Examining the Need for Communication Competencies for Research Engineers

A Qualitative Case Study at the U.S. Army Corps of Engineers

Engineer Research Development Center

by

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ABSTRACT

Previous literature suggests that engineers are known for lacking communication skill and training, despite an illustrated need for it established by accredited engineering organizations. Limited research has been done to effectively include communication competencies in engineering education. The current study sought to identify what communication competencies research engineers need to function at a research and development center, and to develop recommendations for training for both university and workplace setting. This qualitative case study included semi-structured, in-depth interviews with 10 employees of the U.S. Army Corps of Engineer's premier research center: Engineer Research Development Center (ERDC). The sample consisted of six research engineers and four other allied professionals. The analysis indicated that engineers valued the three main competencies of collaboration, audience adaptation, and interpersonal understanding. These are built upon foundational skills, including oral and visual communication skills, written skills, and active listening skills. Results also showed that engineers preferred an integrated approach to engineer communication training and identified university courses and workplace trainings as two different sources of communication learning. Findings were consistent with two theories of communication learning: communication across the curriculum (CXC) and communication in the disciplines (CID). Practical applications are offered for educators in communication and engineering fields, as well as career development professionals.

DEDICATION

This work is dedicated to my family.

To my parents, Rob and Sheri, who cultivated my curiosity as a child and introduced a passion for education and learning. You have given me the drive, discipline, and dedication that allows me to accomplish anything. You are my inspirations, and I am eternally grateful to be your daughter. 123.

To Afton, Abi, Scott, and Katie, you have been a constant source of happiness, encouragement, and understanding throughout my life. You made me into who I am today, and I love you all with everything in me.

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CHAPTER 1

Introduction

How do you tell the difference between an introverted and an extroverted engineer? An introverted engineer looks at their own feet when they are talking to you, while an extroverted engineer looks at your feet when they're talking to you.

Participants 5 & 7

As implied by the quote above, some literature suggests that members of the STEM workforce have become somewhat renowned for lacking communication skills, especially with those outside of their own fields (Willoughby et al., 2018). This sense of 'notoriety' led a greater number of undergraduate science programs to focus on an introduction of generic communication skills, with mixed implementation success (Mercer-Mapstone & Kuchel, 2016). Darling and Dannels (2003) state that communication skills are the "lifeblood of a practicing engineer" (p. 15), and that failures in communication can be detrimental. An often-used example of a calamitous communication failure is the famed launch of the space shuttle Challenger, whose explosion took the lives of seven astronauts in 1986. It was widely reported that if the proper information regarding O-rings had reached the correct people, seven lives would have been saved (Teitel, 2018). Linvill, Tallapragada, and Kaye (2019) assert that since communication plays a central role in the process of science, STEM professionals "have a responsibility to communicate to the general public and enhance understanding of science" (p. 309). These concerns surfaced more than 20 years ago in the work of communication scholars Darling and Dannels (2003). Their research found that although "communication skills are critical to engineering practices, other studies report that these

skills are being inadequately developed in engineering courses and curricula nationwide," (p. 2), despite the American Society of Mechanical Engineers suggesting focus on the "development of students' professional and communication skills" in their Vision 2030 project goals (ASME, 2022).

The Accreditation Board for Engineering and Technology (ABET)—the non-governmental organization that accredits post-secondary education programs in applied and natural science, computing, engineering, and engineering technology—provides criteria for engineering programs. Their criteria are developed to foster the systematic pursuit of improvement in the quality of engineering education that satisfies the needs of its constituencies in a dynamic and competitive environment (ABET, 2021). Under *Criterion 3: Student Outcome*, 3 of the 7 outcomes include language that pertains to communication skills. Their first communication criterion is "an ability to communicate effectively with a range of audiences" (ABET, 2021, I. General Criteria for Baccalaureate Level Programs, para. 5). Before ideas and projects have been constructed, engineers have an obligation to first understand the expectations of the client or project. Success as a communicator comes from an ability to know an audience, and tailor a message to their understanding. This requires communication with both lay publics and technical experts.

