views on this, he said, *So, again, I think reasonably not all engineers want to take that path. Many engineers have no desire or interest in stepping into managerial leadership, but every engineer is going to have to do those other things, again, self-direction and motivation leadership. Yeah, that's the way I see it, and again, I think managerial leadership is for some people and it's not for other people. I would say from a personal perspective, I dipped my toe in that and decided I didn't like it. And I think a lot of technical people probably have that same experience.*

Similarly, Sawyer while sharing his views of how engineering professionals go through different stages of leadership in their career, commented on this managerial level of leadership and said,

Engineers after a while become project managers…. And when the project manager does a really good job, then he/she climbs the ladder and becomes a VP of production and so forth hopefully by excellent service that they've done, and a lot of times, it all boils down to how much money you make for the company.

4.1.3. Sub-Theme 3: Perceived Role of Engineering Leaders in an Organization

Sub-theme 3 discusses participants' perspectives on whether the responsibilities of an engineering leader are confined to engineering alone or extend to influencing other aspects of the organization. That is, the main focus here is to understand whether the perception of engineering leadership by the participants is restricted to those with formal engineering training or whether it is more expansive across the organization to non-engineers and other stakeholders. Concerning whether the role of an engineering leader in the organization is broad, four out of the seven engineering leaders in the industry perceived the role of an engineering leader to be exclusive to leading engineering efforts or mentoring younger engineers, while only one out of seven engineering ABET leaders shared this view. The remaining six ABET leaders and three professional engineers had a broader outlook on the role of an engineering leader in the organization. For instance, adopting a broader outlook on the role of an engineering leader in the organization, Lilly (ABET leader) said:

> *So, I would say I don't think you have to be an engineer to provide leadership to engineers, and engineers who are leaders could also provide leadership to other non-engineers. I think leadership is a bigger umbrella than the profession of engineering.*

In addition, Raymond (industry leader) articulated his broad view from the perspective of ethical behavior by responding that:

> *I don't think the focus should be on the engineering professionals alone. No, I think it's a much broader role and I think a key component of this is really engineering ethics and professional ethics. So, as engineers, we are responsible for the public interest in public safety. And so, we have an ethical obligation. I would argue leadership in those aspects. So, we need to engage in the broader society as engineers but look out for the public interest and safety.*

Meanwhile, in contrast to this view, Kate (ABET leader) viewed the role of an engineering leader in the context of organizational mission as applied to engineering professionals alone as she stated that:

> *I guess I see engineering leadership in the context of engineering leadership as applied to engineering professionals. I guess I see that in the context of organizational mission. So, in my particular job, when I am dealing as a leader with my fellow engineers, it tends to be in the context of how engineering specifically relates to our mission, like, in this case,*

it's the engineers that I deal with as our university faculty and our mission is to teach undergrads to perform community service and to do our research.

In addition, Alex (industry leader) saw the role of an engineering leader as using his or her experience to help other younger engineers succeed and stated that:

Yeah. So, I think for that one, it's really about like enabling others to do the best they can. I think, you know, for example, I may interact with some younger engineers or people that don't have as much experience as I have, and then, so from my perspective, my goal is to kind of bring them up to speed so they can be in a position where they can deliver. I think that's kind of how I see it.

4.2. Theme 2: The Core Essence of Engineering Leadership

The core essences of an experience depict the basic characteristics of an experience that are universal and presented in particular instances of a phenomenon. The phenomenon being investigated in this study is engineering leadership. Therefore, this theme sheds light on the basic personal and professional characteristics of engineering leadership that have been exhibited in the professional practice of the engineering leaders in this study as they narrate their leadership experiences. The highlighted characteristics of engineering leadership in the context of this theme translate to the identified engineering leadership skills. This theme also goes further to point out those skills that the engineering leaders in this study regarded as essential to engineering leadership success. Based on Smith et al., (2009)'s assertion that a higher frequency of emergence of certain themes in an open-ended or unstructured, interview could be an indication of their relative importance or relevance to the participants, the identified skills in this study are classified into three categories which are critical, essential and needed skills.

These terms used in the classification are defined in the context of this study as:

- *Critical skill*: This refers to a skill that is of utmost importance without which the desired leadership outcome or goal may not be successful or achievable.
- *Essential skill*: This refers to a skill that is necessary or indispensable to achieving the desired leadership outcome, which even though it may not carry the same sense of importance as a critical skill is still indispensable.
- *Needed skill*: This refers to a skill that is required for actualizing leadership purposes or objectives, which despite its importance, may be regarded as slightly lower in necessity compared to critical or essential skill.

Table 4.2 shows the total number of participants who identified each engineering leadership skill as important, while Figure 4.2 shows a classification of these skills based on their relative importance.

Table 4.2

The total number of engineering leaders who identified each skill as important.

SN	Skills	Total No of participants	Relative importance
1	Technical Expertise	13	Critical
2	Teamwork	13	Essential
3	Communication	10	Essential
4	Listening	10	Essential
5	Empathy	10	Essential
6	Rationale Articulation	10	Essential
7	Humility or Ego Management	9	Essential
8	Problem-solving and Critical Thinking	9	Essential
9	Fearless Exploration	8	Needed
10	Strategic Visioning	7	Needed
11	Lifelong Learning	7	Needed
12	Ethical and Trustworthiness	7	Needed
13	Demonstrative Leadership	6	Needed

SN	Skills	Total No of participants	Relative importance
14	Decision Making	6	Needed
15	Collaborative Followership and Delegation	6	Needed
16	Flexibility	5	Needed
17	Organization and Time Management	5	Needed
18	Leadership Identity Awareness	5	Needed

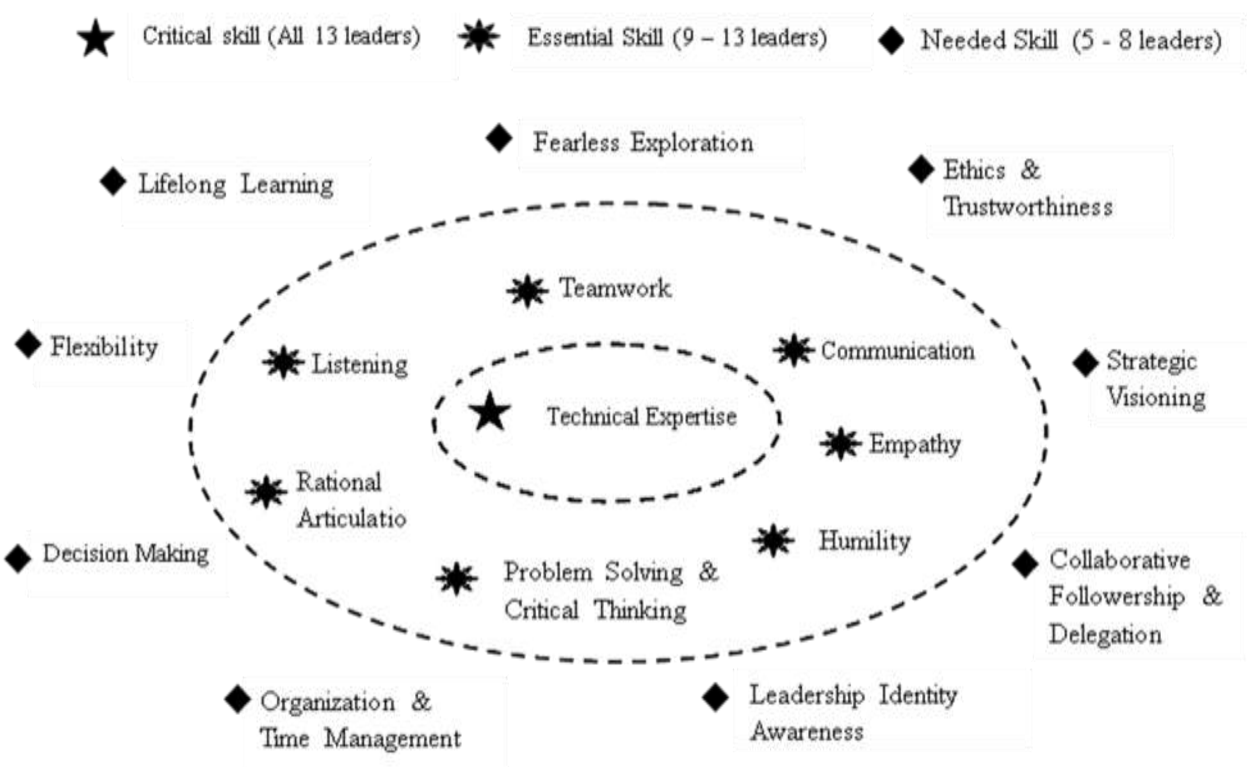

Figure 4.2. Identified Engineering Leadership Skills.

4.2.1. Sub-Theme 1: Critical Engineering Leadership Skill

Engineering leaders in this study identified technical expertise as a critical skill that is of utmost importance. They opined that technical expertise is the foundation upon which engineering leadership stands. A summary of the views they shared on technical expertise is described in the paragraph following.

4.2.1.1. Technical Expertise

All of the industry and ABET leaders characterized technical expertise as a core or critical engineering leadership skill, stating that engineering leadership demands technical expertise and a host of soft skills, which they also referred to as interpersonal skills. For instance, Justin (industry leader) was able to articulate the majority of the dichotomous views shared by the participants when he characterized engineering leadership as consisting of 30 percent technical skills and 70 percent general leadership skills. He described his view by saying:

> *I will probably say maybe like 70 percent is just general leadership, but you have to have a technical understanding and a technical side as well to be that engineering leader. Well, because I mean, I would like to think I have some leadership skills that will help me in a community service aspect, right? Yeah. But, when it comes to an engineering aspect, I need to have that engineering understanding. I mean, we can be the best leaders, but if we don't have an understanding, then you're not going to have the clout of those that you work with to come to you, because part of that engineering leadership is the understanding of that technicality of it as well.*

Allison (ABET leader) expressed her views and concluded that technical expertise is very crucial to engineering leadership, even if it is for the very fact that it gives you the vocabulary to use when leading technical efforts. She stated that:

> *Having some technical background in at least some part of the business is helpful if for no other reason than you now have the vocabulary that you can start to work with others as you move forward.*

This view was shared by Aaron (engineering leader) who noted that even though an engineering leader might not have to use all the technical knowledge learned during his engineering training in the position of leadership, the knowledge allows the engineering leader to suggest various alternative solutions that his team might not have thought of. He expressed this view by stating that:

> *I think it's inherent in an engineering leader that they understand the principles, especially the knowledge of those that can't be changed would help. I think of all of the calculus I had to go through to get an engineering degree, and have I ever used any of it on a regular basis? I would say no, and especially not as a leader, right? I am not doing, you know, partial differential equations at all. However, the fact that I know that it exists and that I know that it can be used to solve certain types of problems helps me as a leader to kind of guide people and say, oh, by the way, have you thought about using finite element analysis, or have you thought about, you know, going back to, you know, the principles that you learn, of water dynamics and how that might apply to this as well. I think as a leader, because you have that basis of knowledge, you can help to explore different alternatives that they may not have thought of.*

Fredrick (engineering leader) is of the opinion that technical expertise is a necessity in engineering leadership because it gives the engineering leader the credibility to assess other people's technical statements. He expressed this view by stating that:

> *Now you might not be a domain expert, but being a domain expert in some technical discipline gives you credibility with those technical people, but it also gives you, I'd say, just the broad scalability to assess other people's technical statements, or maybe at least know the right questions to ask. So, I think that is what differentiates engineering from*

other types of leadership. Engineering leadership is in a, of technical efforts by somebody with technical expertise or maybe at least know the right questions to ask. So, I think that is what differentiates engineering from other types of leadership.

Maxwell (engineering leader) also shared that technical expertise helps the leader to understand what goes into a project and how to measure the success of a project. He said:

So, you need to be technically competent to understand what goes on in the project. And maybe that's one philosophical difference because, the MBA school says, if you have an MBA, you can manage anything from a McDonald's to a car company. You don't need to understand the product. Whereas I think engineering leaders do need to understand the core of their, the core knowledge of their organization. So, technical competence. They need to listen, they need to care, and they also need to show they care, and they really need to stay focused on the end result, because that's ultimately how engineering management and leadership measure the success of the project.

In support of the views on the need for technical competence in leading engineering efforts, one of the engineering leaders, George (industry leader), shared that the major challenge he is currently facing in his engineering company which was acquired and merged with another company whose senior leaders are non-engineers, is that those non-engineering leaders do not have the understanding why it is necessary to have some technical expertise in place and how this is affecting productivity. He stated that:

So, probably the most recent challenge is just trying to convince non-engineers of the importance of having those people with the technical abilities in those roles. So, trying to convince the non-engineers that we need that design talent within our organization, *reticence or we can't move the projects forward. We cannot grow the organization and we can't effectively complete the projects. And the projects we complete inherently have more flaws and more problems without the engineers or those design, those technical types involved in the process. And so, trying to convince the non-engineers that technical expertise really provides benefit for everybody, for them, for the organization, for the project in general. I think that that has been a pretty exceptional challenge, and it has increased over time like I said it's kind of like, trying to convince people that haven't been through the process before that, that your contribution is actually influencing it.*

Similarly, with regards to understanding what goes on in a project, Norah (industry leader) also shared how crucial this is to engineering leadership success by noting that having the understanding of the problem firsthand and guiding her team towards the solution was where she found success as an engineering leader. She described her experience as follows:

So being an engineering leader, it's important to have that experience and that willingness to jump in and understand the problem firsthand. At least that's where I found the most success…. So, from a technical aspect, you have to be able to know how things are going to function. Like being able to think that way so that, you know, how you need to cross-train your engineers and how you need to lay out processes so that they connect to the right points so that your software engineers are talking to your electrical engineers.

4.2.2. Sub-Theme 2: Essential Engineering Leadership Skills

The essential leadership skills identified by the engineering and ABET leaders in this study are teamwork, communication, listening, empathy, problem-solving and critical thinking, rationale articulation, and humility or ego management. The engineering leaders believed that these skills are indispensable to engineering leadership success but are not as important as the critical skills. The ideas presented in this section received validation from no fewer than nine of the thirteen engineering leaders who were part of this study as shown in Table 4.3. This section summarizes the findings that were echoed by these engineering leaders.

4.2.2.1. Teamwork Skill

Teamwork is identified by both the industry leaders and ABET leaders in the study as one of the essential engineering leadership skills. They shared different perspectives on various aspects of managing one's team as a leader, especially based on the experience they have garnered over the years as a leader. One of the perspectives was that an engineering leader must realize that everyone on the team matters. For instance, Allison (ABET leader) gave an analogy of a restaurant in which she said having the best cook in the world without efficient servers will still lead to failure in the end. She described this by saying:

> *It's like a restaurant; if you don't have any servers, you can have the best cooks in the world, but if nobody can get the food to the table, you're not going to be successful…. In the university, maintenance folks are often looked upon as…they're not really important. Well, they are important because if you don't have light, if you don't have heating and cooling, and if nobody cleans the classrooms, the teacher can't do their job…. If you look at any organization, there are a whole bunch of people. And if you remove any one of those people, there's at least the potential that things are going to fall apart.*

Another perspective shared by engineering leaders on teamwork is the need for the leader to recognize that people are not things. This is because engineers have been taught about dealing with things, but as a leader, it is important to take a step back and realize that people are not things. People need to feel valued and respected, especially embracing their individuality as well as avoiding overloading them with too many responsibilities at a time. This view was shared by Lilly (ABET leader) who said:

> *It's always about the people. I lead people, and people have a personal life and professional life. And of course, as a leader, I need them to give 100% of their professional life, but I don't need them to give 150%. And I need to value that each person finds meaning in their profession differently. And how I find meaning doesn't mean how other people find meaning. And I think it took me a long time to see that. So you know, I can't permit slackers, we need everybody to perform, but each person brings something to the table that is really valuable.*

Also, according to Aaron (industry leader), people must be valued and treated with respect. Concerning this, he said:

> *The competency of people management is knowing that people are not things, and as engineers, we're really, really good at dealing with things, right?.... When it comes to dealing with people who don't understand, or, and I'm talking engineers or non-engineers alike. Yes. Speaking to them in a way that they feel heard, that they feel, you know, valued. That is not something that comes naturally to a lot of engineers because we're very by the book, fact-based, and if you can't handle it, then you move on. And that's just not the way the world works*.

One of the engineering leaders, Norah (industry leader) said she discovered by experience that people need a lot more assistance or support from their leader to carry out their duties effectively, which is somehow contrary to the common opinion that leadership is about assigning responsibility. In her words, she said:

> *I think when I first became a leader, a very first manager position. I thought it was going to be more just organization, right? Pull people together, give them the information they need, and let them go on their way. I've learned that people of all functions need a lot more handholding through the different types of things they need. They need someone to listen, that trust piece. They need someone who knows that they've got their back when it comes to their future and their opportunities at work.*

On the issue of people needing more assistance or handholding from their superiors, some of the industry leaders in this study pointed out the issue of the "curse of knowledge". This is a term used to describe a situation in which after someone has become an expert, he or she expects the subordinates to be as good as they are. They noted that the majority of team-leadership failures come from this situation. They reiterated that patience with team members until they are able to stand on their own is a result of being conscious of the curse of knowledge and working on it continuously. As regards this, Aaron (industry leader) said:

> *I think the second challenge is, we just assume that because I've been in the department for 18 years, that people know what I know….. And I believe they call it the curse of knowledge, right? You can't un-know something once you know it. That's it. Yeah. It's hard to put yourself in a place where you never knew that thing. And so, a challenge that I have is overcoming the curse of knowledge and saying, you know what? Most of the people that I've talked to haven't experienced what it's like to be a roadway designer… So how can I take my experience and put it in such a way that they can understand it?*

Also, Sawyer (ABET leader) while giving an overview of what engineering entails noted that project management kickstarts the leadership responsibility of engineers but the key thing to know is that this role entails working with engineers with less experience.

Do the best you can do, truly the best you can do, you know. Engineers after a while become project managers and project manager management is the leadership for an engineer. So, it's going to be working with a bunch of other engineers with less experience and managing the project.

Justin (industry leader), drawing from his leadership experience, highlighted that it is crucial to mentor and continue to show love for the team one is working with as a means of creating a culture of buy-in and earning their loyalty to stay with the company. He noted that it takes 21-24 months for a new employee to become profitable and if they leave in search of job satisfaction after 2 years, it ends up as a loss of investment on the company's part. He shared this view by saying that:

And so, part of a leader is you want to promote, or as a director or a team lead, project manager, you want…to mentor, continue to love and share that vision…. That's how we're going to create, loyal employees that will want to stay with the company and not change jobs as frequently……in the job market in engineering today, you're well aware, I mean, it used to be the average engineer was with the same company for six years. Now it's down to like three to four years, and then to tie into that, studies have shown at least that we've been told, that it takes up to 21 months to 24 months for a new employee to become profitable. So, if you hire somebody and by the time they become profitable, and then they leave two years later. You're never gonna get your investment out of them, right?, and so, part of it is you have to understand, and for our company our culture is, we try to develop a culture of just buying-in so to speak, that there's something more than the almighty dollar that, that an engineer would chase.

4.2.2.2. Communication Skills

Communication is another essential engineering leadership skill identified by industry and ABET leaders in this study. They placed emphasis on it using terms like, “super-important”, “is key”, or repeating it over and over. They emphasized the importance of being able to communicate to a broader audience and the importance of tailoring one’s communication to the audience accordingly. For instance, Sawyer (ABET leader) believes that considering the changing landscape of the educational system where an engineer is required to function with people from different backgrounds, an engineering leader must be diverse in terms of relating and communicating with a broader audience. He described this view by saying that:

> *The whole of education is changing. It's no longer a mechanical engineer that will function only as a mechanical engineer, electrical engineer, or chemical engineer. They are going to be working with each other. They're going to be working with a lot of data and a lot of computing folks. They're going to be working with HR, with management, with marketing, with all those. So, they have to be able to be diverse in terms of communicating and relating to these different folks.*

Maxwell (ABET leader) shared his views on this by stating that it is important for the engineering leader to understand that people are different, and as such, learn to customize their conversation to individuals and situations. He shared this view using his experience when he stated that:

> *When I was an associate provost, my immediate boss was a history major. She had a Ph.D. in history, and she very much brought a liberal arts thinking approach to things. She did not tend to be numerical. She just had a very different view on how to approach things. So, a lot of it is understanding that people are different and understanding what*

she valued, how she wanted to be approached, and how to communicate within that set of rules.

He further said:

There are differences dealing with people who grew up in different parts of the world. None of them are horrifically difficult to overcome, but you need to step back and understand what makes that person tick.

Similarly, Alex (industry leader) considers knowing the audience and tailoring one's conversation to their interest as a viable way to engage people who have non-engineering background in conversation that will foster cooperation. He expressed this view by saying that:

I think you have to think from their angle, like, for example, if you're talking to someone from marketing, I'm an engineer, right? So, I think from their perspective, you have to know, okay, what things matter to them. From the information that you have, you have to kind of pair those two together. Because from their perspective, maybe they don't care about technical details, but they only care about how the product is going to sell. Is the product going to be marketable? So, you kind of have to kind of highlight your conversation towards that angle they have. I think it's kind of like knowing the audience and shifting the focus toward whatever they may wanna look at.

Also, Sawyer (ABET leader) demonstrated emphasis on the importance of communication by saying that:

Leadership requires clear communication. Obviously, as I said, communication in the written and verbal, listening, that's the key. I cannot emphasize it enough. Some people *have to fail several times to learn and some just never learn, but again, we're talking about leadership, the key is communication, communication, communication.*

Aaron (industry leader) accentuates the importance of communication to leadership by placing a strong emphasis on its significance using the phrase" super important", highlighting knowing your audience and customizing your message accordingly is essential to effective communication. He stated that:

Okay, when it comes to a leader, I'm going to go back to communication, be able to communicate effectively. And there's so much in communication, right? Knowing your audience, having your message down, you know, face it. In fact, communication in general is super important.

He further noted that as a means to foster communication skills in engineering students and suggested that one of the ways that could be achieved is asking them to explain their engineering solutions to a third grader or a non-engineer in a way that will be meaningful to them. He said:

But as you understand principles of engineering and you're communicating those I think, having communications classes, right, to be able to say, take this very technical thing and explain it to a third grader. Oh right, or the one that I like is, you're sitting at dinner with your mom, who is a non-engineer and you have to explain what you do. How are you going to phrase this in such a way that will be meaningful to her?

Similarly, Raymond (industry leader) noted that engineering leaders must possess communication skills to effectively communicate engineering results to non-engineers, such as policymakers, project owners, and the public. He stated that:

I think you could say communication is a leadership skill that engineers have to have. And it's really not to talk to other engineers, it's to talk to people who are not engineers. That's the real job of the engineer, to be able to communicate the engineering results to non-engineers. And that's going to be policymakers, it's going to be owners of projects, it's going to be the public?.....And I mean, people are generally educated, so it's not a lack of education, but you got to still talk to them in a language that they can understand.

Maxwell (ABET leader) reinstates the importance of recognizing that the cultural and professional background of people influences how they convey their message and that must be embraced to foster effective communication. He said:

A lot of them, like for example, when I was an associate provost, my immediate boss was a history major. She had a Ph.D. in history, and she very much brought a liberal arts thinking approach to things. She did not tend to be numerical. She just had a very different view on how to approach things. So, a lot of it is understanding that people are different and understanding what she valued, how she wanted to be approached, and how to communicate within that set of rules.

This view about communicating within the boundary of what people value was also supported by Alex (industry leader) who regarding effective communication posited that customizing your information and talking from the perspective of what matters to the people is one of the ways by which one can effectively communicate to a broader audience. He explained this by saying:

I think you have to think from their angle, like, for example, if you're talking to someone from marketing, I'm an engineer, right? So, I think from their perspective, you have to know, okay, what things matter to them. From the information that you have, you have to *kind of pair those two together. Because from their perspective, maybe they don't care about technical details, but they only care about how the product is going to sell. Is the product going to be marketable? So, you kind of have to kind of highlight your conversation towards that angle they have. I think it's kind of like knowing the audience and shifting the focus toward whatever they may wanna look at.*

Lilly (ABET leader) approached her view on the importance of communication skills to leadership from the perspective of internal and external communication. She noted that leadership requires being able to communicate to the external audience what the internal goals are and being able to know what is important to each individual when communicating internally. In her own words, she said:

I think engineering leaders have to be good communicators. So good communication is both internal and external. So for example, let's talk about external communication. During strategic planning, when a college is going forward to talk about "We like to start these new programs. We'd like to change these programs. We're going to need $20 million to do that," that requires me to be able to be able to communicate well to the external audience what our internal goals are…. Internally, I think it's understanding the cultural differences between the departments but also, at some level, cultural differences and communication differences between the various department chairs….. So internal communication just requires understanding what is important to each individual.