Additionally, engineering workspaces are culturally diverse, from gender, socio-economic status, to various global customs and traditions (Hassan, 2009). Accordingly, the second communication criterion is "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" (ABET, 2021, I. General Criteria for Baccalaureate Level Programs, para. 5). Engineering workspaces are ripe with group

work because most projects and workspaces require collaborative participation to meet and make objectives. Learning how to work and communicate interpersonally with a variety of others can be considered essential in forming a cohesive environment and an engineer's career success. The third and final communication criterion is “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” (ABET, 2021, I. General Criteria for Baccalaureate Level Programs, para. 5). As illustrated in the Challenger example, STEM professionals have a duty to report when they observe malfeasance and communicate the situation in ways that respect the rights and personhood of others and refrains from communication that is deceptive or coercive. Being able to both recognize and take accountability is vital in discerning the ethical aspects of engineering, but also in understanding the communication needs of others and the organization.

While ABET, organizations, and researchers have established that communication skills are needed, there is still a lack of specification for the communication needs of engineering students (Hirudayaraj et al., 2021). Washburn et al.’s (2022) research noted that the methods of training scientists vary in their goals and methodologies throughout these programs, with little work being done to track their effectiveness. This is also true of engineers specifically.

Using a qualitative research approach, this paper seeks to investigate what communication competencies and durable skills engineer professionals need in their roles, and how to implement the recommended training before entering in the engineering workplace. This research was conducted with practicing professionals in the U.S. Army

Corps of Engineers' Engineering Research and Development Center. This paper starts with a literature review focused on establishing the need for communication competencies in the engineering workplace. Then, research questions are presented, followed by an explanation of both the USACE ERDC organization and the interview methodology used to conduct these interviews. Study findings consist of an analysis and thematic review of the research data, which includes the communication competencies of collaboration, audience adaptation, and interpersonal understanding that are supported through the building of foundational communication skills. The foundational skills were identified as oral and visual, written, and active listening. This paper proposes a set of recommendations for what communication competencies engineers need to succeed within engineer organizations that can be used to further develop engineer-specific communication training programs. Limitations of the current study, and suggestions for future research are also discussed.

CHAPTER 2

REVIEW OF LITERATURE

Research by Cirinio et. al, (2017) suggests that misconceptions of science knowledge come from the speed at which information is produced and consumed via the internet and that because of the prevalence of the public's faulty understanding, it is more important than ever for scientists of all levels to learn how to effectively communicate. The communication of science has been established since the emergence and development of systematic knowledge but was formalized into the means of scientific journals as early as 1665 (Gross et al., 2000). The modern study of science communication often refers to the use of appropriate skills, media, activities, and dialogue to produce one or more personal responses to science (Burns, O'Connor, & Stocklmayer, 2003). Success in science can be broadly defined, but author William Garvey (1979) defined the main effort of scientists as the ability to manufacture new information with new data, formulating new concepts, or developing conceptual integrations of data, otherwise referred to as theory, but success was measured by their ability to communicate it in a "form so as to be comprehend and verified by other scientists and then used in providing new ground for further exploration" (p. 2). Therefore, he asserts that a scientist's career depends on others' ability to understand their work. Much science communication research has focused on science journalism, science communication training, and strategic science communication.

Research on strategic science communication has included scientist's opinions on communication and their willingness to engage in the communication process. A study conducted in 2017 sought to understand how different scientists viewed different

communication objectives, finding that "communication trainers might seek to reshape if they wanted to get scientists to consider choosing specific communication objectives" (Besley et al., 2017). A 2018 survey study of scientists found that an "overall willingness to engage [with the public] may be driven primarily by attitude toward engagement and scientists' engagement-related efficacy beliefs, controlling for past engagement" (Besley et al., 2018). This is important to note because it suggests that to increase a willingness to engage, it is helpful for scientists to be shown how to communicate and engage, and how it can make a difference.

An emphasis on engineering communication as a subset of broadly defined science communication is important because of the specific training that goes into developing the engineer mindset. Author Guru Madhavan (2015), a biomedical engineer and senior policy adviser, stated that "engineers use a unique mode of thinking based on seeing everything as a system. They see structures that aren't apparent to the layperson, they know how to design under constraints, and they understand trade-offs" (para.1) Understanding how engineers think and communicate allows better training to be developed, that specifically focuses on preparing engineers for communicating knowledge effectively to a wide variety of audiences.