4.2.2.3. Listening Skills

Another essential engineering leadership skill identified by ABET and industry leaders in this study is listening skills, emphasizing listening to understand or listening with understanding. Sawyer (ABET leader) believed that listening is the most important aspect of leadership and intertwines it with communication by noting that it is only when you listen very well that you can receive the right message that is being communicated to you. Speaking of this, he said:

> *Number one is listening, listening before talking. So, when I say communication, it means receiving, making sure you're receiving the right message. That you are receiving the authentic message that comes from the constituencies or from the stakeholders. Because then, you understand how to serve them. So listening is probably the most important aspect of leadership.*

When he was further asked about the reason for this viewpoint, he told a story of how he misinterpreted something that was communicated to him and learned from that incident. He said:

> *Well, I can tell you, I thought that I heard someone clearly but later found out I heard them wrong, and I learned my lessons. So, I have had many failures and I have admitted my failures. I try to learn from those daily, it's a lifelong learning process.*

Lilly (ABET leader) attributed her evolvement as a better leader to her ability to know the importance of listening to all members of her team when she said:

> *I think I'm a better leader here at my second college than I was at the first college. I think, at the first college, I don't think I understood as much the importance of listening to all constituents or valuing the contribution of all departments. I feel like I have a much better sense now that the whole college in this case is made up of many parts, and each part is really important. And to ignore a part because, in my mind, I can't see its importance is on me, not on the unit.*

Similarly, Justin (industry leader) attributed his leadership maturation to his desire to model his character after the engineering leaders he looks up to as mentors, specifically citing listening with understanding. He stated that:

> *So, I think that's how over time I have grown, I've had great examples and mentors and leaders, and I can see how they work, and it gives me a desire to be like them. I see how, for example, I've got one of the owners here at the company, when we have a personnel problem, they don't talk a lot, they do a lot of listening and see, and me, I just want to pipe off and say you're fired, and he'll be just listening with understanding. And so, it's through experiences like that where my leadership, I guess, is growing.*

Kate (ABET leader) noted that while problem-solving is a big part of engineering, listening with understanding should be the first major step of the problem-solving process. According to her:

> *A big part of engineering, we like to say, it's about imagining things that never were and looking at the future and saying, why not? And that kind of thing. But really, we're trying to solve the problems of people and the best way to solve people's problems is to start by listening to them and trying to understand what their needs are.*

Also, Fredrick (engineering leader) noted that he became smarter when he started listening to others and he pointed out that listening with the understanding that everyone on a team is striving to do the right thing even though they may be proposing different solutions and updating one's views or convincing others of one's view has been the hallmark of every good leader he has come across. He said:

> *Hopefully, we learn from our successes, right? And that probably happened with me when I started listening to people more and suddenly realized, hey, I'm a lot smarter when I*

> *listen to other people……I mean, if you look at things in a very positive, let's say optimistic way, it may be a naive way, everybody in a project is trying to do the right thing. And yet, they may be proposing very different solutions. Things that take you in opposite directions. And the only way to rationalize that is to understand why they're advocating these very different positions. And if you can never do that if you're the leader, you can close the door on one and dictate what's going to happen but you're not going to get the best solution in the best way with that approach. So, that's why I think that every good boss, every good leader I've ever had has that ability to really listen, to see things from your perspective and either update their own or convince you of theirs eventually.*

Finally, Alex (engineering leader) regarded listening as a way to foster good decision-making in a challenging environment like engineering where you have to constantly make trade-offs. He stated that:

> *So, I think as an engineering leader, you also have to listen to other people because in a really challenging environment where you have a lot of technical decisions, sometimes it's not really about perfect decisions. There's no perfect decision. Nothing is perfect. Everything is about making tradeoffs. So, you have to think, and you have to let other people have their own thinking. You have to allow yourself to know what they're thinking so that you know what the best tradeoff is.*

4.2.2.4. Empathy

Empathy is another essential engineering leadership skill that industry and ABET leaders in this study deemed as necessary for successful engineering leadership. They noted that the ability of the engineering leader to see things from the perspective of others and show that they care is very key to promoting a healthy work environment, getting an optimal solution when problem-solving, and fostering the resilience needed to succeed when the going gets tough. For instance, Henry (industry leader) believed empathy is crucial for effective problem-solving, and through understanding the current situation with the people or market, empathy helps identify a pathway to achieve desired outcomes. He described this by stating that:

> *I'd probably put empathy at the top….Okay, I think that is where true problem-solving can come from. It's understanding the position of the person that you are trying to work with or the market you're trying to address. I think if you can understand or try to begin to understand where that person is coming from, you can understand what their needs are. .....trying to understand where they are today and then link that with a pathway to get to where they want to be. I think that's why empathy is so important.*

Similarly, Fredrick (engineering leader) opined that empathy is crucial for understanding and addressing problems, noting that looking at things from other people's perspectives could potentially lead to more effective solutions. With regards this, he said:

> *You need empathy. You need to be able to understand people, and, and see things from their perspective as well as your own….you think of all the problems in the world that would go away if people had more empathy. I think it's a very important skill because, first of all, they may be right and you may be wrong. I mean, they may be seeing something from a perspective, that is, let's say correct better than you and they've thought this through in a way you haven't and if you cut them off, you've lost the optimal solution.*

George (industry leader) regarded empathy as an important attribute of leadership needed for team members and employees to be invested in, to build resilience within the organization, and to achieve success as a leader. He stated that:

Well, if you're not empathetic to your employees' situation or to your followers' situations, they don't have any reason to be invested. They're not invested, and their level of engagement is not sufficient to help them endure in the process, to complete the process, or to want to succeed. It doesn't help them build any resilience….. If you're empathetic, they have, they have a tendency to rely on you and to trust that if they just keep pushing forward a little harder, they will actually achieve the end result they need. You'll be successful as a leader, right?

Sawyer (ABET leader) noted that being empathic is the strategy that he used to overcome most of the challenges he encountered in his career as an engineer and as a leader. In his own words, he said:

So, I would not react to people who are getting emotional about certain topics, and I would try to listen to them, listen to where they come from, what are their perspectives. And I try to see the world from their perspective to understand them. So, I have overcome not all the challenges that I've had throughout my career, but most of them that way.

Allison (ABET leader) noted that being empathic and letting your employees know that you have their back is an important characteristic that an engineering leader must cultivate to move things forward. While expressing her views on this, she said:

You have to take care of the people that work for you. Whether it's a committee of people, or whether it's people that are your direct employees. They need to know that you have their back. That if they make a mistake, you're not going to crucify them for it. And you're going to help them when they have trouble….It is a really important skill if you expect to *move things forward…. Sometimes that involves putting yourself in their shoes and try to say, well, why would they think this way?*

Finally, Aaron (engineering leader) admitted that empathy is what has helped him work successfully with people who are not engineers like himself. He explained that:

I moved into an area that is not engineering-specific…when it comes to explaining engineering principles, right? I have an opportunity to say, this is why we do what we do and this is why we choose the projects that we choose and prioritization…our business manager is like, well, that doesn't make any business sense and so we can analyze it from a different viewpoint rather than strictly, does it make engineering sense? And so, yes, I've seen that many non-engineers in this area have expertise in other areas. I'm learning how to do engineering better just by seeing it from their eyes.

4.2.2.5. Rationale Articulation or Explain the Why

Rationale articulation is another essential engineering leadership skill that the ABET and industry leaders in this study identified as crucial for effective engineering leadership. They said that the act of "explaining the whys" behind every decision is the bedrock of motivation. It not only gives people a sense of purpose, but it also enables them to cooperate and work hard. Norah (engineering leader) shared her views on this by saying:

Being able to communicate your why is huge, and again, that, I think that goes across all functions…. I think it's important because you have to be able to give people motivation on what they're in for, on what they're doing, right? Sometimes the tasks that you give somebody may feel pointless, right?…. I'm just throwing out examples, right? We're going to spend two weeks just focused on this one training for this new tool. And if I just say,

> *Hey, cut all your other work and just do this, people aren't going to do it, right? You're going to have some people to do, but you're not going to have them all. So, you need to explain. We have to move to this new tool because this is what the customer is expecting and if we don't comply with this, then we lose money or we have to redo it later…***.** *So, being able to explain, you know, why are we slowing down is so we can speed up or why is this simple task of looking at this bolt or something, matter in the bigger picture?*

Justin (industry leader) believes that based on his experience as an engineering leader, and one who has to work with a lot of people from diverse backgrounds, one of the most critical things to getting people from diverse backgrounds to be more willing to work with engineering personnel on a project is rationale articulation. He describes his views by saying:

> *When you're speaking with other engineers, they understand the language in transportation talk, for example, like clear zone requirements but when we talk with the public, why does the road have to be so wide? Why do you have to have so much right of way?.... that's where you just take a step back and explain to them the rules and the regulations that we have to work with. And just on a simple, basic explanation, have you ever been driving down the freeway, and you wondered why there's so much flat space off to the side of the road? And that's where we explain that's called a clear zone, where it's free of any obstruction. In case an errant vehicle goes off the road, it gives them the ability to come back on. And so, once you explain the process of why we need such a wide right of way, for example, they'll understand it and they're a little bit softer and more willing to work with you when you do that.*

Finally, Allison (ABET leader) believes that rationale articulation is essential to leadership success because people will work hard if they know why what they are doing matters. She stated that:

> *The leader also has to be able to articulate to various groups of people what the requirements are and what this is going to do and why. Why this matters, I think; that's really key for people. People will work really hard if they understand that what they're doing makes a difference.*

4.2.2.6. Problem-solving and Critical Thinking

The engineering and ABET leaders in this study consider problem-solving and critical thinking skills as essential engineering leadership skills needed for leadership success. They noted that it is important that the engineering leader be aware of the fact that contrary to the right and wrong mindset in engineering textbooks and training, big leadership decisions are often not right or wrong, but usually on a spectrum. This often requires the leader to take a step back and consider if there are more nuances to the problem. For instance, Henry (industry leader) shared his views about this when he said:

> *Usually, the answer is not going to be nearly as black and white as we want it to be with the number. Usually, the answer is in the nuance and understanding a little bit deeper than just the number. So, the numbers might tell us that, no, we can't do this, but if we look a little deeper into that problem…and if we can release ourselves from that for just a second and say, all right, yeah, the numbers say this, but let's step back and try to see if there are any more nuances to this problem that we can solve. That will still make two truths true at the same time. Yes, the number is correct, but we also have something else that is correct at the same time. Sometimes, we ignore that second truth.*

Also, Fredrick (ABET leader) shared the view that the decisions involved in problem-solving are sometimes not right or wrong but on a spectrum. He stated that:

> *These big leadership decisions in the end are not right or wrong. They're on a spectrum from sub-optimal to optimal, and the sooner we get them thinking that way, I think the easier it becomes to acknowledge that a decision was suboptimal. , and not take that as a judgment on you personally, right? It's, hey, based on what I did, these are the decisions I made. These are why I made the decisions. It turns out I could have done better. That's different than saying you're wrong.*

Aaron's (ABET leader) view on problem-solving is shared from the perspective of working with people who do not have an engineering background. He noted that in such cases, instead of being analytical, the engineering leader needs to offer more explanation. He expressed his view by saying:

> *Engineers are natural problem solvers and we can dive into the details so quickly when in reality, a brief explanation would probably go a lot further to help the situation move forward. But we want to pick apart every detail to make sure that all the analysis is done correctly when in reality, they just needed an explanation of their question of why. So that's another challenge is we are trained to break problems down into their minute details and as you become a leader, you become a manager, and that becomes less and less important.*

4.2.2.7. Humility or Ego Management

Humility is another essential skill that the industry and ABET leaders in this study considered crucial to engineering leadership success. They noted that engineers, because of their training, often have discipline pride, which makes them think they are better than people from non-engineering backgrounds. These leaders agreed that a leader in the engineering field needs to recognize the expertise of people from other fields of study. They also indicated that being open about mistakes, acknowledging them, and saying sorry to all parties involved, earns the engineering leader respect, rather than portraying, being perfect, as people can see through that. With regards to recognizing the expertise of people from non-engineering backgrounds, Fredrick (ABET leader) said that:

> *Your technical expertise may be deep and narrow, but, each individual, ideally, each individual brings some unique expertise to the table…. The people in marketing, the people in sales, they don't know what we know, that's true, but you don't know what they need to know too…. A marketing person knows how to position a product, I don't know how to do that. Now a salesperson is out on the frontline dealing with the customer, which, maybe, I never do,…. you have to humble yourself and recognize that there's a vast world of things that you can't do, and you need to depend on those other people to get that done. And, and I think that's really that's really the key to success.*
>
> *Similarly, Aaron (industry leader) noted that:*
>
> *And I think by understanding that you can learn something from anyone….. A little bit of of humility when you go into these things goes a long way.*

Kate (ABET leader) also shared this view about discipline pride, noting that engineering is training and not synonymous with wisdom, and that humility is an important aspect of engineering leadership. She stated that:

> *There is something wrong with discipline pride…. Sometimes there's a bit of a tendency to think that our education makes us better than everyone else, and maybe wiser than everyone else. But I haven't run into anything that's made me think that's true…. I guess this is all leading up to humility; is another really important aspect of engineering leadership…. We're not better or wiser than our fellow men are. We are people who have a high degree of skill and specific knowledge and that's great. You know, engineering is training, it's not intelligence. It's training… it's not synonymous with wisdom. It's just my training…. It's an area that I trained for. It's not something I was born with.*

With regard to ego management, Maxwell (ABET leader) noted that admitting any mistake made in the course of decision-making earns the leader forgiveness and respect while portraying the "I am perfect" attitude makes people lose respect for such a leader. He took a cue from his leadership experience concerning this, admitting that he had been wrong at all levels of leadership, but admitting the mistake and saying sorry is how to manage such situations. In his words, he explained this by saying:

> *As you know, engineers tend to be perfectionists. But when you lead people, and you work with people, you might be wrong. You might say, let's go in this direction, and it turns out to not be correct. The end. To say, oops, my fault. I was wrong. I have found in all levels of leadership; I have found I was wrong. I'm sorry. I'm going to do my best to fix it. That gets you a lot of forgiveness. Whereas, if you sort of pretend, oh, I wasn't wrong, that doesn't work with people because they can really see through that…. And that I'm perfect, I'm not going to say I'm wrong, it just doesn't get you anywhere and people lose respect for you. Because while you have to respect people, the people that you're leading, they have to respect you too.*

4.2.3. Sub-Theme 3: Needed Engineering Leadership Skills

The needed engineering leadership skills identified by the engineering leaders in this study are fearless exploration, strategic visioning, lifelong learning, ethical and trustworthiness, demonstrative leadership, decision-making, collaborative followership and delegation, flexibility, organization and time management, and leadership identity awareness. This was articulated by a total number of five to eight engineering leaders who participated in this study as shown in Table 4.3. This section presents the findings of the needed engineering leadership skills as foretold by the engineering leaders in this study.

4.2.3.1 Fearless Exploration Skill or "Not Afraid to Fail"

Fearless exploration, according to the engineering leaders in this study, is described as the ability of the leader to act without being afraid to fail, while also understanding the risks involved. Fearless exploration is identified by the ABET and industry leaders as one of the needed engineering leadership skills necessary for success. According to the participants in this study, fearless exploration is a means of avoiding catastrophic failures because it involves making mistakes and learning from them. Also, they noted that failure is one of the ways by which leadership acumen is acquired. This latter view was shared by Sawyer (industry leader) who stated that:

> *So, it (leadership) requires a lot of soft skills. And soft skills, some of them are taught, some of them you have to acquire through experience, through mentorship, and sometimes through failure…. Failure is the best teacher, but it's not the most pleasant teacher, Some people have to fail several times to learn and some just never learn…. So, I have had many failures and I have admitted my failures. I try to learn from those daily. It's a lifelong learning process.*

Fredrick (ABET leader) believes that a leader is fundamentally needed to make decisions, however, there are times when the decisions made will be wrong. He noted that it is important for a leader to have the confidence not only to make decisions but also to be wrong. He expressed his views by saying:

> *Your job is to fundamentally make those decisions. An indecisive leader, a wishy-washy leader, a leader that can't make up their mind because there's always another piece of data that they want to get, to me, those are ineffective leaders. That really ties in with confidence. I mean, I think those really go together because you have to have the confidence to be wrong sometimes. The confidence to say, I made a decision, yeah, it was wrong. We should have gone the other way. To have the confidence to have made that decision, but also the confidence to acknowledge your mistake.*

Raymond (industry leader) also shared this view about the fact that it takes self-confidence to admit to being wrong when he said:

> *I think it's hard for anybody who has a sense of pride... to be wrong. And so, that takes self-confidence to accept that you're wrong, being able to stand up to what you think is wrong in society, on a project or whatever, that takes a lot of self-confidence.*

Maxwell's (industry leader) perspective on being willing to be wrong could be interpreted to mean that leadership in the engineering field is not for anyone who is not willing to be wrong. Sharing this opinion, he said:

> *It (leadership) has tremendous value because you can do what you can do as an individual but to be leading a team, to be leading an organization, you can be far more*

productive that way. It has a lot of value but it takes time. It takes effort. It takes being willing to be wrong.

Justin (industry leader) opined based on his experience that mistakes are unavoidable in engineering leadership and he believed that it is a means of avoiding catastrophic failures if properly managed. In his words, he said:

And so, understanding that, yes, we are going to falter. We're going to fail, but we can fail forward and we can, you know, get better from that…. I had a friend share with me, um, the acronym FAIL, F A I L stands for First Attempt In Learning. When you talk about catastrophic failure, right? Typically, that is multiple failures that add up to something that's just horrible…. And so, if you can learn from your mistake and make those changes, the idea or the probability of catastrophic failure is minimal.

4.2.3.2. Ethics and Trustworthiness

Engineering leaders in this study believe that being ethical and trustworthy is a leadership skill that is foundational to the practice of engineering. They emphasized the importance of the leader having strong ethics to put their feet down in situations that collide with the engineering code of ethics. For instance, George (industry leader) shares his views about being ethical and not compromising when presented with situations that defy ethical standards. He described this by saying that:

I think that integrity, not compromising when you feel like you're outside of ethical boundaries, or when you feel like there are decisions that harm others as a role, from your role as an engineer. I think that's important. I think that you need to take that engineering duty very seriously. And if you have the potential to harm others, or you see *that risk, you need to stand behind it and take the high ground. And I think that is important as an engineer and to not capitulate or give in to what other leadership demands are or what other productions strategies require.*

Kate (ABET leader) expressed her views on following the code of ethics of the engineering profession. This is important because it means observing the profession's code of ethics is what gives identity to a leader in engineering. The implication is that anyone not observing this code of ethics, even if in principle, such a person is regarded as part of us by training, in practice, such one is not of us. She stated that:

Well, again, I guess I would define it (engineering leadership) as leadership that's set in the context of our profession. And I guess when I think about our profession, I tend to think about the Society of Professional Engineers' code of ethics. So yeah, I guess I would define engineering leadership, as leadership that that always has the goals of our profession in mind.

Similarly, Raymond (industry leader) emphasized the importance of ethical understanding and conduct to engineering leadership success by saying that:

Yes, you need to have strong ethics. You need to understand the engineering code of ethics, you need to be multidisciplinary to the degree possible.

Also, Sawyer (ABET) when sharing his opinion on the nature of engineering leadership categorized ethics as a required skill for leadership in engineering. He stated that:

Well, a part of the leadership for an engineer is something that they can be taught. They can be taught, while a part of it is inherent in nature. Not everyone is born a leader….

but leadership requires clear communication, requires trust based on ethical conduct, and moralities.

4.2.3.4. Lifelong Learning

Lifelong Learning is another needed engineering leadership skill that the industry and ABET leaders in this study pointed out as necessary for leadership success. These leaders shared how they are continuously honing their leadership skills through reading books, training, podcasts, and experiences. For instance, Henry (industry leader) attributed his leadership acumen to learning from books. He said:

> *I listen to a lot of books and those books, many of them have to do with business management, business management techniques, or maybe entrepreneurial mindset as a whole, which would help me understand the big picture of operating a business. So, like we need the accountant to be able to do these things in order to have the business run the way it needs to run…. I would say would be listening to books and trying to look at the lessons that I get out of those books in my practice.*

Similarly, Sawyer (ABET leader) attested to being influenced by a book he read on leadership which gave him a perspective on being a servant leader which is the leadership identity that guides his leadership practice. He explained this by saying:

> *One of the influences is, I guess a book that I read, which had an impact on me, the book called Synchronicity (The Inner part of Leadership)…. That book had a lot of influence, in terms of understanding what is servant leadership and then realizing that, where Gandhi came from or where, you know, most of the leaders, that necessarily have a leadership position and are not presidents or vice presidents of this and that, and people*

still follow them… book influenced me more than anything else. No, it didn't dramatically change me suddenly overnight, but it just turned on a lot of lights for me.

Lilly (ABET leader) believes that engineering leaders must be informed about what is happening nationally and internationally to be able to connect well with the broader landscape. She stated that:

I think engineering leaders need to get outside of being just engineers and be able to see the broader landscape, which means doing a lot of either reading or listening to podcasts or however we gather information today to sort of see what the horizon is. You have to be able to see what's happening nationally or internationally, you know, to be able to communicate that really well.

Arron (industry leader) also gave his views on this by emphasizing that adopting a growth mindset is key to being successful in the engineering field. He shared his views by stating that,

Continuously learning and being of the learner mindset rather than the judge or fixed mindset. And I think as engineers, we like to be judges because the answer is in the back of the book, right? I know the right answer. But in reality, we need to bring in things like politics and emotion. And that is not an easy thing to do because you can't quantify it. You can't put that down.

Norah (industry leader) described that one of the ways by which she engages in lifelong learning is to share her leadership experience and listen to other people's experiences in order to avoid making their mistakes. She explained this view as:

And then being at the level I'm at today, you know, it's just you've got to listen to the battle scars of other people, and you've got to share yours too, so that people understand where you've come from, and in that communication and that trust, like you kind of internalize their experiences a little bit so that you can help not make their mistakes too.

4.2.3.5. Strategic Visioning or Big-Picture Oriented

Strategic visioning is the ability to see the big picture and it has also been identified as one of the needed engineering leadership skills by the ABET and industry leaders in this study. Allison (ABET leader) described the importance of having the ability to see the big picture and aligning that with the organizational mission as vital for effective leadership when she said:

So, to be a good engineering leader, you must be able to step outside of your specialty, and look at the big picture, and understand how the big picture fits in with the mission. You have to be very big-picture-oriented. You have to be able to step away from the individual tasks and see how everything integrates and then you have to be able to communicate that.

This view was also shared by Aaron (industry leader), who described seeing the big picture as the ability of the leader to be able to explain why what they are doing is important, and how it connects to the overall purpose of the organization. He encapsulates this by saying that:

For instance, we have design squad leaders and they are engineering managers and they are over very technical things and they have to have the technical knowledge and be able to apply it and be able to communicate to those frontline designers what that means, but they also have to be able to pull the purpose of the department or that project and be able to translate that down into their instructions, to say not only here's how you design a *curve or here's how you model a roadway, but this is why it's important. This is the bigger picture.*

He further lamented that it took him a long time to realize and understand the concept himself saying that:

Now, as you move on, you're less and less technically oriented, but you're more and more big-picture oriented. And instead of focusing so much on the technical aspects of getting it just right, I would now, if I were to go back into that, I would say, how does what you're doing improve the quality of life? So, give that bigger vision, the purpose behind what they're doing. And I've learned over the years that I could have been doing that from the get-go. I could have, I didn't know it. I didn't understand it myself.

Henry (industry leader) opined that strategic visioning is the hallmark of a good leader as this connotes the ability to foresee the resources needed to solve a problem within the engineering team. He mentioned that:

I think in my mind, what makes a good leader is they can look at the big picture and see all of the resources that are needed to solve that problem and can identify those talents within the engineering team and apply those talents to the problems that need to be solved.

Another important construct that emerged from engineering leaders that relates to seeing the big picture is the ability of an engineering leader to foresee how what they produce will influence human situations (industry leader, George). Similarly, how their products will be used was also regarded as another element of the big picture by the participants (industry leader, Norah).

4.2.3.6. Collaborative Followership and Delegation

Collaborative followership and delegation skills have also been identified by the industry and ABET leaders in this study as a needed engineering leadership skill that is very important to leadership success. They indicated that leaders should be good followers whenever they find themselves as members of another team. They also noted that to achieve success, a leader needs to learn to delegate. For instance, when talking about collaborative followership, Sawyer (ABET leader) shared his views that leaders should also be good followers without attempting to share in the credit. He stated that:

> *You know, a good leader is also a follower. Because sometimes you need to follow, and that's your constituencies, your stakeholders. So you have to understand what your stakeholders' needs are so as a leader, can address the needs…you do not have to be in a leadership position to lead. You can still lead without having a leadership position. This is another experience that I can share with you throughout my career, I've led quite a few projects, but I was not in the leader position. I helped the leader, but the leader got the credit for it, which is fine. The purpose was served, and everyone was happy at the end of the day.*

In the same light, Raymond (industry leader) expressed his views that leaders should aspire to be good team members and recognize that they don't have to always be in leadership positions to lead. He said that:

> *I think a leader also needs to be a good follower…and if somebody else steps up, or if you're on a committee, and a committee chair assignment rotates around, a leader needs*

to be a good committee member, a good team member, and allow for others to lead and not take over the leadership. Leaders don't always need to be in the leadership role.