In addition to advancing technologies, economic dynamics and the emergence of global communication affect the practice of being an engineer (Itani & Srour, 2016). Borrowing from their experience as a STEM professor, Borowczak (2015) argued there is a 'gross misconception' in the education of STEM students in teaching and believing that their career work will rely on a technical skill set. This was furthered by the assertion that effective communication is at the "cornerstone of every successful STEM practitioner,

researcher, and educator" (2015, p. 18). The review of engineering communication literature has been divided into three distinct sections to understand and explain the need for communication centric training for engineers: communication within an engineering workplace, defining engineering-specific communication competencies, and the effect of previously established communication training.

Communication in Context: The Engineering Workplace

Communication needs of an engineering workforce are distinctive and intrinsically tied to the types of work done in these spaces. This section of the literature review is split into the dimensions of engineering communication and communication tasks that have been identified by previous research studies.

Dimensions of Engineering Communication

Darling and Dannel's (2003) study first details what types of oral communication are important in the engineering workplace, specifically focusing on the audiences and the relationship between oral communication and writing skills. Then, using their findings, they address the implication this research can have on scholarship, research, and practice. Using qualitative research techniques to analyze data collected from a larger research project, Darling and Dannels (2003) identified that 50 percent of participants identified public speaking—presentations, formal speaking, public seminars, and technical presentations—as the most important form of oral communication event in the workplace. 32% of the responses indicated that meetings—chairperson of meeting, running meetings, facilitation meetings—were the most important form of oral communication event. The top two results were followed by interpersonal/and informal

speaking, training, and selling. Their findings suggest that the audiences of oral communication are more varied, but not limited to between peers inside the company, non-technical audiences, management, customers, government agencies, and employees. Darling and Dannel's (2003) overarching message is:

> [Talk] in the engineering workplace is not always the formal speeches we teach in the communication discipline—but it is not perfunctory or peripheral to an engineer's job either—it does matter. In fact, it not only matters to their daily activities, but to those customers and clients that engineers interact with daily. As practicing engineers continue to talk about the importance of talk in their workplaces, there is a clear opportunity (if not mandate) for educators in the disciplines and communication scholars to not only lend an ear but also to collaborate on the development of sound instruction, scholarship, and curricula that has the potential for making strong contributions to students and faculty for whom talk matters in important ways. (p.15)

Linvill and colleagues (2019) outline the idea that as the continual widening of public skepticism towards the sciences grows, it is more important than ever to have "targeted training" in communication competencies that will "lead to intelligent public conversations that allow for informed decisions in national and international debates involving science and technology" (p. 309). Additionally, Linvill et al. contend that learning oral communication skills is principal in the field of engineering. Affirming this idea in a global context, Masduki and Zakaria (2020) conducted a qualitative interview study on civil engineering graduates in Malaysia in order to deduce the types of communication skills that are needed in the civil engineering workplace, and how those

skills are used. They found four significant communication themes needed in the civil engineering workplace, including oral communication, written communication, visual communication, and interpersonal communication (Masduki & Zakaria, 2020).

Communication Tasks: What Engineers Do with Communication

In addition to Masduki and Zakaria's (2020) four themes, their work identified specific communication tasks that correlate. Their participants reported that oral communication was mandatory, as misunderstandings lead to mistakes. Additionally, one participant emphasized that team discussion and group work happen each day and learning how to work and communicate with a team is of the utmost importance. Written communication was also identified, but in this study those tasks tended to refer to social media, emailing, memos, and technical reports. Interpersonal communication was both implicit and implied, especially as it revolved around teamwork and cooperation. Participants reported that listening was the social skill many engineers lack and need to develop rapport. Additionally, participants mentioned that non-verbal communication is crucial to avoiding misunderstanding in the engineering workplace (p. 3080). Visual communication was the final communication theme, and includes tasks such as marketing, technical drawing, scheduling, charts, illustration, etc. (p. 3076). This was identified as important because these are needed to provide guidance and plans to others, and it is important to avoid misrepresentation and misunderstanding. This study provided a general overview of communication in the workplace but due to the small number of respondents ($N = 5$) it remains limited in scope.