In terms of delegation, Allison (ABET leader) believes that it is important to learn, as a leader, to delegate to free up your time, especially if you have capable hands around. She shared this view by saying:

And so, leaders have to pay attention to all of that kind of stuff. But they need to figure how to get rid of the stuff that doesn't matter….. Well, when we say stuff that doesn't matter, it's not saying it's not important. There are things that are important, that are relative, that don't require all your skill set. So you also have to figure out, are there people who can do things for you? Does your admin have the capability of doing some of these things that you've been doing that are taking your time?, that that individual has plenty of skills to do it, and can give you the finished product that you can then review, rather than you taking your time to search the records or whatever it might be. So, understanding that, I think it's Warren Buffet who said that our most precious commodity is time, We have to use it well.

In support of this view, Kate (ABET leader) told the story of how she wasted time doing things by herself when she was new to leadership. She described the experience as follows:

So, like, in my really earliest days, I was not good at delegating, and I actually wasted a lot of time doing stuff that these are the things that we pay the admin staff for and, figuring out where, you know, the boundaries between their jobs and my job was a little bit, I did have to learn to delegate certain things myself.

Justin (industry leader) shared his perspective on delegation that a leader in engineering must try to match people to their skills when delegating to ensure efficiency in engineering product delivery. This is in contrast to the view that, yes, this person has a background in engineering, and thus should be able to do this. This approach rather seeks to be intentional about matching people to their specific areas of interest. In his words, he said:

> *As a leader, we're going to find, okay, this person likes roadway design. This person likes surveys, the survey aspect is right of way. And so, if they know that we love them and we're trying to seek an understanding of what they want, then we're naturally going to take the old good to great book talks about getting the right person on the right bus, and then once they're on the right bus, you get them in the right seat…. And just because now we know what their capabilities are, what their desires are, and try and match our needs with what they can bring, then it's just naturally going to bloom and it's, the efficiency is going to be there in the engineering product delivery.*

4.2.3.7. Demonstrative Leadership or Leading by Example

Leading by example or demonstrative leadership is another needed engineering leadership skill that engineering leaders in this study, particularly, the industry leaders consider necessary for effective engineering leadership. They emphasized the importance of leaders exhibiting actions or behaviors that they expect from their team. This includes prompt execution of tasks and upholding of values that foster trust respect, and a positive workplace environment. For instance, Norah (industry leader) noted that leading by example is an essential characteristic of engineering leadership and a means of fostering a culture of trust within the team, and where she has found most success. She expressed this by saying:

> *So being an engineering leader, it's important to have that experience and that willingness to jump in and understand the problem firsthand. At least that's where I found the most success. So again, being that example, leading by example, and showing them who I am and what I'm doing, creating that culture of trust is a leadership trait that you can take into any function.*

Similarly, Henry (industry leader) attributed the success he found as an engineering leader to mentoring others and guiding them through the process having walked through it himself and leading by example. He stated that:

> *I have found myself regularly in leadership roles within engineering teams, and I think the reason I find myself there and have found success there is because maybe naturally it comes to me to be a mentor to other engineers…and because I understood those fundamentals, I had walked through it myself, I was able to help coach others to walk through the processes. I think a good leader is someone who can understand the problem that's being solved by the team and can show by example how to solve that problem in a good way. And so, they lead by example.*

Also, Sawyer (ABET leader) noted that walking the talk and being a role model is the essence of leadership, which means it is a core characteristic that constitutes effective leadership. He stated that:

> *Leaders are the trusted individuals by a group of people that they trust to navigate through a path, through a direction. Yeah. So, that's the essence of leadership….. As they say, walk the talk, you got to be the role model of what you preach…. So, be congruent,*

be aligned with what you say and what you do and follow up with the promises that have been made.

Justin (industry leader) described a leader as someone who is always trying to train their replacement when expressing his views on leading by example. He noted that:

Yes. I think an engineering leader Is going to have to have some patience, going back to that vision of a leader. A leader is one that is always trying to train their replacement. And so, if you have that vision as a leader, then you're going to have patience in teaching and, and mentoring and bringing those along, so that you can give them the experience…. If you can do that and understand that I think that's where being a true engineering leader, where it boils down to.

George (Industry leader) expressed his views on leading by example from the perspective of demonstrating actions that people can witness; not just passive leaders who merely give directions without actively participating in the actions themselves. He stated that:

I think that a big part of engineering leadership is leading by example. I think that a big part of it is being present to lead. I think that in order to demonstrate effective leadership, you have to be present, people have to witness it, they have to witness your actions in order for you to demonstrate engineering leadership.

4.2.3.8. Decision-Making Skill

Decision-making acumen is another needed engineering leadership skill that industry and ABET leaders in this study considered very important for leadership success in engineering. They noted that it is important that an engineering leader understands that the key to effective leadership is making decisions with the information you have at hand and recognizing that you’re never going to have all the information. They also noted that the ability to make quick decisions based on the data at hand is the hallmark of leadership. Fredrick (ABET leader) shared his beliefs about this when he said:

> *The ability to drill down and focus on what you have and make the best decision in the time possible, to me that’s sort of the hallmark of a leader…. When you're in a leadership role, people are looking at you, for direction, and decisions. Again, you may be evaluating different alternatives that different people are bringing to you but you've gotta pick one and you have to at some point acknowledge that there's always going to be risk, right? You're always never gonna have all the information.*

Similarly, Sawyer (industry leader) expressed his view on the ability to make decisions with the information at hand as a way to overcome decision-making difficulty when he said:

> *A lot of times when we become too analytical, we lose sight that we need to make a decision. So, decision-making becomes very hard for us. In this world, you’ve got to make a quick decision based on the information you have.*

Alex (industry leader) and Maxwell (ABET leader) discussed the importance of decision-making acumen for leaders in engineering from the perspective of supporting every decision made with facts or data. They noted that having evidence for what is driving a decision makes people to be more agreeable. Alex shared his views on this when he said:

> *Engineers are very detailed as far as the technical goes. So, they really want to understand, like, fundamentally, what is driving that decision?.... You have to be able to support your point of view, you know, you gotta have some type of supporting evidence for whatever you're presenting…. But if you don't show that type of evidence, I think*

people are going to have questions about, are you really doing the right thing or not? So, you have to talk about that.

Also, Maxwell expressed his views about this through his workplace experience. He stated that:

Well, the culture of engineering tends to be numerical. So, a lot of leadership has got to be numbers-driven. What does the data tell you? And, in my university, if you don't have data, you're not going to win the argument. Any argument or discussion that starts with, I think or I feel, is destined to be dead on arrival. It's got to be driven by the data.

4.2.3.9. Flexibility

Flexibility, which the industry and ABET leaders in this study described as the ability to accommodate the views of others and not be rigid about a personal stance is another needed skill identified as required for leadership success in engineering. They noted that a leader in engineering must be flexible in their approach to dealing with people as well as when solving problems. For instance, Maxwell (ABET leader) shared an experience about how he dealt with a situation in which he had to work with a boss who did not have an engineering background. He shared this experience stating that:

When I was an associate provost, my immediate boss was a history major. She had a Ph.D. in history, and she very much brought a liberal arts thinking approach to things. She did not tend to be numerical. She just had a very different view on how to approach things. So, a lot of it is understanding that people are different and understanding what she valued, how she wanted to be approached, and how to communicate within that set of rules…. There are differences dealing with people who grew up in different parts of the

> *world. None of them are horrifically difficult to overcome, but you need to step back and understand what makes that person tick.*

Aaron (industry leader) believes that being flexible requires adopting a learner's mindset by stating the "why" for your opinion and if you have a judger or rigid mindset, it is important to let it be guided by data or facts, not just an opinion. He shared this view by saying:

> *There's a difference between opinion and fact. And, uh, I think it's important to understand that just because you have an opinion about something doesn't make it so, doesn't make it true. Um, and so when you're a judger mindset, you should base your judgments on fact, not on opinion. And if you're a learner mindset, right? Like we're always learning. We say, this is my opinion, and this is why I think this way. And then say, I am open to being wrong…. I'm open, I'm open to new ideas.*

Raymond (industry leader) approached this subject from the perspective of being competent and not just book smart, and that competency stems from the ability to realize that real-world situations are not as clean as the textbooks present them. As such, there is a need to be flexible to realize that if you don't pay attention to the data or results, you could end up with a wrong answer. He described this by saying:

> *You need to be a good engineer from the technical side, and by that, I don't mean only being book smart, but being competent…when an engineer, a young engineer graduates, they pass the fundamentals of engineering exam and everything…. So, what they have is maybe what we'd call book smart…. But when you get out in the actual field and you start making measurements, one, you certainly realize how difficult it is to measure things. It's all kind of dirty, the numbers aren't really clean. There are always problems in the data.*

But you need to be able to recognize when results are, or the data, may have problems with it. And so you don't just take it because it was in a book. You're able to crunch the numbers and all that, but you could still end up with the wrong answer. So, there's this kind of saying that I use with my engineers, it's better to be approximately right than precisely wrong.

4.2.3.10. Organization and Time Management

The industry and ABET leaders in this study have also recognized organization and time management as needed engineering leadership skills that are required for effective engineering leadership. They noted that being organized, being a list-maker, and paying attention to employees' requests are very important time management strategies for leadership success. For instance, Allison (ABET leader) expressed her view on the need to be organized as an engineering leader, noting that the higher you go, the more things you have to keep track of. She stated that:

Clearly, you have to be well organized because the higher you go in the organization, or the larger the group of people that you're trying to work with, the more things you have to keep track of. So you have to be very organized in that arena without getting bogged down…. As much as I hate doing it, I am still a list maker. And if I have things I know I need to do, I write them down. And that enables me to, every day, look at the list and say, okay, what's most important, what do I have to get done today that's most important.

Also, Fredrick (ABET leader) shared his views about organization and time management, noting that it helps the engineering leader in making sound decisions. He described his views by saying that:

You do need organization…. Organizational skills; again, nobody has confidence in a leader that seems like they're rushing, that needs to be told the same thing more than once because they're not attentive to the details. I think a leader that keeps to a schedule, that is organized with the information that's provided to them, that provides an environment where that organization, those organizational skills, pervade what they're leading,… I think good organizational skills lead to optimal decisions.

George (industry leader) described his views on being organized from the perspective of attending to employees' questions or inquiries as promptly as possible, indicating that they are probably stuck and cannot move forward. So, attending to questions or inquiries promptly, and removing roadblocks they might be facing, will be to the leader's benefit in the end. He explained this view by stating that:

I think that that presence when someone comes to you with a question, it probably can't wait because they're to a point where they're stuck and without getting that question resolved, they can't move forward. And, but I think that being present is also like you mentioned, it's more of a direct interaction and trying to build that rapport with the people you're trying to lead as well.

Norah (industry leader) expressed her views on this by describing how she helps her team free up their time to achieve work-life balance and avoid burnout. She described the experience of how she helps them resolve their to-do list by saying:

There's always a sense of urgency with engineering on, you know, hey, we got to get this done. And so, helping my employees understand when it's okay to take a breath, when it's okay to, you know, that'll be here Monday. You don't have to be here all weekend and *sacrificing your life for this bracket you're designing, you know, like helping them understand that time management piece. Because, you know, you don't live to work, you work to live…. So, something I like to do to help my employees is just one thing, what are your priorities? Let's know what's on your to-do list, right? And let's talk through, you know, when each of those things has to be done, or how do we communicate with if there are two number one priorities, how can I help you communicate with those leads that, hey, this isn't going to get done? Hey, I need two more days. Like, this is more important. You know, how do I help remove those roadblocks so that they can take a breath and not feel the stress of the world on them?*

4.2.3.11. Leadership Identity Awareness/ Know your leadership style

Leadership Identity Awareness is another engineering leadership skill identified by engineering leaders in this study as needed for effective engineering leadership. The Industry and ABET leaders in this study expressed their leadership identity awareness by describing their leadership styles and how they have been incorporating the principles of the leadership styles into their practice as engineering leaders. For example, Sawyer (industry leader) who adopted the servant leadership identity attributed understanding that leadership style to a book he read and described using its principles in his career and as an engineering leader. He expressed this view by stating that:

To me, leaders are servants. A good example of this is Gandhi or Jesus. There are so many leaders that they didn't call them leaders. It's basically based on the trust and the servancy that they have. So, this something that engineering didn't teach me…. I guess a book that I read, which had an impact on me, the book called Synchronicity and the Synchronicity book was a biography, a real biography of a person…. That book had a lot *of influence, in terms of understanding what is servant leadership, and then realizing that, where Gandhi came from or where, you know, most of the leaders, that necessarily have a leadership position and are not presidents or vice presidents of this and that, and people still follow them…. They're there to serve with every cell in their body. That's their intention.*

He further expressed how he is practicing this identity in his leadership by saying:

So, I have had many failures and I have admitted my failures. I try to learn from those daily,… the moment of realization that, okay, I made a mistake, I need to apologize. I need to correct it, and I need to move on. That's what I call humility. That's what I call humbleness. And that's one of the pillars of being a good servant leader.

Justin (industry leader) also described how they adopted a situational and authentic leadership style in their company which is focused on knowing the professional love languages of their employees and catering to that, as well as intentional delegation of roles to people based on their ability. He described his views on adopting an authentic leadership style to bring out the best in their employees by saying:

Our leadership within our company, our leadership core, what we'll call our attributes, first of all, we try to love the individuals that we work with in a professional way, so to speak. If we show our best interest to them, then they can feel love, to where they will want to perform at a high level…. So, we did a couple of years ago to understand the professional love languages of our coworkers or those that we supervise. And if we understand that, then that's how we cater our leadership style to those individuals.

Lilly (ABET leader) believes that people always have their expectations of one's leadership identity or style. She described this view based on her experience when she stated:

My challenge when I was much younger was being taken seriously because I was a woman. Particularly, when I was in a leadership position and maybe it was 90% male, realizing perhaps I would have a different leadership style; that didn't mean we weren't going to be successful, but the approach to getting to the goal would be a bit different.

4.3. Theme 3: Contextual Differences in the Definition of Engineering Leadership and Classification of Engineering Leadership Skills

Determining contextual differences in the definition of engineering leadership and classification of engineering leadership skills resulted from the phenomenological inquiry employed in this study. The differences provide insights into how situational factors in the work environment of engineering leaders and the size of the organization shape their definition and identification of engineering leadership skills. The two sub-themes that emerged and were discussed in this section are (1) ABET vs. industry engineering leaders' perspectives on engineering leadership definition and (2) the scale of industry and its influence on engineering leadership definition.

4.3.1. Sub-Theme 1: ABET versus Industry Engineering Leaders' Perspectives on Engineering Leadership Definition and Classification of Engineering Leadership Skills

This sub-theme offers an insight into understanding the differences, overlap, or agreement in the ways which engineering leaders conceptualized and articulated the definition of engineering leadership and engineering leadership skills in the educational and professional context of engineering. Table 4.3 summarizes definitions of engineering leadership by the ABET leaders and professional engineers in the industry. The letters DD stands for direct definition and PP stands for paraphrased definition.

SN	ABET Leaders	Industry Leaders
1	Engineering leadership is being able to manage process flow in accordance with the mission or goal to enable the things that need to be done to get done through the people because the people are your resource. – Allison, DD.	Engineering leadership involves technical knowledge and big-picture-oriented approaches. Leaders communicate technical concepts and translate the department's purpose into instructions, conversations on values, and mission discussions. - Aaron, PP.
2	Engineering leadership is an umbrella of leadership which is helping move a group in a direction I would like them to move because I see where they could go…. I sort of see leadership as getting people to follow you. It's like following the leader. -Lilly, DD.	I think any leadership, but engineering specific, I think is putting someone or a team in a position that they can succeed, and they don't need you. So, they can have their own thinking and they can pursue their passions and enjoy their work…I think it's about enabling people..- Alex, PP.
3	Engineering leadership is leadership that's set in the context of our profession. When I think about our profession, I tend to think about the Society of Professional Engineers' code of ethics. So yeah, I would define engineering leadership, as leadership that always has the goals of our profession in mind. – Kate, DD.	Engineering leadership means seeing the overall picture of what needs to be accomplished on the technical solution within a business unit and understanding how to engage people in solving that technical problem is probably how I would summarize it. - Henry, DD.
4	Leadership in engineering, like any other discipline, requires soft skills, unlike the military, which differs in its approach and structure. – Sawyer, PP.	Engineering leadership is having the ability to understand and work with the same tools that my engineers have, having high-level working knowledge to answer questions and understand potential issues and, fostering trust, and understanding their career expectations.- Norah, PP.
5	What defines engineering leadership is leadership over a technical effort. What is unique about engine engineering leadership is you can't separate it from the technical side of what is being done. And the result of every engineering effort is some sort of technical project. – Fredrick, PP.	Engineering leadership is leading by example. I think that a big part of it is being present to lead, taking responsibility for one's decisions and having integrity not to compromise ethical boundaries. -George, PP.

6	It is leadership in the context of goals associated with engineering, and philosophically, I don't think that's different from any other leadership. – Maxwell, DD	Engineering leadership involves not necessarily having all the answers but knowing where to seek them from others. It requires knowledge, experience, and love for coworkers, clients, and jobs. It involves guiding others through the project process, not just the technical side.-Justin, PP.
7	NA	Engineering leadership involves stepping forth to protect the public interest when clients' interests contradict the public good. Engineers have an ethical responsibility to be resourceful and efficient with client's money or resources, but must not resolve to cut corners.- Raymond, PP.

Table 4.3

A Summary of Definitions of Engineering Leadership by ABET Leaders and Industry Professionals

In terms of the engineering leadership skills identification, Table 4.4 shows the breakdown of the number of ABET and industry leaders who identified each of the listed skill as necessary for engineering leadership success.

Table 4.4

Engineering Leadership Skills Identified by the Participants

SN	SKILLS	ABET Leaders (N=6)	INDUSTRY Leaders (N=7)	TOTAL (N=13)
1	Technical Expertise	6	7	13
2	Teamwork	6	7	13
3	Communication	5	5	10
4	Listening	6	4	10
5	Empathy	4	6	10
6	Rationale Articulation	4	6	10
7	Humility or Ego Management	5	4	9

SN	SKILLS	ABET Leaders (N=6)	INDUSTRY Leaders (N=7)	TOTAL (N=13)
8	Problem-solving and Critical Thinking	2	7	9
9	Fearless Exploration	3	5	8
10	Strategic Visioning	2	5	7
11	Lifelong Learning	3	4	7
12	Ethical and Trustworthiness	3	4	7
13	Demonstrative Leadership	1	5	6
14	Decision Making	4	2	6
15	Collaborative Followership and Delegation	4	2	6
16	Flexibility	3	2	5
17	Organization and Time Management	3	2	5
18	Leadership Identity Awareness	2	3	5

4.3.2. Sub-Theme 2: Size of Industry and its Influence on Engineering Leadership Definition and Skills Classification

This sub-theme highlights how the definition of engineering leadership and the engineering leadership skills categorization are influenced by the size of the organization. This is explored through comparing how engineering leaders from the small, medium, and large sized companies who participated in this study defined engineering leadership and its associated skills. Table 4.5 shows the engineering leadership definition by engineering leaders with respect to size of the company, while Table 4.6. shows the distribution of industry engineering leaders who identified the highlighted engineering leadership skills as important for engineering leadership success in each size of the company.

Table 4.5

Definition of Engineering Leadership by Categorized by Company Size

SN	Engineering Leaders' Definition	Size of the Company
1	Engineering leadership involves being big-picture oriented and being able to communicate technical concepts and translate the department's purpose into instructions, conversations on values, and mission discussions. – Aaron.	Large
2	Engineering leadership is having the ability to understand and work with the same tools that my engineers have, having high-level working knowledge to answer questions and understand potential issues, as well as fostering trust, and understanding their career expectations. – Norah.	Large
3	I think any leadership, but engineering specific, I think is putting someone or a team in a position that they can succeed, and they don't need you. So, they can have their own thinking and they can pursue their passions and enjoy their work…I think it's about enabling people..- Alex.	Large
4	Engineering leadership is leading by example. I think that a big part of it is being present to lead, taking responsibility for one's decisions and having integrity not to compromise ethical boundaries. -George.	Medium
5	Engineering leadership involves not necessarily having all the answers but knowing where to seek them from others. It requires knowledge, experience, and love for coworkers, clients, and jobs. It involves guiding others through the project process, not just the technical side.- Justin.	Medium
6	Engineering leadership means seeing the overall picture of what needs to be accomplished on the technical solution within a business unit and understanding how to engage people in solving that technical problem is probably how I would summarize it. – Henry.	Small

SN	Engineering Leaders' Definition	Size of the Company
7	Engineering leadership involves stepping forth to protect the public interest when clients' interests contradict the public good. Engineers have an ethical responsibility to be resourceful and efficient with client's money or resources, but must not resolve to cut corners.- Raymond.	Small

Table 4.6

Distribution of Industry Engineering Leaders Identification of Engineering Skills based on the Size of the Company

SN	SKILLS	Large (N=3)	Medium (N=2)	Small (N=2)
1	Communication	3	1	1
2	Listening	3	1	0
3	Technical Expertise	3	2	2
4	Empathy	3	2	1
5	Strategic Visioning	2	1	2
6	Demonstrative Leadership	1	2	2
7	Teamwork	3	2	2
8	Rationale Articulation	3	2	1
9	Fearless Exploration	3	1	1
10	Humility or Ego Management	2	1	1
11	Decision Making	1	1	0
12	Problem-solving and Critical Thinking	3	2	2
13	Lifelong Learning	2	0	2
14	Ethical and Trustworthiness	2	1	1
15	Flexibility	1	0	1
16	Organization and Time Management	1	1	0
17	Collaborative Followership and Delegation	1	0	1
18	Leadership Identity Awareness	0	2	1

4.4. Theme 4: The Role of Training and Experience in Engineering Leadership Success

This theme examines the role of formal training in engineering leadership success from the perspective of engineering leaders who participated in this study. The theme highlights the role of experiential learning in leadership development from the narratives of the participants. Most of the participants decried the lack of leadership training in engineering while noting that they had to learn the hard way, through many mistakes and failures. A typical example is Sawyer (industry leader) who gave an insight into how he became the leader that he is today, noting that he has had many failures along the way. He described his experience as follows:

> *So, it (leadership) requires a lot of soft skills. And soft skills, some of them are taught, some of them you have to acquire through experience, through mentorship, and sometimes through failure…. Failure is the best teacher, but it's not the most pleasant teacher,…. So, I have had many failures and I have admitted my failures. I try to learn from those daily.*

Kate (ABET leader) also had a similar story to tell. She described how she found leadership hard when she first became a leader because she had no formal training, and that she became better by failing a lot. In her words, she said:

> *Gosh, it was hard when I first started because my university doesn't really offer any leadership training, so I've had to figure it out. So, I feel like, you know, the lack of training, stumbling around and failing a lot, which is kind of, it kicks stuff out, you know, like, it's embarrassing. I like to feel like I'm good at my job. And I haven't always understood what this job is supposed to be. Hmm … there was a really vague job description and no training, and I do feel like I just picked around for the first several years and just made some stuff up.*

Aaron (ABET leader) believed that getting trained on communication skills in college would have helped him in his career, and he also noted that having interpersonal skills to relate with others is essential, and working in teams is not the same as having this training. He shared his views by saying that:

> *I think it's that communication skills that you could learn in college and, and I think that that would have helped me a little bit. The other part would be Interpersonal skills and people skills…. We're very technical, we're abrupt, this is, these are the facts, this is what I've calculated. But, understanding how to talk with people a little bit more. I think that's something that you could learn in some courses in college. And to some extent you do when you work with teams, but it's just not the same.*

Raymond (industry leader) is of the opinion that engineering education needs to do more to enhance the communication skills of their graduates, as the problem about engineering graduates not being good communicators still lingers. He expressed his opinion that:

> *Sometimes, my team will send out an email and I'll look at it, oh my gosh, you know, that could have been worded a lot better…. So, I think one of the weaknesses we have in engineering education is on the communication side, and engineers frequently are not initially really good communicators. I would like to see more of that in Engineering education, I would like to see, both spoken communication, presentation, and all that.*

Alex (industry leader) also attested to the fact that it is imperative for communication and interpersonal skills needed to interact successfully with people, be taught in the engineering curriculum. He noted that although experience is a major way by which leadership acumen is acquired, nevertheless, there are core skills that can be taught that would be beneficial. He shared his views by saying that:

> *I think going back to my time, for example, the engineering curriculum, it's just technical. You don't get any interpersonal communication. You don't have that unless you do, like, an MBA. I know people that did both… then an MBA that kind of gives them some perspective…. School is not gonna be able to teach you everything, you have to learn things when you go to the field. But I think there are some core skills like that, like you know, how to communicate and interact that can be taught. I think that those are very important.*

CHAPTER 5

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

This study embarked on a phenomenological exploration to define engineering leadership and identify critical leadership skills from the perspectives of ABET leaders and professional engineers in the industry. The study gathered rich qualitative data through in-depth, semi-structured interviews with six engineering leaders from ABET and seven engineering leaders from industry, making a total of thirteen study participants.

Four prominent themes emerged from the phenomenological analysis to provide an understanding of engineering leadership from the perspectives of the engineering leaders. These four themes are: 1) engineering leaders' conceptualization and articulation of engineering leadership, 2) the core essences of engineering leadership, 3) contextual differences in engineering leadership definition and skills, and 4) the role of training and experience in engineering leadership success. As such, the four themes and sub-themes are used to answer the research questions.