Mellors-Bourne, Connor, and Jackson (2011) conducted a study consisting of a survey and qualitative interviews, focusing on STEM graduates, which included a section

outlining the skills being sought of new STEM employees. They reported that communication skills were listed as a priority by employers, because

> …they have to be able to talk about science but not in too detailed a way and understand what communicating science to the general public means…STEM graduates were thought more likely to have strengths in this area and so could be at an advantage over others in getting through selection processes (p. 156).

Most research has focused on the training that is being done for undergraduates to prepare for the workplace, without in-depth analysis of what is needed in the various workspaces. To investigate what communication goes on in an engineering workspace, Clarkson (2016) highlighted the idea that "communication tasks" for engineers cannot be confined or placed into a single system, meaning that engineers must develop and adapt per project, especially with emerging technologies. Their study created a framework of guiding principles of science communication, which aimed to integrate skills that focus on the development of written, oral, and visual communication skills into courses that are more focused on the technical skills. The framework produced from this study focused on logistical considerations, communication considerations, content development and design, and software tools needed as an organizing structure (Clarkson, 2016). Another survey reported that to succeed in engineering jobs, entry-level engineers are expected to possess communication, teamwork, management, and entrepreneurial skills (Itani & Srour, 2016).

Professional engineers have reported spending 32% of their time in the workplace utilizing verbal communication (Cruz et al., 2021). Additionally, Cruz and colleagues

observed that they spend 28% of their time writing to others. They recorded that engineers mentioned they spend “on average 57% of their working hours on active communication such as writing emails and reports, making phone calls and having meetings [and that] in technology sectors, engineers are constantly exchanging information between other engineering fields and society. They need to communicate effectively to show their vision, to put plans into practice, and to stimulate feedback mechanisms" (p. 8). These statistics help with the visualization of the communication needs of young graduates but show less of the needs of mid- and senior-level engineers.

Engineering Education: Addressing the Need for “Durable Skills”

Engineering workspaces are unique, but still require similar bases of non-technical skills to function effectively. While each study uses unique wording to identify the communication competencies needed in STEM, and in engineering disciplines in particular, the literature shows the demand for engineers to be both competent and experienced in both technical and durable skills. The study of non-technical skills has long been the focus of academic work, namely in the field of sociology (Hurrell, et. al., 2012). The introduction of the intersection between specific communication skills and the STEM workforce began emerging in the early 1980s (Linvill et. al., 2019). Since then, research has continually linked the need for communication with engineers, but specific training has continued to be limited.

Identified Deficiencies

Riemer’s (2007) work conveys that as the world becomes more and more interconnected, the need for further communication competencies continues to grow.

Students are leaving their secondary and tertiary education opportunities without a grasp of communication basics, and thus not having a sufficient base to excel in the professional, global engineering space. The identified deficiencies in communication skills education were attributed to "student's attitudes to communication, insufficient course content, deficient or inappropriate teaching methods, and a lack of opportunity for engineering students to practice communication skills" (Riemer, 2007, p. 91). Riemer references ten overarching forms of communication prowess needed for a practicing engineer, with four of those being specific and definitive skills: oral communication skills, listening skills, written communication skills, and visual communications skills.

In focusing on oral communication skills, Riemer (2007) wrote that "oral communication and presentation skills are considered one of the best career enhancers and to be the single biggest factor in determining a student's career success or failure" (p. 92). Riemer's (2007) claim comes from employers "echoing" the need for oral communication for over a decade across multiple disciplines (p. 92). Despite the idea of increasing importance, and that "the scientific community agrees that training in oral communication skills will benefit our future colleagues" research shows that still "relatively little emphasis is placed on this training" (Willoughby et al., 2018, p. 2). This shows that there is clearly a need for communication competency training that correlates with the communication themes needed in the engineering workplace.