5.1. Discussions on Theme 1: Engineering Leaders' Conceptualization and Articulation of Engineering Leadership

This theme encapsulates the various ways by which the leaders exemplified the core principles of engineering leadership based on their experience. This was explored using approaches the participants used in defining engineering leadership, their convergent and divergent views on engineering leadership, and their perception of the broadness of the role of an engineering leader in an organization.

5.1.1. The Definition of Engineering Leadership

The classification of prominent leadership theories and empirical research in the literature resulted in five approaches to defining leadership. These include *the trait approach*, *the behavioral approach*, *the power-influence approach*, *the situational approach*, and *the integrative approach* (Jackson et al., 2015; Yukl, 2013). Every definition of leadership in any professional sphere will fall into one of these approaches. The definition of engineering leadership provided by engineering leaders in ABET can be categorized into *trait*, *behavioral*, *power-influence*, and *situational* approaches. Three out of the six ABET leaders' definitions of engineering leadership fall under the *situational* approach with their emphasis being on having the goal and ethics of the engineering profession in mind as a leader. The remaining three fall under the *trait, behavioral*, and *power-influence* approaches with emphases on having soft skills as an engineering leader, managing people and processes to achieve organizational goals, and influencing teams to follow organizational leadership.

Similarly, professional engineering leaders in the industry that participated in this study defined engineering leadership with definitions that can be classified under the *situational, behavioral*, and *integrated* approaches. Three out of the seven industry professional engineering leaders' definitions fall into the *behavioral* approach with an emphasis on demonstrating ethical behaviors, leading by example, and collaboration. One out of the remaining four industry professional engineering leaders' definitions falls into the *situational* approach of defining leadership with an emphasis on engineering leadership that allows individuals or a team to thrive independently. The remaining three definitions fall into the *integrated* approach with an emphasis on having technical knowledge, solving technical problems, and having interpersonal skills to foster trust and work satisfaction.

It should be noted that while the *situational* approach was more pronounced in the ABET leader's definition of engineering leadership, the *behavioral* approach was more pronounced in the definition of the industry leaders. According to Northouse (2019), the main focus of the *behavioral* approach is what the leaders do and how they act. This approach is composed of task behaviors which explain how leaders help their members to achieve their objectives and relationship behaviors, which are how leaders help followers to feel comfortable with each other and the situation of their work. It is no surprise that industry leaders emphasize this approach in their definition of engineering leadership since the majority of their responsibilities involve hands-on technical projects and require them to take on active roles. Meanwhile, the *situational* approach focuses on situational variables such as the type of the organization, the nature of work performed by the leader's unit, the nature of the external environment, the characteristics of the followers, and how well leaders can adapt their behavior to lead effectively in those situations (Yulk, 2013). This resonates with the majority of the definitions given by the ABET leaders which focus on defining leadership within the engineering context.

5.1.2. The Diversity and Commonality of Perspectives on Engineering Leadership and General Leadership

The majority of the engineering leaders in this study, when asked to differentiate engineering leadership from general leadership, or leadership in other domains, found it very difficult to articulate differences between the two leadership domains, and hesitated in their responses. For instance, one of the engineering leaders in the industry said, *"You know, yeah, it's hard for me to tell. Is there any difference? Leadership is leadership. Another leader from ABET said, "I'm not so sure if engineering leadership is that much different than just leadership in general*." When asked to further explain the reasons for their hesitation and why they think there might not be a difference between the two leadership domains, their responses implied that the traits and characteristics of a good leader are the same regardless of the leadership domain. The views shared by these engineering leaders are in agreement with the study conducted by Cox et al., (2012) in which the authors concluded that there was little difference in engineering leadership attributes and general leadership attributes. Also, Newstead et al., (2021) posited that the attributes of good leadership are across multiple domains and situated in being ethical, authentic, and virtuous.

Furthermore, in examining the divergent views of the engineering leaders on general leadership and engineering leadership, a further probe in asking these engineering leaders to share their views on whether there are specific skills or competencies that are unique to engineering leadership compared to leadership in other domains was conducted. This resulted in the dichotomous differentiation in which the engineering leaders characterized engineering leadership as consisting of technical expertise and a host of soft skills, also referred to as interpersonal skills, people skills, or professional skills. They noted that technical knowledge or expertise is a major contributor that differentiates engineering leadership from general leadership and that technical expertise is not only a necessary component of engineering leadership but also a core component of engineering leadership. This dichotomous view of characterizing engineering leadership resonated with the assertion made by Newstead et al., (2021) and described in Figure 5.1 below, that there is evidence in philosophy and social science literature that the dual-core of good leadership is character and competence. In addition to this, Rottmann et al., (2015) in their grounded theory study on engineering leadership pointed out that there have been calls for engineering students to be socialized to view their discipline as having both technical and humanistic aspects.

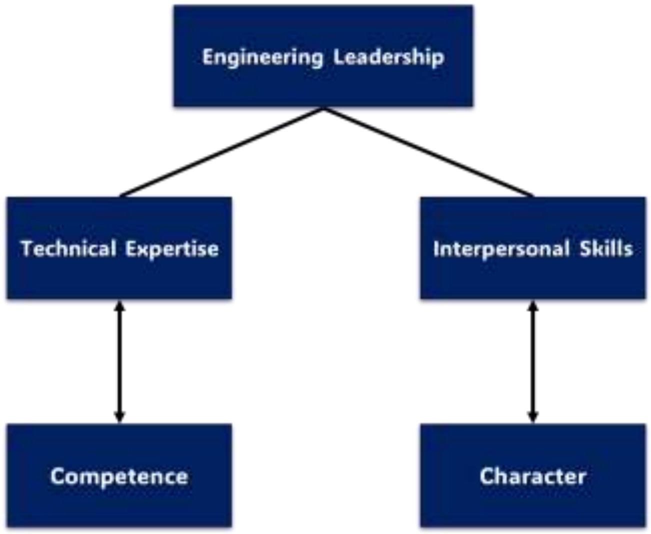

Figure 5.1. The dichotomous view of engineering leadership.

In further discussing this dichotomous view of engineering leadership, while the engineering leaders in this study have reiterated that technical expertise is a core characteristic of engineering leadership, they argue that the interpersonal skills that a typical engineering leader will need on the job to lead effectively and successfully is more important than the technical knowledge. This view was generally implied by many of the engineering leaders but was not precisely articulated. For instance, one of the industry leaders said, "*I think of all of the calculus I had to go through to get an engineering degree, and have I ever used any of it on a regular basis? I would say no, and especially not as a leader, right?"* Also, an ABET leader, when expressing his views on this said, *"So, it (engineering leadership) requires a lot of soft skills*." However, one of the engineering leaders in the industry was able to articulate this view that other engineering leaders in the study have been implying but were not able to precisely articulate. He said concerning engineering leadership that,

> *"I will probably say maybe like 70 percent is just general leadership, but you have to have a technical understanding and a technical side as well to be that engineering leader.*

…. if we don't have an understanding, then you're not going to have the clout of those that you work with to come to you, because part of that engineering leadership is the understanding of that technicality of it as well."

This view was supported by Hess (2018) who noted that typically, an engineer in any technical position will spend less than 50% of his time on engineering-focus tasks. He asserted that much of the day-to-day activities of practicing engineers, irrespective of their vocations, will be spent on interacting with other individuals or groups of individuals in and outside the organization, where they will need to make decisions and discuss directions, goals, and performance. He concluded by saying that the percentage of engineering-focused tasks decreases with the responsibility level, and less than 20% is typical in high-level leadership or management positions. Gruber et al., (2022) also lend an insight into this view by quoting a research participant identified in their study who said:

"As a student, I had a view that they (soft skills) were not as important as my technical knowledge; it is the technical knowledge that would bring the solution of problems or new ideas. But now, working, I see that you will hardly have the ideas for the problems alone. And the time you spend dealing with people (or with yourself) is extremely longer than the time you deal with technical information. In my case it is roughly 90% people to 10% technical. So today I see that these skills are extremely important to achieve a good performance at work (p.63)."

In addition, Reeve et al., (2015) in their study on the ebb and flow of engineering leadership orientations noted that on analyzing their data of engineering professionals by developmental stage, they found that as engineering professionals with at least six years of experience progressed through their careers from students to junior engineers to senior engineers, and that the percentage who prioritized technical mastery dropped from 69% to 28%, while the percentage who prioritized collaborative optimization and organizational innovation rose from 20% to 43% and from 11% to 29% respectively. Also, Bowman & Farr (2000) posited that as engineers advance up the corporate ladder, leadership becomes an essential skill. Senior management engineers are more interested in the business side of procuring and successfully managing projects, hence they spend less time on traditional engineering details.

Figure 5.2 shows the dichotomous distribution of soft skills and technical skills according to the findings in this study while Figure 5.3 shows the relationship between leadership responsibility and technical skills usage in the workplace.

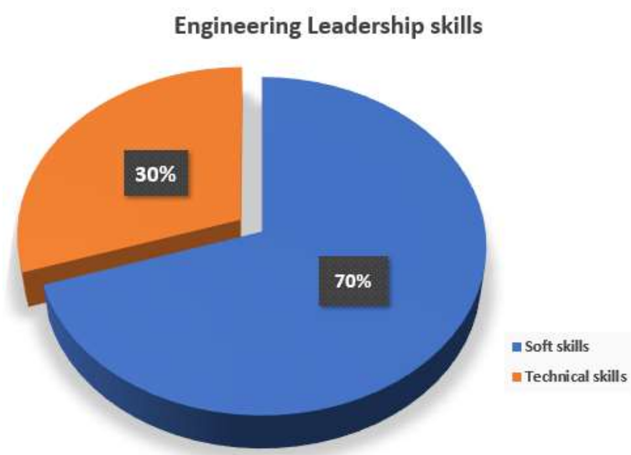

Figure 5.2. 70-30 Engineering Leadership dichotomous distribution.

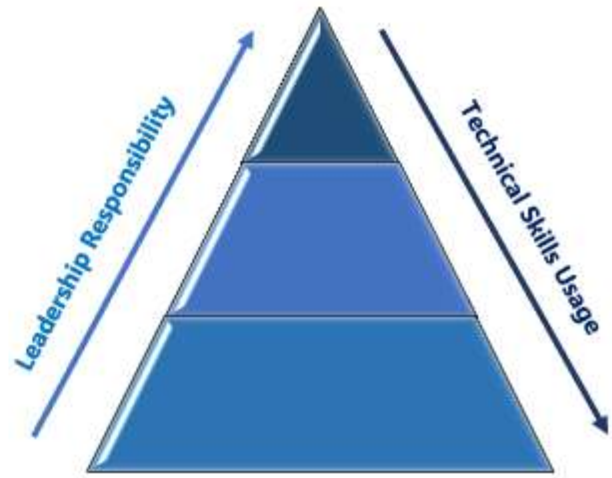

Figure 5.3. The Relationship between Leadership Responsibility and Technical Skills Usage.

5.1.3. The Perceived Role of an Engineering Leader in an Organization

Another salient sub-theme that emerged from theme 1 concerning how engineering leaders conceptualized engineering leadership is the perception of the engineering leaders in terms of whether or not the role of an engineering leader is expansive across an organization (see Figure 5.4).

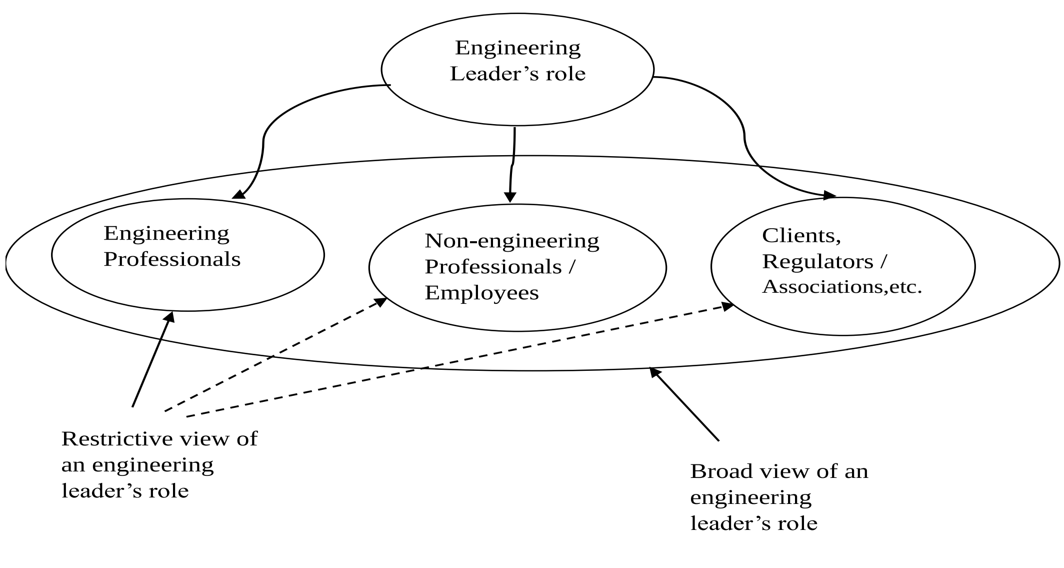

Figure 5.4. The Perspectives of the Study Participants about Engineering Leader's Role in an Organization.

Figure 5.4 shows that the study participants who have a restrictive view of the role of engineering leaders in an organization believe that an engineering leader can relate with other people in the organization, like non-engineering professionals and clients, but when it comes to managing or influencing people, they believe that the responsibility of an engineering leader is confined to engineers alone. However, those with a broad view of an engineering leader's role believed that an engineer should not only be able to successfully influence, manage, or provide leadership to engineers alone, but also to non-engineering professionals in the organization including clients, regulating bodies, and so on.

Although all the leaders in this study attested to having worked with non-engineering professionals while carrying out their leadership responsibilities, only 8 out of the 13 engineering leaders believed that an engineering leader has the responsibility to effectively lead, mentor, and influence both engineering and non-engineering professionals in an organization. The remaining 5 engineering leaders articulated their beliefs about the broadness of the engineering leader's role in an organization as exclusive to leading engineering efforts and mentoring younger engineers. It appears that the situational variable, which is the organizational environment, must have accounted for this view because 4 out of these 5 leaders are from industry and only one is from ABET.

It is important to know that it is not enough for today's engineering leaders to be able to work with people from non-engineering backgrounds alone, they must be ready to take on the responsibility of leading in non-engineering domains as well. This is the major call in the National Academy of Engineering (NAE) reports in which NAE called for engineering institutions to commence educating engineering graduates to be broadly educated such that they see themselves as global citizens who are capable of leading in both business and public service and are ethically grounded and inclusive of all sectors of society (NAE, 2004; NAE 5005). Specifically, NAE, 2004 stated that,

> *"…with the growing interdependence between technology and the economic and social foundations of modern society, there will be an increasing number of opportunities for engineers to exercise their potential as leaders, not only in business but also in the nonprofit and government sectors (p. 55)."*

Today, the expectation of the engineering leader to function effectively in modern society extends beyond the scope of being able to work with people with non-engineering backgrounds alone. It extends to being open to taking on leadership roles in the interdisciplinary spheres, in society at large, and generally extending their tentacles beyond the traditional engineering field of practice.

In addition to this, another significant finding from this study is the perspective shared by some of the engineering leaders in this study, that all engineers are leaders but not all engineers are managerial leaders. They noted that there are different stages of leadership in the engineering profession and that every engineering professional goes through at least two of these stages during their career. A representation of these stages is shown in Figure 5.5.

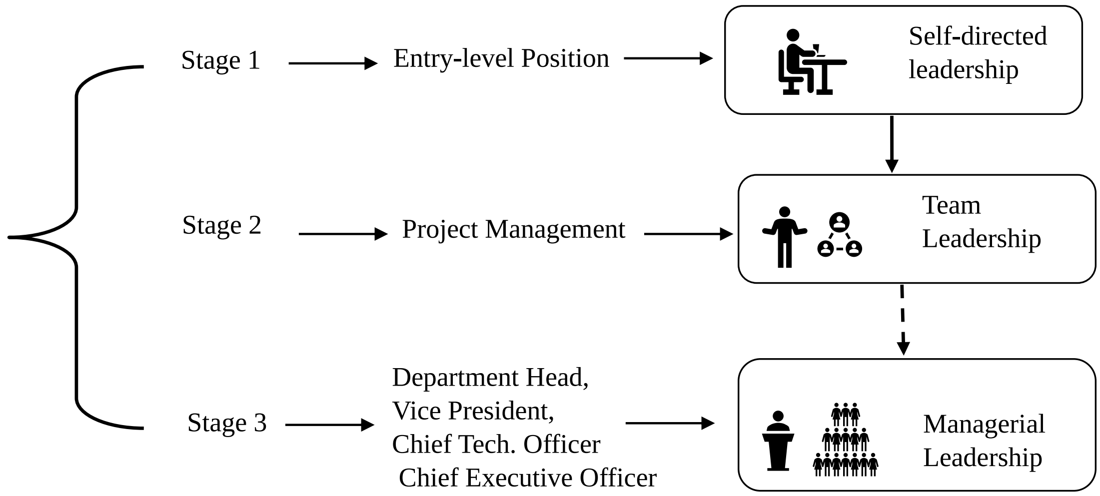

Figure 5.5. The Three Stages of Leadership in the Engineering Profession.

The engineering leaders believed that leadership for an engineer starts from the entry-level position where the engineering professional engages in self-directed leadership. This continues until the time that he/she moves into a project management position where the leader engages in team leadership. The engineering professional then proceeds into higher positions, such as the department head position, the vice president position, the chief technical officer, or the chief executive officer position where he/she engages in managerial leadership. The engineering leaders who gave this perspective noted that typically, many engineers stay at the second stage for the remainder of their careers because they do not like managerial leadership.

As regards self-directed leadership, Klassen et al., (2017) pointed out in their study on leadership conceptions in early career engineers, that one of the participants, an entry-level employee, who was previously an engineering student intern, and was later employed by the company, considered herself a leader. She noted that even though her role does not involve working with a team, she still regarded herself as a leader because her manager considered her an expert on the job. They noted that the participant said, "*The project that I started on as a student…I have transitioned into being the leader of that. Not so much of a team. What started off as two of us and now it's just…me. I still think of it as a leading role because when it comes to talking with my manager he considers me the expert of it. I tell him what's going on and he trusts that I know the next steps for the project (*p.10)."

In addition, there is evidence in the literature that the engineering industry strongly demands entry-level engineers possess leadership skills (Hartman et al., 2016). This also lends credence to this view on self-directed engineering leadership. Rottmann et al., (2015) also opined that the typical career trajectory of an engineering professional is from technical work, which is more self-directed, to project management roles, which are people-centric and demand that the engineering professional learn how to work with people. Thus, it can be said that every engineering professional goes through these stages of self-directed leadership to team leadership. Also, this finding on the stages of engineering leadership is similar to Simpson et al., (2019)'s conceptualization of leadership, in which the authors posited that leadership occurs at four levels which they referred to as self, team, organization, and society. Therefore, as indicated by one of the engineering leaders in this study, when referring to the idea that not everyone is interested in leadership, especially in the engineering field of practice, efforts should be made to qualify the leadership being referred to as "managerial leadership".

In addition to this, it should also be noted that this view on stages of engineering leadership shared by the engineering leaders in this study contrasted with the notion shared by some of the engineering professionals in the study conducted by Rottmann et al., (2015). In their study, the authors noted that engineering professionals expressed resistance to the idea of leadership stating emphatically that "leadership is not us". The authors did note that this resistance resulted from the conflicting views they had about their identity as engineers and leadership in general and suggested ways to help foster leadership identity in engineering professionals. All of this evidence shows the necessity for engineering institutions to be relentless in their efforts to continue educating engineering graduates, especially in fostering their understanding of leadership as part of their professional career experience.

5.2. Discussions on Theme 2: The Core Essences of Engineering Leadership

The second major theme that emerged from this study is the core essences of engineering leadership. The core essence of an experience according to Johnson & Christensen (2017) refers to the commonality or the invariant structure of the experience. It depicts the basic characteristics of an experience that is universal and present in particular instances of a phenomenon. For example, in the case of graduating students preparing for the commencement ceremony, the core essence of their experience will be a feeling of accomplishment, a feeling of excitement and joy, anxiety about what the future holds, mixed feelings about the loss of relationships or separation from friends, and so on. This theme examined the various leadership skills that were commonly employed by the engineering leaders in this study as they narrated their experiences in the engineering field. Im et al., (2023) noted that the concept of essence is deeply rooted in phenomenology, as it seeks to uncover the inner core and meaning of people's lived experiences, and Alase (2017) referred to it as a 'meaning unit,' which represents the central meaning of the 'lived experiences' conveyed by research participants. The core essence of engineering leadership as described by the engineering leaders in this study delved into the heart of what it what it takes to lead in the field of engineering. The narratives of the engineering leaders in this study were used in identifying the core essences of engineering leadership and these core essences embodied the leadership skills that the study participants believed are essential for engineering leadership success. Thus, the core essences of engineering leadership, which translates to the engineering leadership skills identified in this study are grouped into three categories based on the total number of engineering leaders who identified each skill as important to engineering leadership. The three categories are critical, essential, and needed skills. Table 5.1 shows the total number of engineering leaders who identified each engineering leadership skill as important and Figure 5.6 shows their classification based on their relative importance.

Table 5.1.

The total number of engineering leaders who identified each skill as important.

SN	Skills	Total No of participants	Relative importance
1	Technical Expertise	13	Critical
2	Teamwork	13	Essential
3	Communication	10	Essential
4	Listening	10	Essential
5	Empathy	10	Essential
6	Rationale Articulation	10	Essential
7	Humility or Ego Management	9	Essential
8	Problem-solving and Critical Thinking	9	Essential
9	Fearless Exploration	8	Needed
10	Strategic Visioning	7	Needed
11	Lifelong Learning	7	Needed
12	Ethical and Trustworthiness	7	Needed
13	Demonstrative Leadership	6	Needed
14	Decision Making	6	Needed
15	Collaborative Followership and Delegation	6	Needed
16	Flexibility	5	Needed
17	Organization and Time Management	5	Needed
18	Leadership Identity Awareness	5	Needed

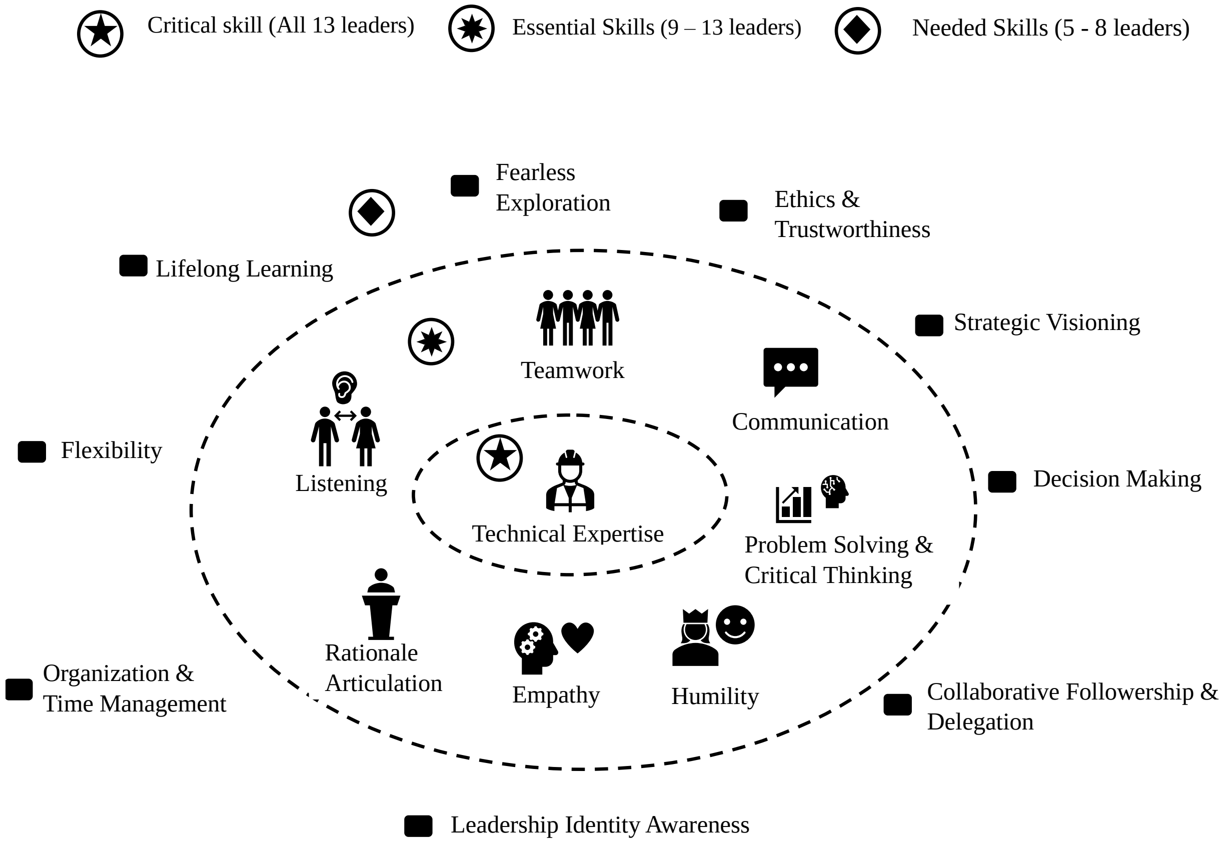

Figure 5.6. Identified Engineering Leadership Skills.

Technical Expertise

Engineering leaders who participated in this study all agreed that technical expertise is critical engineering leadership skills (see Table 5.1). They assert that engineering leadership skills constitute technical expertise and a host of problem-solving, organizational, and interpersonal skills (see Figure 5.6). Although they pointed out that typically engineering leadership requires a higher percentage of interpersonal skills, they noted that a background in technical knowledge/expertise is required to function effectively in an engineering leadership position. During data analysis, some of the salient points that emerged from the discussion on technical expertise are: 1) technical expertise gives a leader the vocabulary to use when leading technical efforts, 2) it gives the engineering leader the ability to suggest various alternative solutions that the team might not have thought of when problem-solving, and 3) that without technical expertise, a leader would not have the credibility to assess other people's technical statements. Some of the leaders indicated that technical expertise is crucial because it allows the leader to be able to understand the problem firsthand, and understanding the problem firsthand helps the leader to be able to guide the group to success. In addition, technical expertise helps the leader to understand what goes on in a project and how to measure the project's success. In support of the latter statement, one of the leaders shared a major challenge he was currently facing in his engineering company. He mentioned that his company had been acquired and merged with another company whose senior leaders are non-engineers. The problem he highlighted was that these non-engineering leaders do not understand the importance of having some technical expertise in place, and he lamented how this lack of understanding was negatively affecting productivity.

Technical expertise has also been characterized as a major component of engineering leadership in literature (Chan et al., 2021; Cox et al., 2012; Farler & Hann, 2021; Farr & Brazil, 2009; Johnson et al., 2015; Li et al., 2022, Paul et al., 2018). A study conducted by Johnson et al., (2015) shows that technical knowledge is needed for a team leader to provide meaningful guidance to team members, as well as understand different approaches team members might be exploring in solving problems. Also, Rottmann et al., (2015) in their grounded theory research on engineering leadership found that technical mastery included the ability to recognize peer's expertise, the ability to comprehend colleagues' questions and clarify their confusion, as well as the ability to support their growth through formal and informal mentorship responsibilities. All these resonate with the themes discussed by participants in this study as the reasons why technical expertise is important to engineering leadership. Paul et al., (2018) also posited that it is essential that engineering leaders possess technical skills and engineering competency to be personally effective. In addition to this, a study by Chan et al., (2021) revealed that contrary to some schools of thought, that engineers must abandon their technical identities to embrace leadership roles, they found that engineering leaders in the field and those outside of traditional engineering industry sectors retain technical dimensions of their professional identities. The implication of this is that engineering leadership is rooted in technical knowledge and capabilities. Also, Li et al., (2022), in their study about what makes an exemplary engineering leader, highlighted that technical expertise is essential to engineering leadership and it is the one factor that serves as the main difference between engineering leadership and general leadership.

Teamwork

Teamwork is one of the essential engineering leadership skills that all the engineering leaders in this study unanimously agreed were indispensable for engineering leadership success. One of the central highlights of their perspective is that it is important to recognize that every member of your team matters. They told many stories and used various analogies to stress this point. One of the stories told is a restaurant analogy where the engineering leader highlighted that if you have the best cooks in the world, but incompetent servers or inefficient cleaners, you are not going to be successful in the business. Teamwork has been identified in the literature as a key factor in achieving engineering leadership success (Crumpton-Young et al., 2010; Hess, 2018; Li et al., 2022; Simpson et al., 2019; Rasoul & Junger, 2012; Wolfinbarger, 2022). For instance, Hess (2018) stated that effective leaders recognize that in order to attain success, every member of the organization is important, and every member of the organization must contribute. He noted that employees need to be engaged, encouraged to contribute, trusted to perform, and valued if they are to contribute to the fullest extent possible.

Another permeating theme that the engineering leaders discussed centers on "*people are your most important resource; you need to genuinely care about them*", "*people are not things"* and more importantly "*effective engineering leadership requires an awareness and management of the curse of knowledge*". They reiterate the need for the leader to value, respect, and embrace the individuality of his team members. In view of this assertion, Hess (2018) noted that engineers are trained to solve problems using fundamental principles and make decisions using carefully generated data. However, "people are not data and do not function in a well-defined manner. Engineers face diverse situations in their technical careers, including those involving beliefs, values, biases, and emotions of people, hence the need for them to learn to value people as individuals and also manage them (p.7)".

Also, one of the engineering leaders noted that showing love and care for the employee is a means to create loyal employees who will not change jobs frequently. According to him, studies have shown that it takes 12-24 months for a new employee to become profitable, and it is the company that will be at a loss if such an employee leaves after 2 years due to job dissatisfaction. Maintaining employee loyalty and retention is crucial for sustaining organizational performance. To achieve this, organizations should focus on increasing employee satisfaction and fostering a sense of importance. Supporting employees, treating them well, acknowledging their input, and positively appraising their work leads to a stronger sense of self-esteem, job motivation, and job satisfaction. This, in turn, boosts their desire to stay with the organization (Osemeke, 2016; Zanabazar & Jigjiddor, 2021).

Communication skills

The engineering leaders in this study emphasized communication as an essential engineering leadership skill that is very important for successful engineering leadership. They emphasized the importance of clear communication, knowing the audience, and customizing one's information accordingly, as well as being able to communicate engineering solutions to non-engineers, especially policymakers, project owners, and the public. The importance of communication skills to effective engineering leadership has been highlighted in the literature (Farler & Haan, 2021; Farr & Brazil, 2009; Hartmann and Jahren, 2015; Hess, 2018; Li et al., 2022; Lopes et al., 2015; Paul et al., 2018; Rottmann et al., 2016). For instance, regarding knowing the audience and communicating with them from the perspective of what they value, authors have noted that engineering professionals must recognize the importance of knowing and tailoring their conversation toward the audience if they ever wish to deliver the message or information in a way that resonates with the recipients (Farr & Haan, 2021; Hess, 2018). They posited that the message being conveyed must appeal to the perspective and specific circumstances associated with the audience, and that in situations where the audience is comprised of people from different backgrounds, cultures, and generations, conveying the message in as clear terms as possible is the solution. In addition, authors have emphasized that engineering professionals in modern times need to learn how to speak with a wide range of people and explain difficult technical subjects understandably (Hess, 2018; Li et al., 2022).

Listening Skills

The engineering professionals in this study also highlighted listening skills as one of the essential engineering leadership skills that are foundational to effective engineering leadership. They noted that listening before talking, listening with understanding, and listening to all the members of one's team is a skill that a leader must endeavor to pay attention to and develop in order to be successful and avoid making expensive mistakes. One of the leaders related an experience where he said he misinterpreted a message because he didn't listen to understand it and that cost him a lot. He has learned from it and moved on. Authors have pointed out that listening is one of the most important leadership skills (Hess, 2018; Gruber et al., 2022; Paul et al., 2018; Yulk, 2013). According to Hess (2018), listening is a very important leadership skill that is often overlooked and especially lacking in technically trained individuals. The author noted that listening is a critical component of communication, without which miscommunication is evident. He pointed out that unless the message being passed is heard and understood, no communication has occurred, and he reiterated that the act of effective listening, also known as "active listening", is a critical skill for which most technically trained persons need improvement. He noted that effective leaders do not interrupt people to tell them how to solve their problems, but rather enable them to explain before guiding them, sometimes with insightful questions, to find their own solutions. Also, Gruber et al., (2022) described active listening as knowing how to listen to understand, that is, knowing how to listen while trying to understand the individual or team in a discussion.

The majority of the leaders in this study attested to the fact that becoming a better leader or evolving as a leader, can be attributed to listening skills. Another leader related as part of his leadership experience that he realized that he became a lot smarter when he started listening to other people. In support of this, Yulk (2013) pointed out that there is evidence in the literature that training supervisors on active listening resulted in higher performance ratings for the supervisors after one year. He also noted that another study found that human relations training designed to increase the use of active listening and praising their staff resulted in a 17 percent increase in worker productivity six months after training was completed.

Empathy

Empathy, which was described by the engineering leaders in this study as the ability of a person to see things from the perspective of others, is another essential engineering leadership skill identified as indispensable for effective engineering leadership. They noted that a healthy work atmosphere, optimal solution-finding during problem-solving, and the resilience to persevere in difficult tasks, are all greatly aided by an engineering leader's capacity to empathize with their team members and demonstrate genuine concern for their well-being. One of the engineering leaders noted that he puts empathy at the top of all engineering leadership skills needed to be a successful engineering leader because, from his experience, empathy is where true problem-solving comes from.

This description of empathy given by the engineering leaders in this study resonates with what Paul & Falls (2018) referred to as “perspective taking”. The authors described their view on empathy as understanding where others are coming from to be able to interact better and being open to other perspectives. Some of the participants in this study opined that empathy does not come naturally to engineers, and there is evidence in the literature that engineering students have significantly lower empathy than students from other programs (Rasoal et al., 2012). Empathy tends to be undervalued or overlooked within engineering (Wilson & Mukhopadhyaya, 2022). Paul & Falls (2018) noted in their study that empathy is an essential aspect of leadership that can no longer be ignored if we want to prevent the continuation of ethical disasters in the business world. Hence, there is a need for engineering leadership educators to make efforts to emphasize empathy in the engineering leadership curriculum.

Rational Articulation

Rationale articulation is described by the engineering leaders in this study as the ability to “explain the why” of every decision and it is one of the essential engineering leadership skills highlighted as necessary for a successful engineering leadership. Almost all engineering leaders in the study emphasized that rationale articulation is important in getting people to agree with one’s views, as a person, and as a leader. They opined that the act of explaining the “whys” behind every decision is the bedrock of motivation, stating that it is an effective means of giving people a sense of purpose, a substantial means of winning their cooperation, and a viable means of getting them to work hard. This agrees with Sinek (2011) who explained that rationale articulation, or explaining the why, is foundational to motivating people and getting them to work because it gives people a sense of purpose or belonging. He noted that a great leader is known for his ability to inspire people to act, and the art of inspiring people to act is rooted in giving people a sense of purpose, by explaining the why. This gives birth to motivation, which in turn results in followers who would act for the good of the organization because they want to, and not because they have to. The engineering leaders in this study also noted that aside from the importance of rationale articulation in the engineering work environment, every engineering leader who has successfully worked with people from non-engineering backgrounds will attest to this fact that explaining the why is their “go-to” in breaking the ice and winning the people’s understanding.

Humility

Humility has been described by engineering leaders in this study as an essential skill needed for successful leadership, especially in engineering. They noted that engineers tend to have discipline pride because of their training, and this makes them think that they are better than people from non-engineering backgrounds. The leaders stated that it is important for engineering professionals to realize that training is not synonymous with wisdom and that there are a host of things that professionals from other fields, like marketing executives, accountants, musical directors, entertainers, etc., can do that they (*engineers*) cannot do. As such, it is important to recognize the expertise of people from other fields of study. Hess (2018) stated that the viewpoint of some engineering leaders, that non-technically trained individuals are clueless, is neither correct nor appropriate, and according to Paul & Falls (2018), having a belief system that everyone has worth and should be respected, is the hallmark of humility. The authors noted that although self-awareness is frequently used to characterize humility, it is possible to have correct self-awareness, yet lack humility, by viewing others as inferior to oneself. Also, Li et al., (2022) said that engineering leaders need to have the confidence to be humble. The authors noted that although confidence is more closely associated with pride than humility, it is confidence that eliminates the anxiety that often hinders a leader from being humble.

Another important construct that the engineering leaders in this study opined was that, naturally, engineers are perfectionists, and as such, they do not often know how to manage mistakes. The participants noted that being honest about mistakes, acknowledging them, and apologizing to all parties involved wins the engineering leader respect, rather than projecting the image of perfection. They reiterated that people usually see through that, and it makes them lose respect for such a leader. This view was shared by Hess (2018) who said that many technically trained individuals usually aspire to be perfectionists, and so have trouble accepting their own or other people's mistakes. He observed that a leader who exhibits pride often displays arrogance, appears indifferent or unapproachable, and believes himself or herself to be perfect. He stated that such a leader usually does not admit that he or she is wrong, blames others for mistakes, and claims credit for achievements. He concluded by reiterating that all these are detrimental to effective technical leadership.

Problem-solving and Critical thinking Skills

The engineering leaders in this study highlighted problem-solving and critical thinking as one essential engineering leadership skills. They noted leadership is rooted in problem-solving-associated decision-making. However, in contrast to the right and wrong mindset in engineering textbooks, big leadership decisions are usually on a spectrum, often neither totally right nor wrong. Thus, a leader must know how and when to step back and critically consider if there are more nuances to the problem, as well as what the tradeoffs are. Problem-solving skills have also been identified as an essential component of engineering leadership in literature (Crumpton-Young, 2010; Hess, 2018; Rottmann et al., 2015). Authors have noted that professional practice demands graduates from four-year engineering education to be competent in taking up and solving problems that do not have answers published in the back of books (Kumar & Hsiao, 2007). Also, Hess (2018) shared this view, asserting that engineering professionals in the workplace are usually expected to use the problem-solving skills acquired during their engineering studies to address open-ended problems with boundary conditions that require an "approximate or optimum" solution, such as in the process or product design problems. This is in contrast to the wrong or right approach that they have been used to in their training. It is therefore essential for educators to develop awareness and practice dealing with these kinds of problems with only better or poorer approaches, rather than right or wrong answers.

Bowman & Farr (2000) also posited that students must be taught to think like engineering leaders in order to produce engineering leaders, and this will have to do with training them to take into consideration both controllable and uncontrollable factors such as social, cultural, legal, financial, and technical variables during problem-solving. Being able to solve problems in this manner demands that students learn to improve their critical thinking skills, which according to Winston & Patterson (2006), involves a leader's use of logic and reasoning to assess facts, synthesize information, and gain insight into the significance of the environmental factors.

Another important common finding that emerged is that when problem-solving involves people from non-engineering backgrounds, it is important to offer more explanation than being analytical. According to Hess (2018), engineers often carry precision and details to the extreme which other people from diverse backgrounds feel is obsessive and pompous. Meanwhile, they were just trying to strive for clarity. He concluded by noting that engineers must recognize that their successful personality traits may hinder their leadership roles, especially when dealing with people from diverse backgrounds and those who lack a deep understanding of technical details.

Fearless Exploration or Not Afraid to Fail

The engineering leaders in this study identified fearless exploration as the ability of the leader to act without being afraid to fail while also understanding the risks involved in carrying out the action. They consider this as one of the needed engineering leadership skills necessary for leadership success. They noted that failure is one of the ways by which leadership acumen is acquired and cannot be avoided because leadership is about decision-making, and not all decisions made will turn out right. This view was also shared by Hess (2018) who posited that effective leaders are not afraid of or deterred by failure, as they are cognizant of the fact that failure provides them with fresh information or insight that enables them to discern a better approach or strategy for action, or, at the very least, an alternative one. Some dominant findings that permeate the discussion of the engineering leaders on this subject are, *"leadership takes being willing to be wrong"*, "*you have to have the confidence to be wrong"* and *"it takes having* *the self-confidence to admit that you are wrong"*. Thus, suggesting that if someone is not willing to be wrong, such a person should not venture into leadership. One of the engineering leaders redefined failure as "F A I L - First Attempt In Learning".

Paul & Falls (2018) in their study on alumni perspectives on their undergraduate engineering leadership experiences noted that when their study participants were asked about the most important skills they value in themselves or other engineering leaders they have worked with, their responses included not being afraid to look stupid, leaving pride at the door, being willing to be wrong, and not pretending to know everything. This is very similar to most of the views shared by engineering leaders in this study. Hess (2018) noted that ego often leads to avoiding risks, as peers and supervisors may perceive failures as being foolish or ill-conceived. He stated that recognizing that significant advancements can only be achieved through taking risks and analyzing failures to prevent repeating them. This is followed by self-forgiveness because the inability to move on after failure can lead to second-guessing every risk we take and thereby severely limit potential accomplishments. Yulk (2013) also said that ineffective leaders tend to be defensive about mistakes and failure. They usually react to failure by attempting to conceal their mistakes or blame others for it. It is common for successful leaders to acknowledge their mistakes, take responsibility for them, and subsequently implement corrective measures. Winston & Patterson (2006) posited that followers who are apprehensive about the responsibility associated with the risk of failure can gain confidence when their leaders engage and collaborate with them in iterative risk-taking and decision-making.

Ethics and Trustworthiness, Strategic visioning, Lifelong learning

Engineering leaders in this study identified ethics and trustworthiness as another essence of engineering leadership that is needed to be an effective engineering leader. They emphasized the importance of the leader having strong ethics to put their “foot down” in situations when client’s interest collides with the engineering code of ethics or is unfavorable to the public. Newstead et al., (2021), when exploring what constitutes good leadership and emphasizing ethics, explained that when it comes to training leaders, the goal should not only be to increase the influence and effectiveness of individuals who hold leadership positions. Rather, engaging in effective and ethical leadership behaviors should be promoted and fostered in individuals because today’s modern world features some incredibly effective leaders who wield massive influence and urge their followers towards ambitious goals. However, many of these goals are glaringly unethical. Henkel & Ade (2022) noted that being a principled and ethical leader is the most significant way to get employees to do what is right. They noted that it is important that leaders adhere to the code of ethics of their profession to avoid poor decision-making or scandal as double standards will destroy trust and relationships between leaders and their followers and their clients.

The engineering leaders in this study also identified strategic visioning or being big-picture oriented as one of the essences of engineering leadership that is needed for success as a leader. They noted that based on their experiences, being big-picture-oriented as a leader helps the leader to align his or her work with the organization’s mission. This helps in being able to explain “the whys” to the team in terms of how their work is connected to the overall purpose of the organization. This, in turn, enhances the motivation of the team and results in leadership success. Paul et al., (2018) in their study on the proposed definition of engineering leadership, noted that one of the constructs that emerged from their study is defining engineering leadership as the ability to see the big picture and to effectively coordinate people and resources to achieve project goals. Also, another finding of this research that resulted from this strategic visioning discussion is that this particular skill helps the leader to foresee the resources needed to move the project forward and succeed. One of the participants described strategic visioning as the hallmark of a good leader.

Lifelong Learning is an important essence of engineering leadership that the engineering leaders in this study pointed out as needed for leadership success. They noted that it is important that a leader adopts a growth mindset rather than a fixed mindset. The leader must be well informed about what is happening in their career sphere, and what is happening nationally and internationally to make informed decisions. The importance of life-long learning to engineering leadership success has also been discussed in the literature (Athreya & Kalkhoff, 2010; Cox et al., 2012; Hess, 2018; Kendall et al., 2018; Paul et al., 2018; Paul & Falls, 2018; Reeve et al., 2015). For instance, Hess (2018) posited that a leader's adoption of a growth mindset leads to leadership effectiveness and efficiency of team and organizational operations. Engineering leaders in this study also emphasized and shared their experiences about reading books on leadership and management, attending training sessions on leadership, listening to podcasts, and paying attention to, and internalizing both their leadership experiences and other people's leadership experiences. Effective leadership in today's world requires a desire and willingness to learn and adapt, especially taking action to address gaps in knowledge, skills, and abilities throughout one's career (Cox et al., 1012; Reeve et al., 2015; Yulk, 2013).

Demonstrative Leadership, Decision-Making, Collaborative Followership and Delegation

Demonstrative leadership is described in this study as leading by example, and a few of the engineering leaders have referred to it as, "walking the talk". They emphasized the importance of demonstrative leadership to engineering leadership success by noting that demonstrating actions or behaviors that they expect from their team, both in performing tasks and upholding values, that promote mutual respect, create a culture of trust and confidence in the leader as a mentor, and fosters a positive work environment. The five out of the six leaders who emphasized this are from industry and they reiterated that this was where they found the most success in their career as engineering leaders. Stressing the importance of demonstrative leadership, one of the engineering leaders said, "*Yeah, so, that's the essence of leadership*" and another one stated that *"a leader is one that is always trying to train their replacement*". Leroy et al., (2022) noted that even though the act of *not* walking one's talk in organizations is quite common, it is very detrimental to credibility and trust, and team members usually lose respect and trust in such leaders. Also, Van Dyck et al., (2013) reported that there is evidence in earlier studies that leaders' walking the talk is positively correlated with outcomes such as trust in the leader, follower work satisfaction, organizational citizenship behavior, improved follower job performance, team priority of safety, and team psychological safety. At the same time, it was negatively correlated with behaviors such as absenteeism, stress, deviant character, and professional errors committed in an organization.

Decision-making acumen is another essence of engineering leadership that engineering leaders in this study considered needed for leadership success. They noted that since leadership is about making decisions and giving direction, a leader's effectiveness is known by their ability to recognize that they are never going to have all the information, and thus make decisions with the information at hand. They regarded the ability to make quick decisions based on the data at hand as the hallmark of leadership. Hess (2018) posited that the art of decision-making demands that a lot of decisions be made with less than adequate data or information to avoid missing the window of opportunity which is critical in achieving substantial success. He noted that engineers and scientists seem to find this unappealing as they love to consider all factors. He also indicated that being an indecisive leader who is unable to make important decisions while waiting for additional information results in being viewed as an incompetent leader by the followers. Another salient finding that emerged in the discussion on the leader's decision-making skills was the importance of data-driven decision-making. The engineering leaders emphasized that from their experience as leaders, supporting every decision made with facts or data, or having evidence for what is driving a decision, makes people more agreeable. This relates to the rationale articulation discussed earlier.

Another needed engineering leadership skill identified by engineering leaders in this study is collaborative followership and delegation. The engineering leaders emphasized the importance of the leader being a good follower or team member without trying to share the credit whenever they find themselves on another team. Paul et al., (2018) said that it is crucial for a leader to recognize the suitable moments to assume the position of a follower and possess a genuine willingness to embrace that role In other words, a leader should not view the act of becoming a follower as a sign of weakness or inferiority. Rather, as an opportunity to foster collaboration and build strong relationships. Another important finding that permeated this discussion was that an engineering leader needs to step away from their perfectionist self and learn to delegate things whenever they have capable hands to do so. Concerning this, they indicated that a leader needs to know that time is their most valuable asset and should be wisely managed. Hess (2018) noted that leaders must prioritize effective and efficient time management in order to enhance their abilities, skills, and accomplishments. He stated that some new technical leaders prefer relying solely on themselves to achieve tasks, however, time constraints often make it impractical. The engineering leaders also highlighted the importance of matching people to their skills, not just their engineering degree, when delegating, to ensure efficiency in engineering product delivery. Cox et al., (2012) said that delegating responsibilities to capable individuals allows for a more balanced and successful approach to leadership. As such, engineering leaders should employ this in their leadership.

Flexibility, Organization and Time Management, Leadership Identity Awareness

The engineering leaders in this study also identified flexibility as one of the needed engineering leadership skills that contribute to leadership success. They described flexibility as the ability of the leader to accommodate the views of other members of his team when problem-solving, and not be rigid about personal beliefs. Flexibility has also been identified as an essential engineering leadership skill in literature (Cox et al., 2012; Hess, 2018; NAE, 2004; Morell, 2020; Reeve et al., 2015; Wilson & Mukhopadhyaya, 2022). Hess (2018) posited that inflexibility and narrow-mindedness hinder technical leaders from exploring novel or alternative solutions and understanding situations from different perspectives. Consequently, followers may become frustrated, lose motivation, and feel hopeless due to the leader's resistance to reconsidering choices or decisions. The study participants also noted that flexibility extends to being adaptable in one’s approach to dealing with people, as well as in the work environment. In view of this, Cox et al., (2012) said that besides showcasing leadership principles and demonstrating an understanding of policies, engineers must possess the flexibility to effectively navigate and adjust to the constantly evolving world and technologies around them.

Organization and time management skills have also been identified as needed engineering leadership skills that contribute to leadership success. The engineering leaders opined that being a list-maker to keep track of things is very important in leadership, as nobody has confidence in a leader who needs to be told the same thing more than once. Heckman & Kautz (2012) emphasized the importance of being organized when they said that being an organized, hardworking, and responsible individual predicts educational attainment, health, and labor market outcomes. Also, the engineering professionals in this study noted that part of being organized is responding to questions or inquiries from employees as quickly as possible, knowing that when employees come to you with questions, they probably can't wait because they are stuck and cannot move forward. Engineers have been credited with being well-organized, methodical, and rational professionals (Hess, 2018), and efforts should be made to maintain the status quo when educating engineers.

Another needed engineering leadership skill identified by the participants of this study is leadership identity awareness, which refers to the ability of a leader to know their leadership style. The engineering leaders who participated in this study demonstrated their awareness of their leadership identities by discussing the leadership styles that they employ, and how they implement those leadership style concepts into their practice as engineering leaders. For instance, one of the leaders identified as a servant leader, and another identified as an authentic leader. Their perspectives on leadership identity connote that having an awareness of one's leadership identity helps in leadership performance because it determines the trajectory of one's leadership behaviors. Wilson & Mukhopadhyaya (2022) indicated that engineering professionals' identity and dominion of influence which determines their day-to-day activities of problem-solving are formed by a set of beliefs. The implication of this is that what an engineering professional believes to be their identity will reflect in day-to-day leadership behavior.