Core Durable Skills in Practice

Communication competencies historically fall under the category of soft skills, though recent studies have called for the renaming of soft skills to durable skills. This push allows for training to be approached from a "perspective [that] empowers talent to

make dynamic, longer-term contributions to an organization" (Daniel, 2020, para. 1). Hurell et al. (2013) advances the idea that while these skills are non-technical and not reliant on abstract reasoning in nature, they focus on the abilities needed to facilitate mastered performance in particular contexts. For the purpose of this study, the definition of durable skills follows Hirudayaraj et al., (2021): a disparate set of personal attributes, traits, attitudes, and behaviors, although focus and attention will be given to Riemer (2007)'s aforementioned communication specific skills. Hirudayaraj et al. (2021)'s research states that "[durable skills are] less tangible, hard to quantify, and rather challenging to define" (p. 7). The authors employed a survey to assess four areas of durable skill research, namely what [durable skills] do employers expect entry-level engineers to demonstrate, which [durable skills] are most important? Their research illustrated the need to further develop and train STEM students on their communication skills, interpersonal skills, and personality characteristics (Hirudayaraj et al., 2021). Literature shows that the integration of [durable] skills into science courses has been difficult because higher education institutions are designed to be individual entities, meaning that the decisions being made by science academics. As a result, when communication skills are taught traditionally, and do not reflect the diversity of skills needed (Mercer-Mapstone & Kuchel, 2016). In order to deduce what types of activities could be designed and implemented in undergraduate courses that would develop a diverse range of communication, as well as learn what is to gain by introducing a science communication template to said undergraduate courses, researchers Mercer-Mapstone and Kuchel (2016) identified seven core communication skills they believed to be most relevant to effective science communication (p. 125):

- Identify and understand a suitable target audience,
- Use language that is appropriate for your target audience,
- Separate essential from non-essential factual content in a context that is relevant to the target audience,
- Consider the social, political, and cultural context of the scientific information, use/consider style elements appropriate for the mode of communication (such as humor, anecdotes, analogy, metaphors, rhetoric, images, body language, eye contact, and diagrams),
- Consider the levels of prior knowledge in the target audience,
- Identify the purpose and intended outcome of the communication.

The National Science Foundation (NSF) funded a research project, entitled STEM *STORYTELLERS: Improving the Oral Communication Skills of STEM Graduate Students* (Willoughby et al., 2018), to develop a "a fellowship program for Ph.D. students that will provide multifaceted training and practice in oral communication to prepare them to effectively convey science to people with a wide variety of backgrounds" (p. 3). For this developing program, researchers created a 'jargonness' equation, to measure and evaluate how much jargon the students are using in order to reduce the use of jargon in students' performances.

Following that evaluation, additional training in presenting to live audiences was provided. From that, a rubric was developed to evaluate the effectiveness of the public address. The Public Speaking Competency Rubric Core Performance Standard is listed in Table 1.

Table 1

Public Speaking Competence Rubric Core Performance Standards

Item Numbers	Competency Measured
1	Selects a topic appropriate to the audience and occasion
2	Formulated an introduction that orients the audience to the topic and speaker
3	Uses effective organizational patterns
4	Locates, synthesizes, and employs compelling supporting material
5	Develops a conclusion that reinforces the thesis and provides a psychological closure
6	Demonstrates a careful choice of words
7	Effectively uses a vocal expression and paralanguage to engage the audience
8	Demonstrates supportive non-verbal behavior
9	Successfully adapts the presentation to the audiences

These articles demonstrate the well-documented push to develop communication-based training for scientists, particularly oral communication skills (Linvill et al., 2019), but further research suggests that less exploration has been done on competencies outside of public speaking.

Approaches and Effects of Communication Training

Riemer's (2007) research indicates that while engineering education is already crowded, the current communication education must be improved in order for engineering graduates to see success in their careers (p. 98). While courses and sections of communication specific curriculum have already been included in universities across

the globe, Riemer presents the notion that the inclusion of communication education is not enough to benefit students.

Integrated Approaches

Because of the discipline-specific approach of engineering scholarship, communication competencies tend to be taught by science academics, who have not received the specialization needed to educate undergraduates on a topic like communication "that they themselves may find challenging" (Mercer-Mapstone & Kuchel, 2016). While Mercer-Mapstone and Kuchel (2015) theorize that one reason that a rationale for recent graduates to have "more generic communication skills could be that the inclusion of communication content in science courses is left mostly to the discretion of the scientists in charge of lecturing and hence reflects the focus of their careers on traditional research and conventional communication to other scientists" (p. 1). This type of training therefore does not reflect the diversity of skills needed. Targeted training of STEM students in effective communication with multiple audiences can lead to intelligent public conversations that allow for informed decisions in national and international debates involving science and technology (Leshner, 2003). Using the previously established literature that focuses on the needs of STEM communication training, Linvill et al. (2019) developed a course with a team of both communication and engineering faculty that was then taught by the communication faculty. The course focused on the teaching of "ethics, communication apprehension, listening, analyzing an audience, and supporting ideas [taught] though an engineering lens" (Linvill et al., 2019, p. 311). They found that "efficacy toward communication and being enrolled in the

[course] related positively to a sense of engineering identity for students at the end of class" (p. 321).

Cirino et al. (2017) argues that there should be an emphasis placed on "training young scientists in how to effectively communicate research to different audiences, so that accurate dissemination of scientific information is shared with both the public and the scientific community" (p. 2), and that this training should be both formal and a priority, instead of the development of these skills occurring by happenstance. To test the idea that there is a link between students who are skillful in learning oral science communication in science to both scientists and the public will also be skillful in learning how to think more critically about research, Cirino et. al (2017) developed a course with activities that "involved (i) the presentation of primary scientific literature to peers, (ii) the development of a research monologue for the public, and (iii) the construction and presentation of a technical poster based on their current undergraduate research" (p. 4). Engineering majors are often course heavy and leave little room for additional required courses. Therefore, integrated approaches tend to be the norm within undergraduate training.

Stand-alone Approaches

Schiebel et al. (2022) reports that both discipline-specific and general communication skills are necessary for the dissemination of accurate and engaging scientific information. Further, they state that "this type of training is rarely provided in curricula, creating a significant skill gap for [undergraduate students, graduate students, and those within two years of graduation from a graduate degree program]" (p. 21). To provide a training where there is an overlap between professional development and

science communication, the authors organized a workshop, where attendants voluntarily participated in sessions consisting of both verbal and visual communication skills (Schiebel et.al., 2022). Using feedback collected from the first two pilot versions of this training workshop, different materials—most notably the development and presentation of conference posters—were implemented into the 2021 workshop. After the workshop, Schielbel et al. (2022) compiled evaluation results, based on the research team's reflections and participant's impressions. The results showed that "Participants overwhelmingly agreed that they: (1) would recommend the workshop to others, and (2) felt the workshop content would be useful in their careers" (p. 22).

Itani and Srour's (2016) research addresses the question of whether universities are preparing their students in non-technical skills well enough to assume their future roles. Most universities began to include the recommendation of soft skills in smaller, tentative ways, while fewer programs have included a mandatory reform of the incorporation of soft skills. Itani and Srour define the most apt communication skills for engineering education as oral communication with managers and peers, presentation skills, business writing skills, and cross-cultural communication abilities, and recommend an integration of those skills at the undergraduate level, similar to Linvill's assessment of CXC (p 2). In addition, to discover how universities are preparing their engineering students in non-technical avenues, the study proposes that "incorporating more soft skills, management, and entrepreneurial studies at the undergraduate level, universities will be contributing to a series of advancements on various levels" (Itani & Srour, 2016, p. 3)

Itani and Srour (2016) developed a 34-question anonymous interview questionaire, with a total of 306 respondents. While this study addresses education

information, perceptions of engineering, and postgraduate plans, the part most relevant to this research was entitled “student perceptions about nontechnical skills and industry expectations” (p. 7). The results of that section showed that students believed that there is room for improvement when it comes to the teaching of soft skills, especially when it came to conducting an oral presentation. Itani and Srour concluded by recommending that “engineering programs must still make more effort to explain to students, through courses, learning experiences, and career advising, the importance of gaining certain skills, especially soft skills, in the workplace [and that] engineering schools should start incorporating the development of important skills for entry-level jobs” (p. 11). While researchers have established that communication skills are needed, the method of training scientists varies in their goals and methodologies throughout these programs, with little work being done to track their effectiveness (Washburn et al., 2022). There has been even less work done in evaluating what the communication needs and effective training of graduated and employed engineers.