Proposed Taxonomy of Engineering Leadership Skills

A re-organization and classification of the skills identified in this study was completed and this led to the creation of a proposed taxonomy of engineering leadership. Taxonomy can be broadly defined as the classification or categorization of concepts, entities, or objects based on shared attributes or characteristics which can facilitate analysis, comparison, and understanding within a particular domain (Abukhader, 2019; Denecke & May, 2023). The taxonomy is classified into three levels as shown in Figure 5.7 and it can be used as a framework for studying and assessing engineering leadership skills.

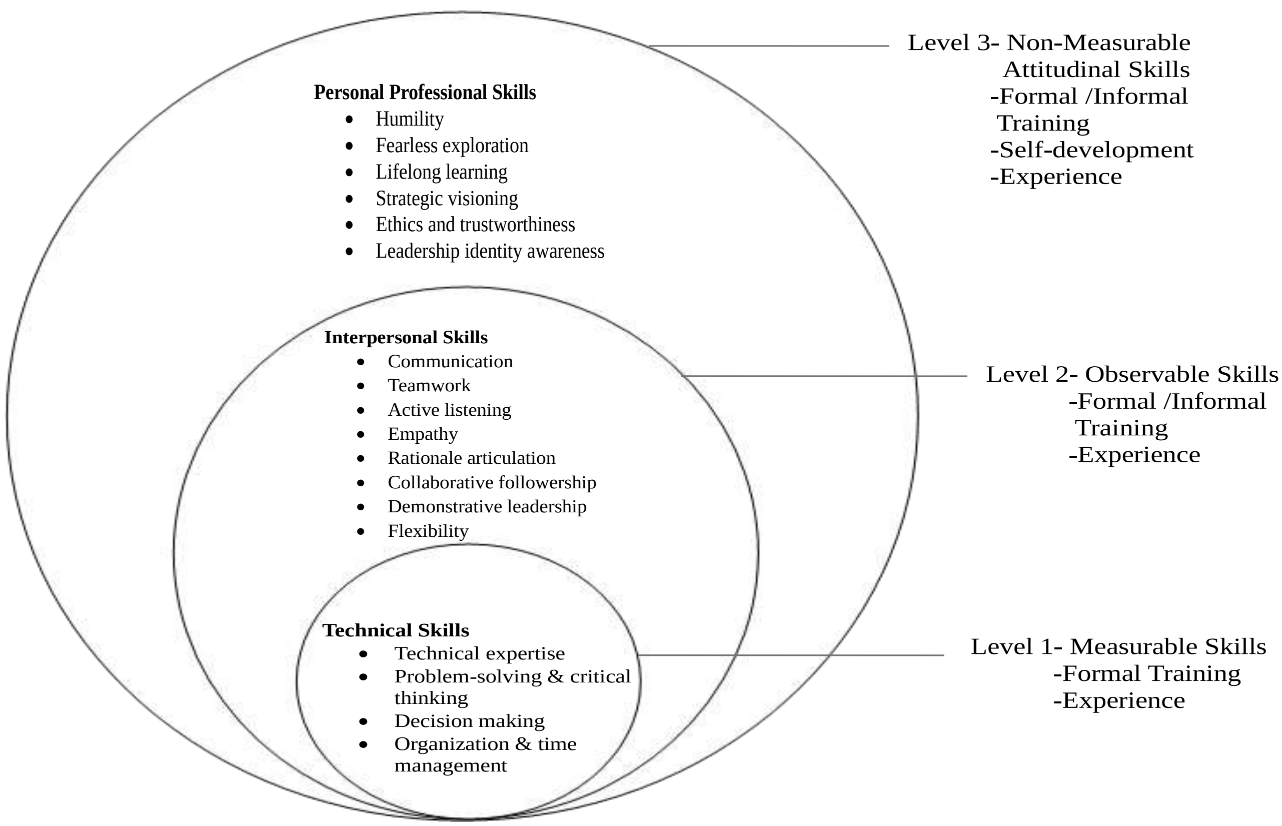

Figure 5.7. Proposed Taxonomy of engineering Leadership skills.

Level 1: Technical Skills (Measurable Skills).

Technical skills refer to specific knowledge or expertise that is directly related to the profession of engineering, that is engineering industry or field, as well as other abilities that are acquired through formal training and practical experience. They are measurable skills that can be measured through evaluation, observations, or tests. Technical skills include:

- Technical expertise
- Problem-solving and critical thinking
- Decision making
- Organization and time management

Level 2: Interpersonal Skills (Observable Skills).

Interpersonal skills refer to skills that involve interacting with other people, both engineering professionals and non-engineering professionals alike, which is why they are often referred to as people skills, soft skills, or social skills. They are mostly acquired through informal training, self-study, and experience, but are also acquired through formal training in situations where their importance is prioritized. These skills assist in building positive relationships and establishing smooth rapport in personal and professional settings that relate to engineering. Interpersonal skills are not easily quantifiable, but they can be observed through interactions and feedback, and assessed using assessment tools like surveys or interviews. Interpersonal skills include:

- Communication
- Teamwork
- Active listening
- Empathy
- Rationale articulation
- Collaborative followership

- Demonstrative leadership
- Flexibility

Level 3: Personal Professional Skills (Non-Measurable Skills).

Personal professional skills refer to a set of skills that reflect the beliefs, values, and attitudes of the engineering leader. They constitute an engineering leader's personal efficiency traits that influence and positively impact interpersonal relationships. They are often acquired through informal training, self-study, and experience, but some of them could also be inborn traits. For instance, some people are naturally bold and fearless, and taking risks is second nature to them. While they are non-measurable skills due to their subjective nature, they involve self-reflection and personal beliefs. They can be assessed through reflective statements or narratives that offer insight into an individual's way of thinking, growth orientation, and values. The personal professional skills are:

- Humility
- Fearless exploration
- Lifelong learning
- Strategic visioning
- Ethics and trustworthiness
- Leadership identity awareness

It should be noted that this taxonomy is in its early stages and still requires testing, adjustments, and refinements over time.

5.3. Discussion on Theme 3: Contextual Differences in the Definition of Engineering Leadership and the Identification of Engineering Leadership Skills

This is the third theme that emerged from this study and was explored in relation to how situational factors, which are the work environment and size of the organization, shaped the definition and classification of engineering leadership skills by the engineering leaders.

One of the findings, with regards to the contextual differences in the engineering leaders' definition of engineering leadership, is that out of the six ABET leaders in this study, four were able to give a direct definition of engineering leadership when they were asked to define the phenomenon, while only one of the engineering leaders in the industry was able to articulate the definition. The remaining two engineering leaders from ABET and six leaders from industry defined engineering leadership using illustrations and stories.

One salient point of view from this is that since this research is a phenomenological study, the definitions provided by the engineering leaders were based on what they valued as leaders. Raffo & Clark (2018) said that since there is no standard definition of leadership, how we define it becomes individualized and represents our values, identities, and the messages we wish to convey to others when expressing our views on leadership. The authors further stated that the definition of leadership, including the words and phrases we employ and their underlying meanings, reveals our attitudes toward leadership and the qualities we look for in a leader. Also, it was obvious that the situational variable of the organizational environment played a part in the definitions given. This is because the majority of the ABET leaders who were able to succinctly define engineering leadership are in the academic sector, while the majority of those who use paraphrased definitions were industry leaders. It should also be noted that while the situational approach of definition was prevalent with the ABET leaders, and the behavioral approach of defining engineering leadership was prevalent with the industry leaders. Also, while there are similarities in the engineering leadership definitions of industry leaders, the ABET leaders' definitions do not share significant similarities.

Another important finding here is that all seven industry leaders indicated that problem-solving and critical thinking are very important engineering leadership skills, while only two of the ABET leaders considered them as important. This could also be due to the work environment since engineers in industry tend to engage in more hands-on responsibilities of product design and production.

5.4. Discussion on Theme 4: The Role of Training and Experience in Engineering Leadership Success

Most of the engineering leaders in this study decried the lack of leadership training in engineering programs while noting that they had to learn the hard way, that is, through many mistakes and failures. For instance, one of the engineering leaders in this study said,

> *"Gosh, it was hard when I first started because my university doesn't really offer any leadership training, so I've had to figure it out. So, I feel like, you know, the lack of training, stumbling around and failing a lot, which is kind of, it kicks stuff out, you know, like, it's embarrassing. I like to feel like I'm good at my job."*

> *This view is in support of Kumar & Hsiao (2007) who asserted that engineers acquire skills in management and leadership by learning soft skills the hard way in industry. This is one of the reasons why many authors have called for the inclusion of interpersonal skills in the engineering curriculum (Felder, 2006; Prados et al., 2005; Sheppard et al., 2009; Samavedham & Ragupathi, 2012; Scardamalia et al., 2012). Engineering leaders in this study believed that colleges of engineering should make efforts to teach*

interpersonal skills such as empathy, listening skills, communication, and others that are highlighted in this study. Contrary to the school of thought that many of these skills can only be acquired through experience, the engineering leaders in this study believed that the majority of the skills can be taught in the classroom, especially communication, empathy, and listening skills. Lopes et al., (2015), in their study exploring a key factor for engineering students to develop interpersonal skills, concluded that interpersonal skills which signify the characteristics of an effective engineer are learnable and could be taught within an educational program. Also, Bowman and Farr (2000) in their study on embedding leadership in civil engineering education noted that even though the focus of their study was not to argue that leadership can be acquired solely in a classroom, they noted that those who argue that leadership cannot be developed to some degree in an academic climate are wrong. Engineering leaders in this study have also echoed similar sentiments, noting that leadership is acquired through training and experience.

In terms of experience, the engineering leaders in this study advocate that engineering institutions in their efforts to teach leadership should incorporate activities that will enable the learners to engage in using the knowledge they have acquired on leadership. They noted it will remain as head knowledge if that is not done. One of the engineering leaders noted that some of the worst leaders he had ever met had all sorts of leadership training in their portfolio, but it did not reflect in their behaviors. He blamed this on the issue of getting trained without putting the knowledge into practice. A large percentage of the engineers believed that experience is very key in leadership acumen acquisition. They advocated for the inclusion of volunteering activities, especially in a non-engineering environment in engineering leadership training or encouragement of their trainees to participate in student club activities.

5.5. Research Questions

Based on the analysis of the themes and sub-themes in the sections above, the research questions established for this study are answered and discussed in the following sections.

RQ 1: How do ABET leaders define engineering leadership and engineering leadership skills based on their experience as engineering leaders?

The ABET leaders in this study defined engineering leadership with emphasis on competency in interpersonal skills in addition to technical skills. This includes the ability to manage people and processes to achieve organizational goals, and being an ethical leader who has the goal and ethics of the engineering profession in mind. Four out of the six ABET leaders were able to articulate a clear definition of engineering leadership while the remaining two used stories and narratives to illustrate their definition. A synthesis of each of their definitions was completed and the main themes that emerged from the definition, as well as the approach used, is highlighted in Figure 5.8.

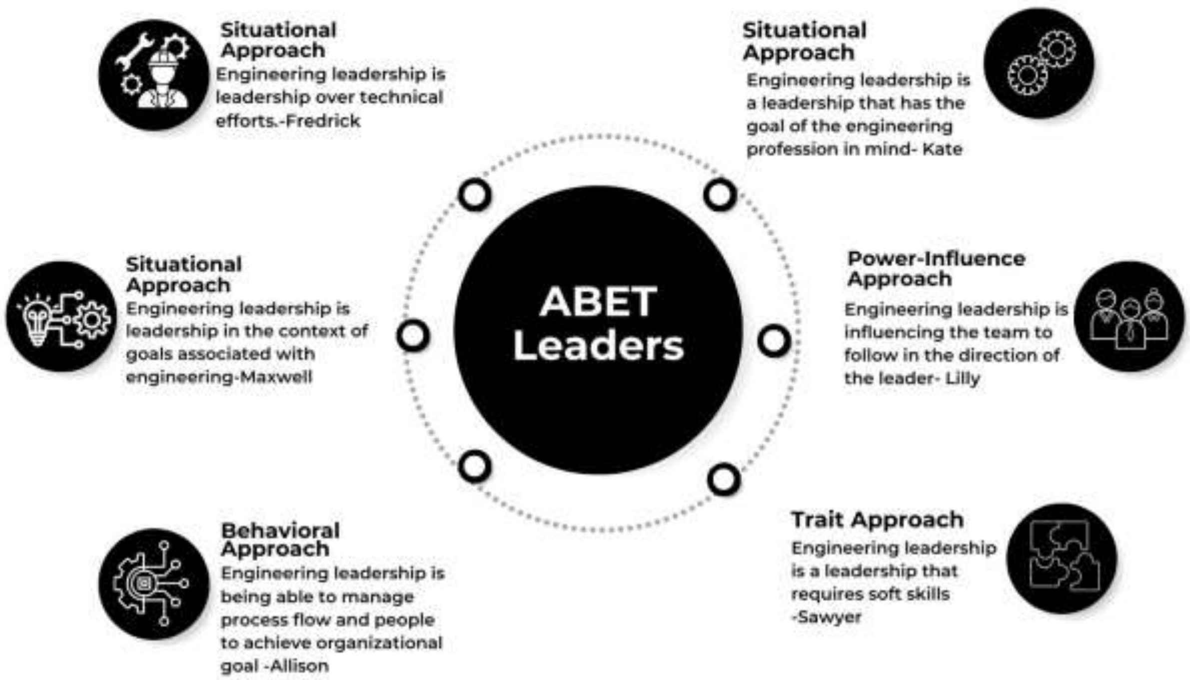

Figure 5.8. Key themes from Engineering Leadership Definitions by ABET Leaders.

It should be noted that the engineering leaders in this study have generally emphasized the importance of interpersonal skills in engineering leadership. While some of the highlighted themes described in Figure 5.8 might not specifically mention interpersonal skills, they do have the undertone of having sound proficiency in interpersonal skills in the process of leading technical efforts. All the definitions of engineering leadership were compiled and iteratively synthesized until a succinct definition was deduced. This was compared with each definition given by the engineering leader to ascertain if it was representative of such a definition. A resulting definition from the iterative synthesizing of the six leadership definitions provided by ABET leaders is:

> *Engineering leadership is the process of using technical knowledge and interpersonal skills to influence and manage teams toward the accomplishment of engineering mission goals while also abiding by engineering professional ethical standards.*

A total number of eighteen leadership skills were identified in this study as very important to engineering leadership based on the narratives of the engineering leaders who participated in the study. Figure 5.9 shows the distribution of the number of ABET leaders who specified each identified skill as important to engineering leadership success. From the figure, it can be seen that technical expertise, teamwork, and listening skills were the most pronounced skills by the ABET leaders while demonstrative leadership was the least pronounced. Communication and humility or ego management were specified by five out of the six ABET leaders as important to the success of engineering leadership, while empathy, rational articulation decision-making, and collaborative followership were specified by four out of the six leaders as important engineering leadership skills. In addition to this, three out of six ABET leaders mentioned fearless exploration, lifelong learning, ethics, trustworthiness, and flexibility, as important to engineering leadership. The two ABET leaders cited problem-solving, critical thinking, and leadership identity awareness as important to engineering leadership. It should be noted that this is an indication of the relative importance of the skills as identified by the engineering leaders in this study. According to Smith et al., (2009), engaging in numeration is good because it could be the only way of indicating the relative importance of some themes. However, according to the authors, this should also not be over-emphasized because sometimes, something that unlocks a further set of meanings for a participant might only be mentioned once. The implication of this is that some of the skills that were not identified by a large number of participants in this study are also important skills in their own right and many of them have been highlighted in the literature and engineering leadership skills. This means that in teaching engineering leadership skills, all of these skills should be considered as necessary for leadership success.

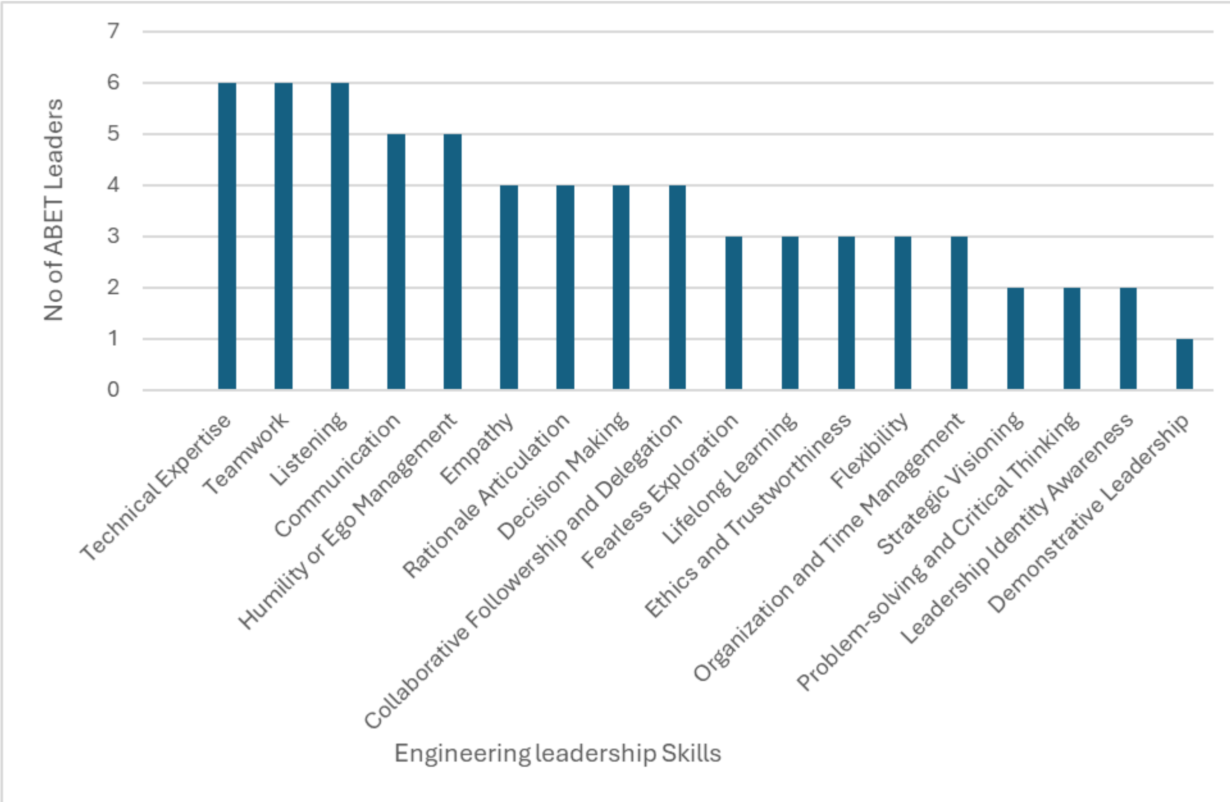

Figure 5.9. The distribution of ABET Leaders who emphasized each of the Identified Engineering Leadership Skills.

RQ 2: How do engineering leaders in the industry define engineering leadership and engineering leadership skills based on their experience as engineering leaders?

The definition of engineering leadership given by the industry leaders in this study can be classified under various approaches to leadership definition, but the behavioral approach was predominant in their definitions. The main emphasis of their definition is on demonstrating technical knowledge and ethical behaviors, leading by example, and having interpersonal skills to collaborate and influence teams to achieve set goals. When asked to define engineering leadership, only one out of the seven industry leaders was able to articulate a clear definition of engineering leadership. Figure 5.10. shows the various approaches used by the industry leaders and the emerging theme from a synthesis of each of their definitions.

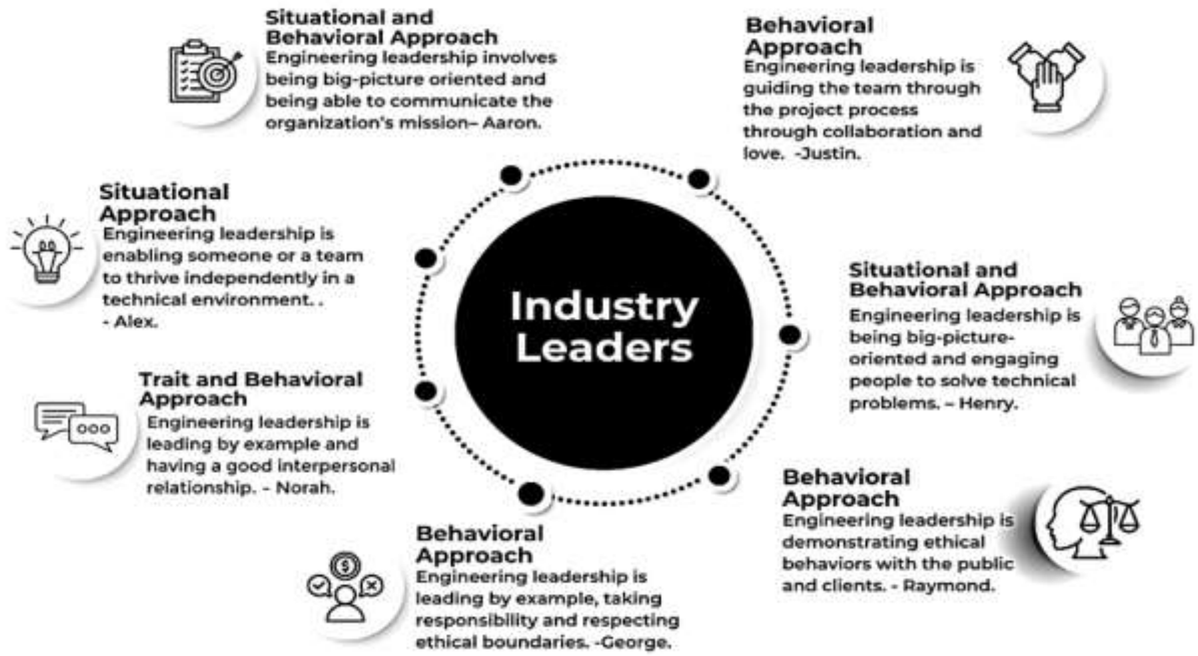

Figure 5.10. Key Themes from Engineering Leadership Definitions by the Industry Leaders.

All the definitions of engineering leadership given were compiled and iteratively synthesized until a succinct definition was deduced. A comparison between each of the definitions was made to ensure that the derived definition from the synthesis reflects each of the definitions. The resulting definition from the iterative synthesis of the six leadership definitions provided by industry leaders is:

Engineering leadership is leveraging on technical expertise and interpersonal skills to guide teams in developing innovative, ethical solutions that meet the organization's goals *and serve the public interest while fostering a culture of trust, autonomy, and collaboration.*

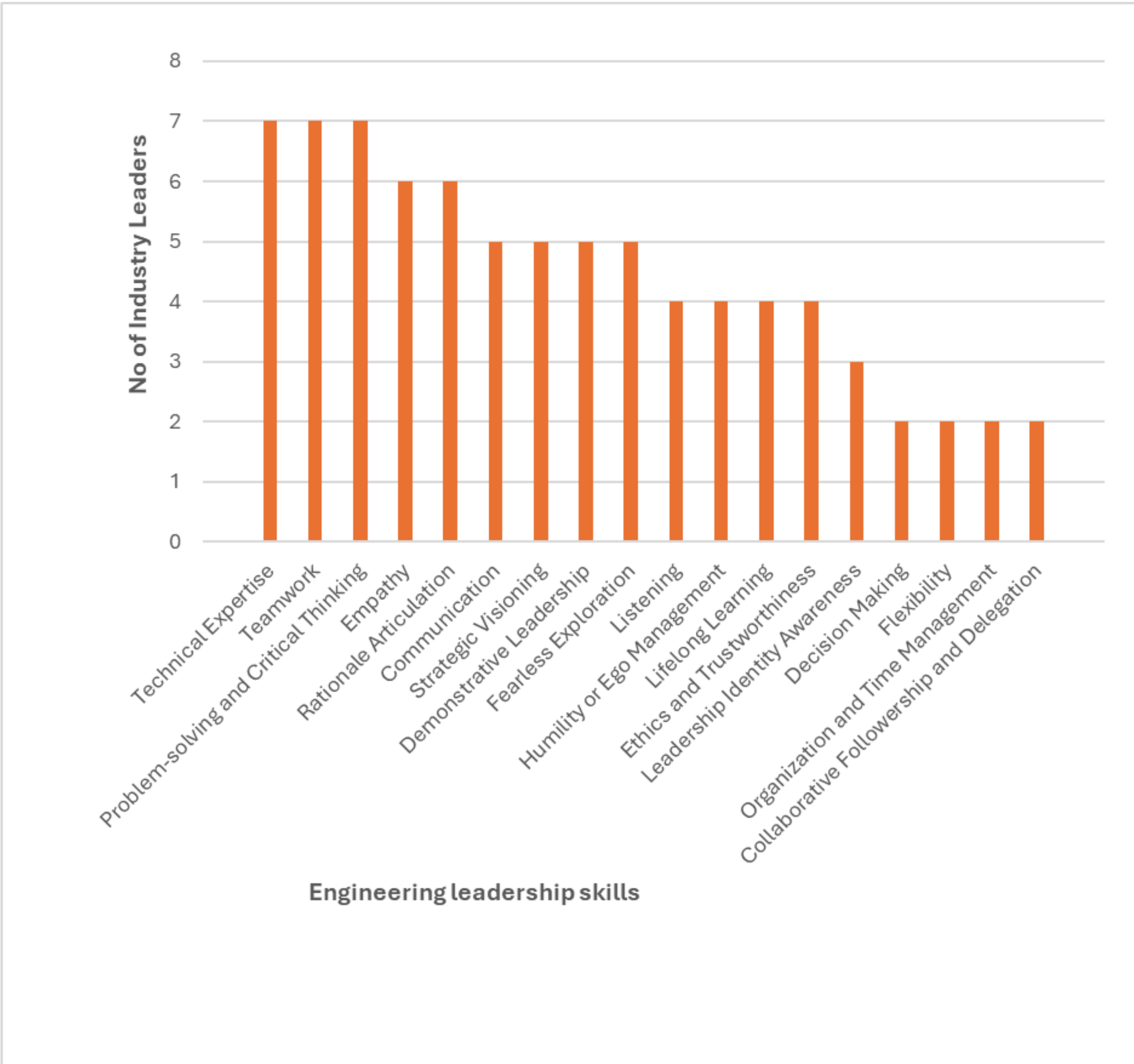

Figure 5.11. Distribution of the Industry leaders who emphasized each of the Identified Engineering Leadership Skills.

With regards to the eighteen identified leadership skills in this study, Figure 5.11 shows the distribution of the number of industry leaders who cited each of the identified skills as important to engineering leadership success. As shown in the Figure, technical expertise, problem-solving and critical thinking, and teamwork skills were the most pronounced identified skills by all the seven industry leaders. Six out of the seven industry leaders identified empathy and rational articulation as essential leadership skills. Communication, strategic visioning, demonstrative leadership as well as fearless exploration skills were mentioned by five out of the seven industry leaders as needed leadership skills. Leadership identity awareness was cited by three out of the seven industry leaders, while the remaining four industry leaders identified decision-making, flexibility, organization, and time management. Collaborative followership and delegation skills were identified by two out of seven industry leaders.

It is important to note that the skills illustrated in the figure are a measure of relative importance in terms of what skills are considered important to engineering leadership by the industry leaders based on their experience.

RQ3: How do ABET leaders' definitions of engineering leadership and identification of engineering leadership skills align with those of engineering professionals in the industry?

The definition of engineering leadership by the ABET leaders is more of a situational approach with an emphasis on having technical expertise and interpersonal skills to manage and influence people in achieving set goals while also maintaining engineering ethical standards. However, the definition of engineering leadership given by the industry leaders is more of a behavioral approach with elements of a situational approach. The industry leaders defined engineering leadership from the perspective of the leader being able to lead technical efforts by example, have interpersonal skills to guide and manage teams to achieve set goals and demonstrate engineering ethical behaviors. It should be noted that although the orientation of the definition of engineering leadership given by the ABET leaders and that of industry leaders is different, their definitions do not significantly conflict with each other, especially when interpreting or making inferences from each of the definitions. The previously synthesized definitions of ABET and industry leaders were combined together and synthesized, and this resulted in an overall proposed definition of engineering leadership, which is defined thus:

> *Engineering leadership is the dynamic integration of technical knowledge with interpersonal skills to guide and inspire teams toward achieving organizational goals and objectives while also maintaining a commitment to engineering ethical standards and promoting a culture of trust, autonomy, respect, and collaborative problem-solving.*

Also, a proposed definition of engineering leadership skills based on the dichotomous views of engineering leadership shared by the engineering leaders in this study is:

> *Engineering Leadership skills refer to a combination of technical and interpersonal skills needed by an engineering professional to effectively influence a group of technical and non-technical personnel and facilitate communal collaborations and mutual understanding to achieve organizational goals.*

A comparison between the number of ABET and industry leaders who mentioned or highlighted each of the eighteen skills identified in this study as important engineering leadership skills is illustrated in Figure 5.12.

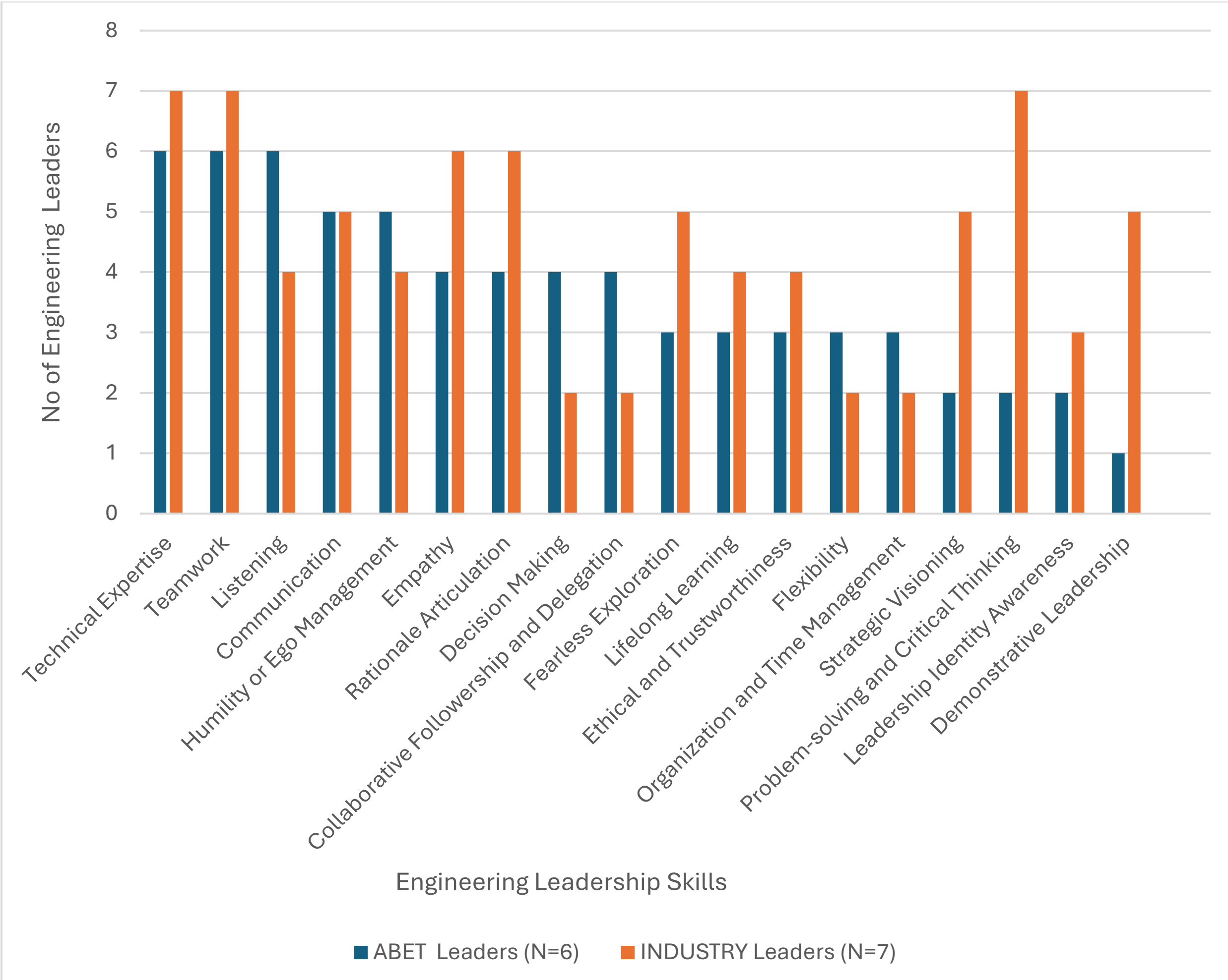

Figure 5.12. Distribution of the comparison between the number of ABET and industry leaders who identified each engineering Leadership Skill.

It can be seen from Figure 5.12. that all six ABET leaders and seven industry leaders identified technical expertise and teamwork as important, while all six ABET leaders identified listening skills as essential engineering leadership skills, and only four out of seven industry leaders cited listening. Also, while all seven industry leaders identified problem-solving and critical thinking as essential engineering leadership skills, only two out of the six engineering leaders identified this as important. This could be attributed to the work environment. All the ABET leaders in this study are in academia where a lot of listening and taking is done, while the industry leaders' day-to-day activities involve providing solutions to certain technical problems which requires much critical thinking and hands-on problem-solving. This pattern of the effect of work environment on the identified engineering leadership skills can be seen all through the engineering leadership skills illustrated in the figure.

5.6. Conclusion

The definition of engineering leadership given by the engineering leaders in this study falls into various approaches to defining leadership that have been identified in the literature. The situational approach which has its orientation in the nature of the organization was more pronounced in the definition of the ABET leaders, while the behavioral approach which focuses on what the leaders do and how they act was more pronounced in the definition of the industry leaders. A major highlight of this finding is that their definitions reflect their work environment as all the ABET leaders in the study are in the academic work environment while the industry leaders are in the work environment that demands actions in leading hands-on technical projects.

Also, this study found that engineering leaders in ABET were more able to articulate the definition of engineering leadership compared to industry leaders who employed stories and paraphrases in defining engineering leadership. In addition, although engineering leadership was defined based on the lived experience of the engineering leaders in this study, after categorizing and synthesizing these definitions, it was found that the difference between the definitions given by ABET leaders and industry leaders was not significant, as both definitions tended to focus on influencing and coordinating teams using interpersonal skills and technical expertise while abiding by the ethical standards of the engineering field of practice. An iterative synthesis of all the definitions resulted in a proposed definition of engineering leadership.

This study also indicated that engineering leadership is made up of technical expertise and interpersonal skills with a ratio of 30 to 70 respectively, and that as an engineering leader moves up the ladder of leadership, the usage of technical skills decreases, and more interpersonal skills are used. Engineering leaders in this study noted that while their technical knowledge provided them with the ability to understand what was going on in a project and mentor their team, they indicated that more of their engineering leadership success can be attributed to active listening, empathy, the ability to tailor communication to the audience, respecting their team members, rationale articulation, etc. This study proposed a definition of engineering leadership skills based on the views shared by engineering leaders in this study.

This study also found that engineering leaders learn interpersonal skills the hard way, as a higher percentage of the engineering leaders in this study shared how they failed a lot because they had no prior training in leadership when they first became leaders and had to learn by failure as they engaged in their leadership roles. They emphasize the need for engineering institutions to make more efforts in providing leadership training for engineering graduates.

This study unveiled three stages of engineering leadership which are self-directed leadership, team leadership, and managerial leadership. The research findings suggested that contrary to some schools of thought that leadership is not for engineers (Rottmann et. al, 2015), every engineer actually engages in leadership starting from self-directed leadership to team leadership, and from team leadership to managerial leadership. It should be noted that most engineers remain in the position of team leadership throughout their careers because they do not choose to pursue managerial leadership. This study therefore concluded that all engineers are leaders, but not all engineers are managerial leaders. The earlier engineering institutions begin to orientate engineering graduates to adopt a leadership identity the better. In addition, when asserting that leadership is not for everyone in the engineering field, efforts should be made to qualify that "managerial" leadership is not for everyone.

A total of 18 skills were identified by engineering leaders in this study as important for engineering leadership success. These included *technical expertise, teamwork, problem-solving and critical thinking, empathy, rationale articulation, communication, strategic visioning, demonstrative leadership, fearless exploration, listening, humility or ego management, lifelong learning, ethics and trustworthiness, leadership identity awareness, decision-making, flexibility, organization and time management, collaborative followership and delegation skills*. This study also found that the work environment influenced the identification of engineering leadership skills as important to engineering leadership practices. This study further proposed a taxonomy of engineering leadership skills based on the identified leadership skills in this study.

This study has been able to propose a definition of engineering leadership as a means of contributing to achieving a consensus on the definition of engineering leadership. In addition, this study identified eighteen engineering leadership skills that are believed to be important to the success of engineering leadership based on the experience of engineering leaders who participated in this study. This study also proposed a definition of engineering leadership skills to facilitate a shared understanding of what constitutes engineering leadership skills.

5.7. Recommendations

One of the findings from this study is that the majority of engineering leaders could not clearly articulate a clear definition of engineering leadership, especially industry leaders. This is no fault of theirs because the typical engineering curriculum is not inclusive of such topics as leadership education. The resistance to adopting leadership identity by some engineering professionals has been highlighted in the literature (Paul et al., 2018; Rottmann et al., 2015;

Wilson & Mukhopadhyaya, 2022), and this is no surprise because it would be difficult for someone to identify with what he or she cannot conceptualize or articulate in the first place. Rottmann et al., (2016) said, "*If we as engineering educators wish to more coherently or systematically develop our students into leaders, we should begin by defining what engineering leadership means* (p. 147)." It is therefore recommended that defining engineering leadership should be promoted by engineering educators and other engineering stakeholders. This is the first step in facilitating a clear understanding of engineering leadership and producing graduates who embrace the leadership responsibilities demanded in the modern workplace.

It is also recommended that engineering educators make efforts in the orientation of engineering students to start seeing engineering as a leadership profession. This study has been able to develop 3-stages of leadership in the engineering profession and that all engineering professionals will engage in leadership at one point in their career, starting from self-leadership to team leadership, to managerial leadership, which is often optional. Promoting this understanding will enhance the willingness of engineering graduates to adopt a leader's identity or self-identify as a leader. Rottmann et al., (2015) in their study on the grounding leadership theory in engineers' professional identities posited that engineering leadership education would be more effective if there is a widespread recognition of engineering as a leadership profession. Hence, engineering educators must orientate upcoming engineering professionals to adopt this mindset.

One of the findings from this study is that the work environment influences the definition of engineering leadership and identified engineering leadership skills provided by both the ABET and industry leaders in this study. To better understand and refine the list of leadership skills provided, it is recommended that engineering professionals in fields like healthcare, legal, and other fields of professionals be included in future studies.

In addition, this study indicated that currently engineering professionals typically learn leadership skills the hard way. Many of the engineering professionals in this study attested to having failed severally to the point of being embarrassed. These engineering professionals emphasized the need to promote interpersonal skills in engineering training. This study therefore recommends the establishment of engineering leadership laboratories where students can be trained in engineering leadership skills. For instance, one of the suggestions of the engineering professionals in this study is to improve engineering graduates' communication skills by asking them to explain their engineering solution to a 3rd grader or someone in the liberal arts in a way that the person will understand. Also, they recommended using active listening skills, which is listening with understanding and checking with the communicator to ensure that the right message is passed across, and giving students ill-structured problem scenarios where they will need to use such skills as humility, respect, and empathy. All these can be implemented in the engineering leadership laboratory and coursework.

Another important recommendation from this study is the need to include internship experiences, especially in a non-engineering environment as part of every leadership training session. This will enhance their ability to be able to effectively communicate and work with a broader audience. The engineering leaders in this study emphasized the need for this experience and they noted that leadership training without the incorporation of a period of internship where the learner can gain experience might not be as impactful as it should be. They emphasized that it is important that engineering leadership educators in engineering institutions encourage their students to engage in student clubs and other extracurricular activities within the institution.

They should also provide support and incentives for them to do so. This will help them to translate their leadership knowledge into actions.

5.8. Future work

A total number of eighteen engineering leadership skills were identified by engineering leaders in this study. Future research should endeavor to refine these skills through empirical methods to better enhance the understanding of how these skills could improve engineering education. Furthermore, one of the limitations of this study is that the research participants who participated in this research were recruited from companies that were based in the state of Utah. Future studies should further explore this topic from the perspectives of participants from other geographical locations to substantiate and or compare results from this study.

In addition, one of the findings from his study is that leadership identity awareness influences leadership behaviors. Future studies should also explore this claim by seeking to understand the relationship between these two entities.

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APPENDICES

APPENDIX A: ELECTRONIC LETTER OF INVITE FOR POTENTIAL PARTICIPANT ENGINEER IN ABET

Subject: Invitation to Participate in Dissertation Research on Engineering Leadership Definition by ABET Leaders and Professional Engineers in the Industry

Dear Engineer,

My name is Yemisi Oyewola, and I am a doctoral student in the Department of Engineering Education at Utah State University. I am contacting you because I am seeking ABET leaders to participate in my dissertation research on Engineering Leadership, and your prominent role as an ABET leader in the Engineering Accreditation Commission makes you an excellent match for my research. I am therefore writing to seek your participation in the study.

My dissertation research topic is defining engineering leadership and engineering leadership skills from the perspective of ABET leaders and Professional Engineers in the industry. The gap that the research is trying to fill is that most of the definitions of engineering leadership and engineering leadership skills in the literature are borrowed from the definition of leadership and leadership skills in the management and psychology literature, and not from the engineering profession's standpoint.

Since ABET makes the rules for engineering institutions and the industry has its expectations of what leadership skills engineering graduates should have, knowing how ABET leaders and engineering professionals in the industry would define engineering leadership and specific engineering leadership skills that should be emphasized in engineering leadership training programs would be important. Findings from the research can guide engineering institutions better in their teaching of engineering leadership and engineering leadership skills.

I intend to have a 30-minute to 45-minute interview with each participant on Zoom. The Zoom video recording will be turned off during this interview. I will also ensure the anonymity of the interview. In addition, I am available to work with your date and time. I plan to collect my data in October and November 2023. Also, a $50 Amazon gift card will be given as a stipend for your time and effort associated with participation in the study after the interview.

I understand that your time is valuable, and I genuinely appreciate any consideration you give to my invitation. Should you have any questions or require further information about the study, please do not hesitate to contact me.

Thank you.

Sincerely,

Yemisi Oyewola

Graduate Research Assistant

APPENDIX B: ELECTRONIC LETTER OF INVITE FOR POTENTIAL PARTICIPANT ENGINEER IN THE INDUSTRY

Subject: Invitation to Participate in Dissertation Research on Engineering Leadership Definition by ABET Leaders and Professional Engineers in the Industry

Dear Engineer,

My name is Yemisi (Victoria) Oyewola, and I am a doctoral student in the Department of Engineering Education at Utah State University. I am contacting you because I am seeking Engineering Professionals in Industry to participate in my dissertation research on Engineering Leadership, and your prominent role as an engineering leader makes you an excellent match for my research. I am therefore writing to seek your participation in the study.

My dissertation research topic is defining engineering leadership and engineering leadership skills from the perspective of ABET leaders and Engineering Professionals in the industry. The gap that the research is trying to fill is that most of the definitions of engineering leadership and engineering leadership skills in the literature are borrowed from the definition of leadership and leadership skills in the management and psychology literature, and not from the engineering profession's standpoint.

Since the industry has its expectations of what leadership skills engineering graduates should have and ABET makes the rules for engineering institutions, knowing how ABET leaders and engineering professionals in leadership positions in the industry would define engineering leadership is important. Also, understanding the specific engineering leadership skills that should be emphasized in engineering leadership training programs from the perspective of the engineering leaders would be very valuable. Findings from the research can guide engineering institutions better in their teaching of engineering leadership and engineering leadership skills.

I intend to have a 30-minute to 45-minute interview with each participant on Zoom. The Zoom video recording will be turned off during this interview. I will also ensure the anonymity of the interview. In addition, I am available to work with your date and time. I plan to collect my data in October 2023. Also, a $50 Amazon gift card will be given as a stipend for your time and effort associated with participation in the study after the interview.

I understand that your time is valuable, and I genuinely appreciate any consideration you give to my invitation. Should you have any questions or require further information about the study, please do not hesitate to reach out to me.

Thank you.

Sincerely,

Yemisi Oyewola
Graduate Research Assistant

APPENDIX C: INTERVIEW PROTOCOL

Interview Protocol

Name: ____

Job Title: ____

Total Number of Years of Engineering Experience: ______________________

Total Number of Years in Leadership Position: ______________________

Industry: ____

Size of Company (if applicable): ______________________________

Part A

Research Questions 1, 2, and 3– Engineering Leadership Definition (ELD) Part

1. a. How would you describe your role as an engineering leader in your organization? That is, what are your primary responsibilities as an engineering leader in your organization?
   b. Based on your experience as an engineering leader, how do you perceive the role of an engineering leader in the broader context of the organization? (*vis-a-vis, the role of an engineering leader in being able to provide effective leadership for both engineering professionals and non-engineering professionals in the organization. Or should engineering leadership be discussed only in the context that relates to engineering professionals alone?*)
   c. Have there been situations in which you have had to handle non-technical roles as an engineering leader? (*That is, times you have had to lead a diverse group of people who are non-engineers*). What challenges did you encounter while handling such roles and how did you overcome those challenges?
   d. Considering all these precious discussions, how would you define engineering leadership based on your experience as a leader?

e. Based on your experience as an engineering leader, what would say are the key differences between engineering leadership and general or conventional leadership?

Part B

Research Questions 1, 2, and 3 – Engineering Leadership Skills (ELS) Identification Part

2. a. Based on your experience, what skills or competencies would you consider necessary for an engineering leader?
   b. Why do you think these are necessary or important skills?
   c. Can you provide examples of how you have applied these skills in your practice as an engineering leader?
   d. Are there skills or competencies you believe are unique to engineering leadership compared to leadership in other domains? Like management, business, etc.
   e. Similarly, are there skills or competencies that you believe are unique to leadership in other domains like management, and business and not engineering leadership?

Part C: Questions designed to substantiate the narratives provided in Parts A and B.

a. How have your experiences as an engineering leader evolved over time? *That is, what were your beliefs about leadership when you first became an engineering leader then and now?* - ELD
b. Can you share specific experiences that significantly influenced your views? - ELS
c. What would you consider the biggest challenge you faced as an engineering leader? How did you address the challenge, and what was the outcome? -ELS
d. Considering your journey as an engineering leader and the wisdom you've gained over the years, could you share what advice you would give to yourself when you first stepped into a leadership role? Or to your younger self as an engineering leader? -ELS
e. In your opinion, how has the culture of engineering impacted leadership positively or negatively within the field? *By "culture", we mean the shared values, beliefs, attitudes, and practices of our profession like a strong emphasis on technical expertise, problem-solving skills, and attention to detail, etc.* -ELS

APPENDIX D: INFORMED CONSENT

Defining Engineering Leadership and Engineering Leadership Skills from the Perspectives of ABET Leaders and Professional Engineers

You are invited to participate in a research study by Dr. Kurt Becker, a Professor in the Department of Engineering Education at Utah State University, and Yemisi Victoria Oyewola, a student researcher in the Engineering Education Department at Utah State University.

The purpose of this research is to define engineering leadership and engineering leadership skills from the perspectives of the Accreditation Board for Engineering and Technology (ABET) leaders and engineering professional leaders in the industry. You are being asked to participate in this research because you are an engineering leader who in addition to having experience working as a professional in the engineering field, has also held leadership position(s) in the field, and is interested in participating in the study on Engineering Leadership.

Your participation in this study is voluntary and you may withdraw your participation at any time for any reason.

If you take part in this study, you will be asked to participate in an interview session that will be conducted via Zoom for 30 to 45 minutes or longer depending on the details of your responses to the interview questions. The interview will involve asking about your perceptions of engineering leadership based on your experience as an engineering leader. During this interview, the Zoom automatic video recording will be de-activated.

The possible risks of participating in this study include loss of confidentiality. The benefits of participating in this study are the help in articulating a definition of engineering leadership and engineering leadership skills that would have taken into consideration the experiences of engineering leaders. This can guide engineering institutions better in their teaching of engineering leadership and engineering leadership skills.

We will make every effort to ensure that the information you provide remains confidential. We will not reveal your identity in any publications, presentations, or reports resulting from this research study. However, it may be possible for someone to recognize the specifics you share with us. In addition to this, all data collected for this study will be stored in a password-protected folder in Box.

We will collect your information through interviews. The interviews will be audio recorded before being transcribed. Online activities always carry a risk of a data breach, but we will use systems and processes that minimize breach opportunities. This qualitative data from the interviews will be securely stored in a password-protected folder in Box. The Box will be used for long-term storage of the data. Any identifying information will be separated and destroyed after the completion of the data analysis, no later than May 2024.

For your participation in this research study, you will receive an Amazon gift card of $50 that will be sent to you via email. This compensation will occur for participating in the interview.

You can decline to participate in any part of this study for any reason and can end your participation at any time.

If you have any questions about this study, you can contact the Principal Investigator at kurt.becker@usu.edu or Victoria Oyewola at yemisi.oyewola@usu.edu. Thank you again for your time and consideration. If you have any concerns about this study, please contact Utah State University's Human Research Protection Office at (435) 797-0567 or irb@usu.edu.

By signing below, you agree to participate in this study. You indicate that you understand the risks and benefits of participation and that you know what you will be asked to do. You also agree that you have asked any questions you

might have and are clear on how to stop your participation in the study if you choose to do so. Please be sure to retain a copy of this form for your records.