Theoretical Framework

Similar to Washburn et al.’s (2022) research on science communication training recommendations, this study was guided by constructivist communication theory. Constructivism communication theory explains how one’s knowledge is structured through their own conceptual categories, categories formed through experience and time (Littlejohn & Floss, 2011, p. 159). Meaning, it builds on the idea that learners use their previous knowledge as a foundation and build on it with new things that they learn. Constructivism argues that when we incorporate new and complex points of views, our

construct of the world will be more refined. The more cognitively complex the construct is, the more adaptative it allows a communicator to be. Adaptation is an important communication function, as well as how to develop complex constructs, which can be learned through education. Focusing on the idea that communication skills can be learned, engineering communicators can implement strategies to become more effective and skilled communicators, and additionally train others in this skill set.

In addition to constructivism, this study takes in account two pedagogical frameworks: communication across the curriculum (CXC) and communication across the discipline (CXC) as training models and addresses engineers' thoughts of both training styles in the research. Introduced in the 1970s, CXC is the integration of skills, particularly communication skills that focus on the development of written, oral, and visual skills, into courses that are required within a STEM discipline. The argument against CXC is that it can 'potentially dilute' the communication-specific skills when focusing on the discipline-specific courses (Linvill et al., 2019, p. 310). To further the research on CXC, the Communication in the Disciplines (CID) model was proposed by Dannels (2001). It incorporates communication skills in a disciplinary specific manner. Dannels (2001) characterized this model by four principles: "1) oral genres are sites for disciplinary learning, 2) oral argument is a situated practice, 3) communication competence is locally negotiated, and 4) learning to communicate is a context driven activity" (p. 147). Linvill et al.'s research explores the ideal that by learning communication competencies in a disciplinary focused manner, it will help STEM professionals establish their personal identities within the workplace environment (2019, p. 310). Based on this research, the following research questions are posed:

Research Questions

RQ1: What communication competencies do engineers believe they need to function within an engineering research organization?

RQ2: What recommendations can be made to further develop engineer-specific communication training programs at both the university and professional level?

CHAPTER 3

METHODOLOGY

To understand both the communication needs engineers have and the most effective training for them, this research utilized a semi-structured interview process to collect detailed opinions, experiences, and concrete examples of the communicative practices used and the role of communication in engineering. The reason this method was chosen is that qualitative research has the unique ability to examine a specific issue in a more detailed fashion and provides experiential data that can offer more analysis. Additionally, open-ended questions can help uncover attitudes, perceptions, and motivations (Washburn et al., 2022). The target population of this study consisted of adults employed by the USACE Engineer and Research Development Center, making this research a case study.

Research Context

USACE & ERDC Background

The United States Corps of Engineers (USACE) is a major command within the U.S. Army that is responsible for managing three primary mission areas: engineer regiment, military construction, and civil works. Within this formation, the U.S. Army Engineer Research and Development Center (ERDC) sits as their premier research facility and one of the most diverse engineering and scientific research organizations in the world. ERDC consists of seven laboratories, spread throughout the United States, employing over 2,000 engineers and scientists. USACE ERDC consists of six laboratories: Information Technology (ITL), Environmental (EL), Cold Regions and

Research (CRREL), Coastal and Hydraulics (CHL), Construction Engineering Research (CERL) and Geotechnical Structures (GSL).

Researcher's Personal Connection with ERDC Section

Research is often fueled by not just scientific interest, but personal interest (Altenmüller et al., 2021). As an undergraduate student, the ERDC's Coastal and Hydraulics Laboratory and the Corporate Communications Office employed me, and that work sparked the initial interest into investigating both the understanding of how communication works in the engineering workspace and what training could be implemented to help develop engineers' skill set. Additionally, because of the location of the laboratories and my time there, I have family and friends that work for ERDC. In view of that fact, it would be remiss to not assume some level of personal connection feasibly affected this research.