______________________	______________________	__________
Participant's Signature	Participant's Name, Printed	Date

APPENDIX E: CODEBOOK

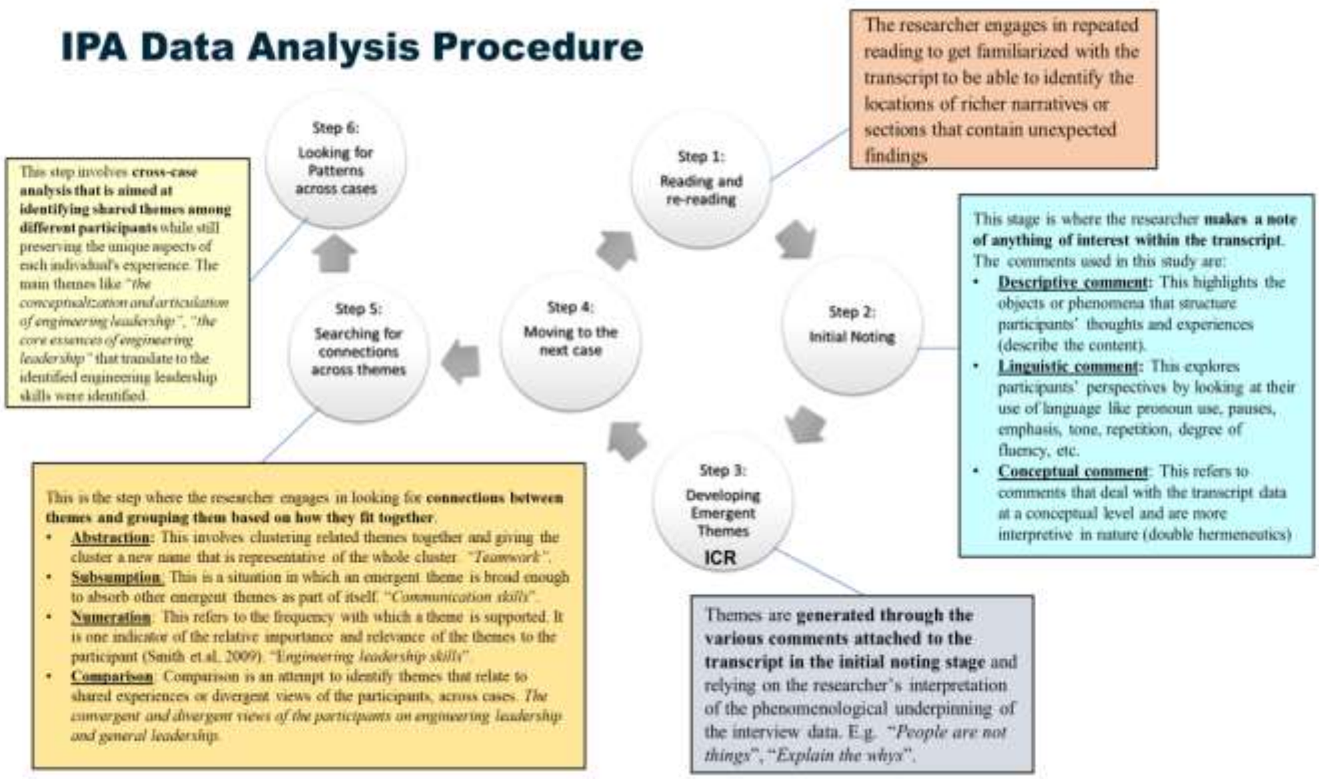
SN	Code System		Memo	Example
1	Engineering Leadership broadness		This has to do with whether the participants perceived or conceptualized the role of an engineering leader as broad in terms of leading both engineering professionals as well as non-engineering professionals in the organization or whether the role is restricted to leading engineers alone.	
		Yes - perceived as broad		E.g. Yes- I don't think it should be on the engineering professionals alone. I think it's a much broader role..... So, as engineers, we are responsible for the public interest in public safety. And so, we have an ethical obligation. I would argue leadership in those aspects (Raymond)
		No- perceived as restricted to engineering professionals alone		E.g. No- I guess I see engineering leadership in the context of engineering leadership as applied to engineering professionals (Kate).
2	Good Engineering Leaders Role/Responsibility		This has to do with what participants perceived as the roles of an effective engineering leader. (*This will highlight engineering leadership skills or behavior.)*	E. g. if you become a successful CEO, it's because you have been able to lead a diverse group where you recognize their talent, you learn to depend on the people, and you surround yourself with people who are the experts. It's no longer your job to be an expert. It's your job to facilitate the experts getting to where we need to be (Team Management / Teamwork)- Allison
3	Challenges & Solution		This has to do with a challenging experience reported by the participant and/or how it was resolved. (*This will highlight engineering skills or behavior.)*	E.g. So a lot of it too is the realization that some people don't really get it…. Well, the thing about people not getting it is to be more patient…..some of the ones that have been here a long time don't understand a lot of things that I think they ought to. And I find that frustrating at moments. (Maxwell)
4	Engineering Leadership Definition		This has to do with participants' conceptualization and articulation of the definition of engineering leadership.	E.g. Engineering leadership....is being able to manage the process flow in accordance with the mission. Or the goal or whatever you want to call it, to enable the things that need to be done to get done through the people because the people are your resource (Allison)

<table>
<tr><td>5</td><td colspan="2">Key Difference(s) between Engineering Leadership and General Leadership</td><td>This has to do with participants' perceived key differences between engineering leadership and general or leadership in other disciplines.</td><td>E.g. I mean, there is a philosophy that…a good CEO can oversee any company…. I don't know that I necessarily agree with that because…. being a domain expert in some technical discipline gives you ...the broad scalability to assess other people's technical statements, or maybe at least know the right questions to ask. So, I think that is what differentiates engineering from other types of leadership. (Fredrick)"</td></tr>
<tr><td rowspan="13">6</td><td colspan="2">Engrleadership Skills</td><td>This has to do with soft skills that participants perceived that an engineering leader should have to be a successful or an effective engineering leader based on their experience.</td><td>E.g communication skills, listening, organization skill, empathy, lifelong learning, etc</td></tr>
<tr><td rowspan="12">Skills that are derived from the transcripts</td><td>Communication Skills</td><td></td><td></td></tr>
<tr><td>Listening skills</td><td></td><td></td></tr>
<tr><td>Empathy/Compassion/Care</td><td></td><td></td></tr>
<tr><td>Humility or Ego Management</td><td></td><td></td></tr>
<tr><td>Problem-Solving</td><td></td><td></td></tr>
<tr><td>Lifelong Learning</td><td></td><td></td></tr>
<tr><td>Not Afraid to Fail/ Failure Mgt</td><td></td><td></td></tr>
<tr><td>Entrepreneurship</td><td></td><td></td></tr>
<tr><td>Ethical and Trustworthy</td><td></td><td></td></tr>
<tr><td>Critical thinking/ work with info you have</td><td></td><td></td></tr>
<tr><td>Explaining the Why</td><td></td><td></td></tr>
<tr><td>Technical Expertise/Skills</td><td></td><td></td></tr>
<tr><td>7</td><td colspan="2">Leadership Evolvement</td><td>This has to do with highlighting the pathways through which the leadership acumen of the participants has grown. That is, identifying what helped them in their leadership skills acquisition. (This will highlight engineering leadership skills or behavior.)</td><td>E.g. When I started as an engineer, I was given my first role... I was all pompous, and I thought, okay, I'm somebody now. People are going to listen to me, So, it was just immaturity. As time goes on, and the more I learn, the more I realize I need to learn more. The more I learn, the more I know that I don't know a whole lot of things. And it's just humility and humbleness (Sawyer)"</td></tr>
</table>

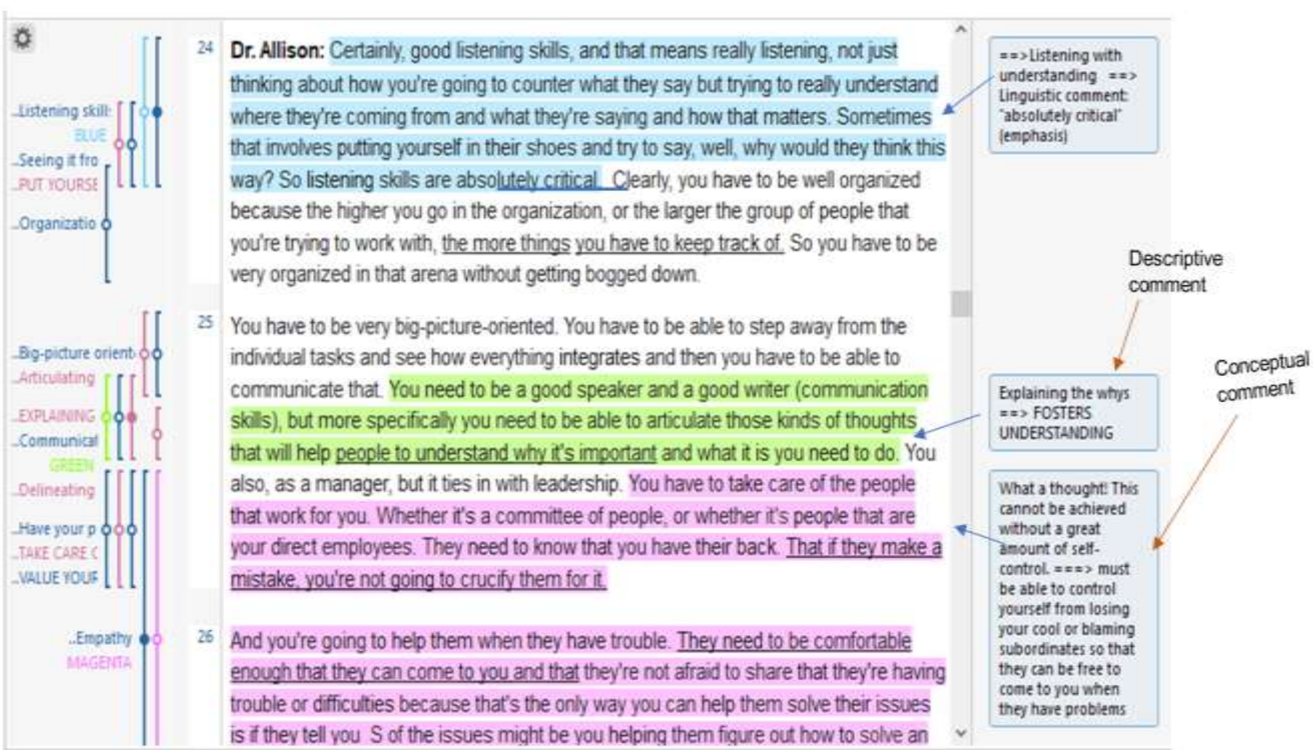
8	Advice to Younger Self		This has to do with what the participants express as a piece of advice they would give their younger selves. (*This will highlight engineering leadership skills or behavior.)*	E.g. What am I going to tell myself? Yeah, I would say take every opportunity you can to learn from your mistakes. Don't be afraid to ask questions, and definitely, don't be afraid to....make your supervisors aware of things that you may want by way of career objectives, instead of waiting for the right guide on what you want your career to be. (Justin)
9	Culture of Engineering		This has to do with participants' perception on how the culture of engineering affected leadership positively or negatively. (T*his will highlight engineering leadership skills or behavior.)*	
		Positive effect of culture		E.g. I think engineers understand the system approach....it doesn't matter what discipline of engineering, they all understand systems. And I think in... Intellectually... they understand the model; the big picture. (Sawyer)
		Negative effect of culture		E.g. Yeah, I think the negative would be that we tend to get into a mindset of, I'm right and you're wrong because we can prove it out with the numbers, right? And I think that's, that's a negative side…. because usually the answer is not going to be nearly as black and white as we want it to be with the number. Usually, the answer is in the nuance and understanding a little bit deeper than just the number (Henry).

APPENDIX F: DATA ANALYSIS PROCESS

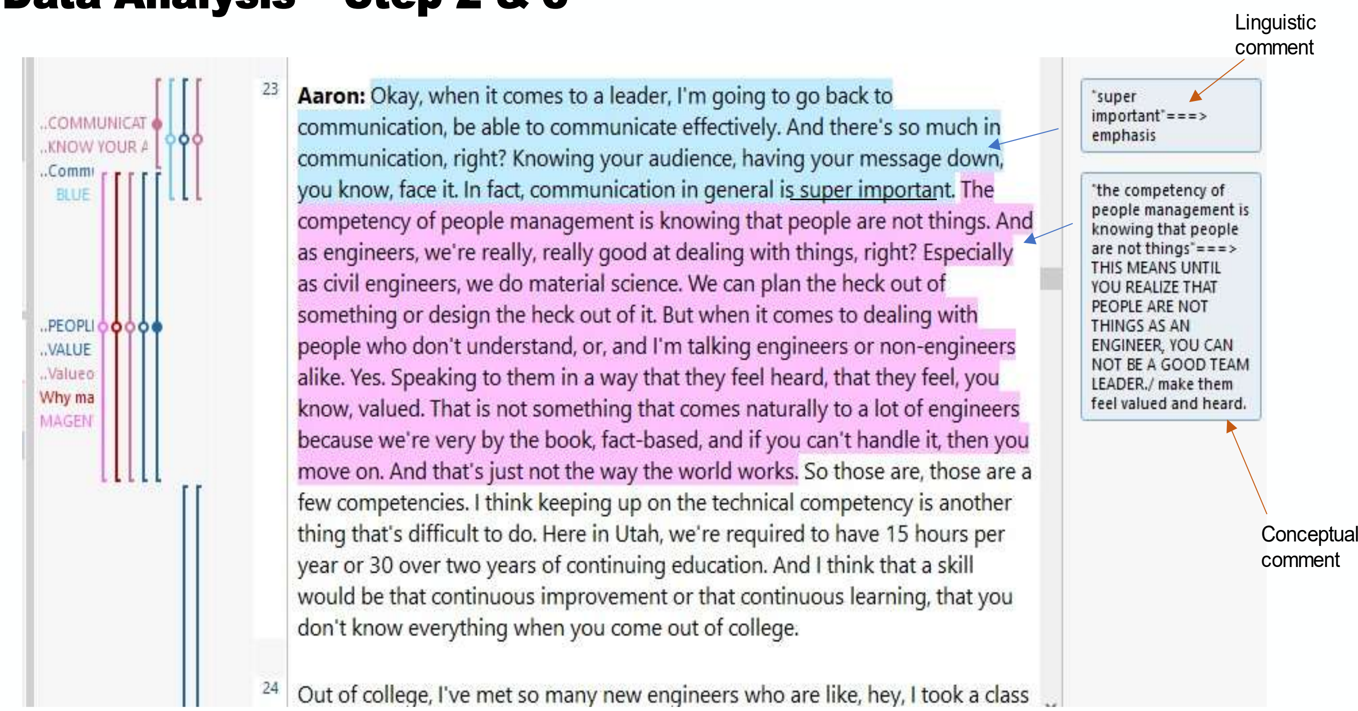
IPA Data Analysis Procedure



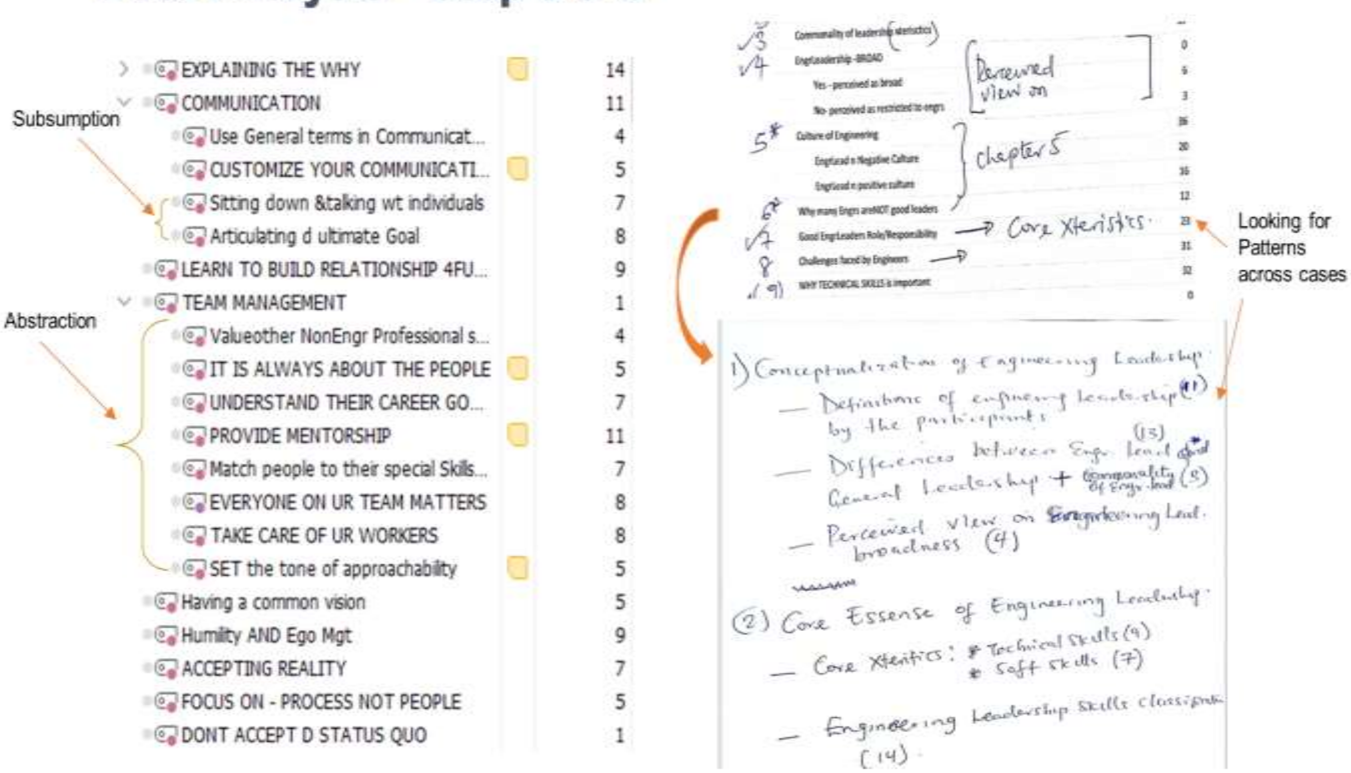
Data Analysis – Step 2 & 3



Data Analysis – Step 2 & 3



Data Analysis – Step 5 & 6



CURRICULUM VITAE

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EDUCATION

Doctor of Philosophy (Ph.D. Engineering Education) **2024**
.Utah State University, Dept. of Engineering Education, Logan, Utah state. USA
Dissertation: *Defining Engineering Leadership from the Perspectives of ABET Leaders and Engineering Professionals in the Industry (Qualitative Study)*

Master of Science (M.sc Information Science) **2014**
University of Ibadan, Oyo state. Nigeria.
Thesis: *Information Audit Awareness Among Small and Medium Scale Enterprises (SMEs) In Ibadan Metropolis. (Mixed-Method Study)*

Bachelor of Science (B.sc Computer Engineering) **2008**
Obafemi Awolowo University, Osun state. Nigeria.
Thesis: *Evaluation of the Performance of the Cyclic Redundancy Check (CRC) Error Detecting Code.*

National Diploma (Computer Science and Mathematics) **2001**
Federal Polytechnic, Ado-Ekiti, Nigeria.
Thesis: *Computerization of Stock-Control System using QBasic Programming Language. A Case Study of Fadekemi Supermarket, Ado-Ekiti.*

WORK EXPERIENCE

Graduate Research Assistant **2021 – 2024**
Department of Engineering Education, Utah State University, USA

Teaching Assistant **June -July 2021**
REU Summer Program, Utah State University, USA
- Taught the REU-assigned participants Statistical Data Analysis

Lecturer II **2016-2020**
Department of Computer Engineering, The Polytechnic, Ibadan, Nigeria.
- Subjects taught: Computer Architecture II, Industrial Management, Practice of Entrepreneurship, Technical Report Writing.

Lecturer III **2014-2016**
Department of Computer Engineering, The Polytechnic, Ibadan, Nigeria.
- Subjects taught: Introduction to Computer Programming, Operating Systems, Practice of Entrepreneurship, Digital Computer Fundamental I, Computer Architecture I

Assistant Lecturer **2010-2014**
Department of Computer Engineering, The Polytechnic, Ibadan, Nigeria.
- Subjects taught: Introduction to Computer Hardware, Computer Architecture I, Internet Technology, Digital Computer Fundamental I, Technical Report Writing I, Computer Architecture I.

Computer Instructor, **2008-2009**
Computer Training School, Dengi, Plateau State (NYSC)
- Conducted Computer literacy workshop on MS Word, MS Excel, and MS PowerPoint.
- Improved the course content by upgrading the training manuals.

Computer Instructor, **2002-2003**
Department of Computer Science, Osun State College of Education, Ilesa, Osun State.

- Participated in Conduction of Computer literacy courses; MS-Word, MS-Excel, MS-Access, MS-PowerPoint, Print Artist, CorelDraw and taught introduction to QBASIC programming language.

ADMINISTRATIVE EXPERIENCE

- Vice President, ASEE Student Club, USU Chapter **2022/2023**
- General Secretary, ASEE Student Club, USU Chapter **2021/2022**
- Departmental Timetable Coordinator **2016-2020**
- Examination Record Officer (Convener) **2016-2018**
- Departmental SIWES Coordinator **2011- 2015**
- ND II Level - Coordinator **2012-2013**
- Convener, Departmental Welfare Committee **2011-2013**
- Member, Departmental Project and Seminar Committee **2012-2020**
- Member, Faculty of Engineering Welfare Committee **2011-2020**

INTERNSHIP

Intern **2006**
BAJET Computer Technologies, Ilesa, Osun State, Nigeria

- Participated in the implementation of the operational software developed for clients
- Participated in the periodic maintenance of the Client's computers

Intern **2005**
Information Technology and Communication Unit, Obafemi Awolowo, University, Osun State, Nigeria.

- Management and maintenance of the school's intranet.
- Participated in routine checks of client's computer system

PROFESSIONAL AFFILIATIONS AND QUALIFICATIONS

Qualification	Awarding Body	Registration No	Date of Award
Member	Society of Women Engineers, USA	2036953	**January, 2022**
Member	American Society for Engineering Education (ASEE)	130071	**March, 2021**
Registered Engineer	Council for Regulation of Engineering in Nigeria (COREN)	R.29,996	**September, 2015**
Corporate Member	Nigerian Society of Engineers (MNSE)	31566	**April, 2014**
Member	International Association of Engineers (IAENG)	134703	**September, 2013**

RESEARCH INTEREST

Curriculum Development
Assessment and Evaluation
Student Engagement and Motivation in STEM
Engineering professional development and technical training

JOURNAL PUBLICATION

- Oyewola, O. M., Ajide, O. O., Osunbunmi, I. S., & **Oyewola, Y. V.** (2022). Examination of Students' Academic Performance in Selected Mechanical Engineering Courses Prior-to-and-During COVID-19 Era. *Emerging Science Journal*, *6*, 247-261.

- Oyewola, O. M., Ajide, O. O., Osunbunmi, I. S., & **Oyewola, Y. V.** (2022). Promoting female enrolment in engineering education for diversity, equality and inclusiveness in the South Pacific Islands. Global Journal of Engineering Education, 24(3), 220-225.

- Ajide-Olufemi, T. E., Amosun, M. D. and **Oyewola, Y. V.** (2020) Investigative Studies on Teacher's Level of Preparedness Towards the Adoption of Computer-Assisted Instruction (CAI) in Schools, *International Journal of Scientific & Engineering Research (IJSER)*, 11 (2), 665-672.

- **Oyewola, Y. V.**, Ajide-Olufemi, T. E., Adebisi, O. A., Busari, O. A. and OMITOLA, A. (2019) "Exploring the use of Social Networking Sites (SNSs) by Engineering Students: A case study of the Federal University of Technology, Minna*", International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)*, 8(12), 11681-11689.

- **Oyewola, Y.V.,** Adebisi, O.A and Busari, O. A. (2017). Investigating The Use Of Mobile Technology For Educational Purpose Among Engineering Students Of The Polytechnic, Ibadan, *International Journal of Scientific & Engineering Research (IJSER)*, 8(3), 327-334, ISSN 2229-5518.

- Adebisi O.A, Oladosu D.A, Busari O.A and **Oyewola, Y.V .** (2015). Design and Implementation of Hospital Management System, *International Journal of Engineering and Innovative Technology (IJEIT)*, 5(1), 31-34.

- Busari O. A., Adebisi O.A, **Oyewola Y.V,** Akanji O.O. (2015). Design of a Microcontroller Based Alarm Enabled Dark Activated Switch*, International Journal of Engineering and Innovative Technology (IJEIT)*, 4 (12), 38-41.

CONFERENCE PUBLICATIONS AND POSTER PRESENTATION

- **Oyewola Y.**, Goodridge W. & Becker K. (2023, April 12) *Progress Report on the Effect of Introducing Biological and Environmental Discipline-Themed Problems in Engineering Mechanics Statics on Students' Self-Efficacy and Perceived Value of the Course* [Poster Presentation], 2023 Utah State University Annual Student Research Symposium, Logan, UT, United States.

- **Oyewola**, **Y.**, Cowburn, B., Barlow, R., Goodridge, W., & Becker, K. (2022). The Effect of Introducing Biological and Environmental Discipline-Themed Problems in Statics on Students' Self-Efficacy and Perceived-Value of the Course. In *2022 ASEE Annual Conference & Exposition*.

- **Oyewola Y.V,** Adebisi O.A, Busari O.A. (2015) 'The Use of Mobile Technology for Educational Purpose among Engineering Students of the Polytechnic, Ibadan., 2nd National Engineering Conference, October 18th – 21st, 2015 at the Conference Center, The Polytechnic Ibadan.

- **Oyewola, Y.V.,** Adebisi, O.A., Busari, O.A. (2013). 'Towards Achieving Sustainable Development: Bridging the Digital Divide in the Polytechnic Educational System'. Faculty of

Science National Conference 2013 - 2nd- 6th June 2013 at the North Campus Assembly Hall, the Polytechnic, Ibadan.

REFERENCES

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