Participants

Before participants could be identified, permission had to be received from both ERDC and the U.S. Army Corps of Engineers' Office of Counsel. Contact was first made regarding this research with ERDC's Office of Corporate Communications (ERDC CC) in September of 2022. ERDC CC reached out to the Office of Counsel, where they requested more information about the extent of the research, including how many interviews, at what level, length of each interview, and the potential time frame. After pertinent information was sent and Arizona State University Educational Partnering Agreement (EPA) with ERDC was confirmed, USACE Office of Counsel signed off on the interview process with the following criteria: ERDC's Corporate Communications Office reserves the right to review any material before publishing and would be in charge

of selecting participants and receiving approval from both their supervisors and their respective laboratories. After permissions were granted from ERDC, the Institutional Review Board (IRB), the group that has been formally designated to review and monitor research involving human subjects, began their review process. After collecting information from the research team and ERDC regarding background and objectives, recruitment methods, consent forms, participation invitation script, and social and behavioral protocol forms, IRB granted approval for this study to be conducted October 2022.

Purposive sampling was used to identify appropriate participants who could provide adequate information and insight regarding the question of what communication competencies are most important in an engineering workplace, and second, what training could be implemented at the undergraduate level to bolster these needed skills. Purposive sampling was used to seek out people who were willing to provide knowledge and experience, and who were approved by supervisors and laboratories (Etikan et al., 2015). Before ERDC's Office of Corporate Communication began the recruitment and approval process, the researcher requested that participants represent a variety of roles and experience levels, including at least two entry-level engineers, two mid-level engineers, two senior-level engineers, and each of the engineers would need to have engineering degrees. In addition to those engineers' specific roles, the researcher also requested one to two lab communications liaisons, one corporate communications liaison, one recruiter, and one member of the strategic integration's office. ERDC CC provided a list of potential interviewees in November 2022 that listed three entry-level engineers, three mid-level engineers, three senior-level engineers, two lab communications liaisons, one

corporate communications officer, one strategic integration officer, and one recruiter. Via email, ten of the fourteen identified candidates volunteered for and scheduled interviews.

Table 2

Description of Participants

Identifier	Qualifier	Age	Gender	Field of Work
Participant 1	Entry Level	25	F	Research Mechanical Engineer GSL
Participant 2	Entry Level	22	M	Research Chemical Engineer EL
Participant 3	Mid-Level	39	M	Mechanical Engineer CRREL
Participant 4	Mid-Level	39	M	Environmental and Chemical Engineer GSL
Participant 5	Senior Engineer	56	M	Civil Engineer - Lead Technical Director ITL
Participant 6	Senior Engineer	44	M	Civil and Military Engineer - Associate Technical Director CHL
Participant 7	N/A	49	F	Corporate Communications Officer
Participant 8	N/A	45	F	Strategic Integration Officer
Participant 9	N/A	38	F	Strategic Communication Officer and CRREL Lab Liaison
Participant 10	N/A	62	F	Strategic Communication Officer and GSL Lab Liaison

Data Collection Methods

Semi-structured interviews were chosen for this research to provide participants more freedom, as this research was more exploratory in nature. Merrigan and Huston (2015) characterized this type of interview format by four properties: (1) it allows for participants to reflect on experiences or concepts that they have in common, (2) it refers back to situations that have been defined previously in the interview, (3) it allows the interviewer to focus on the participants' understanding and meaning-making, and (4) it focuses on the participants' own understanding and meaning of specific understanding and experiences (p. 274). The focus on how the participants understand and make meanings from their personal experiences allows the researcher to see how they construct their own knowledge. A researcher-developed interview guide was created for this study (see Appendix A). Tracy's (2013) chapter on interview planning and design informed the creation of the interview guide (p. 144 - 152). The guide started with opening questions focused on gaining demographic information, building rapport, and learning about academic and work experience. Following these questions, the interview guide turned to research focused questions, both generative and direct. As detailed by Tracy, the interview closed with a catch-all question, meant to allow for any further clarification to be made.

Once participation in the study was confirmed, interviews were scheduled and conducted through Zoom. Interviews lasted between 27 minutes and 63 minutes. Interviews were conducted online due to the varied and distant locations of the various laboratories (Illinois, D.C., and Mississippi). Interviews took place from November 2022 through January of 2023.

Participants verbally consented to participate in the interview and granted permission for the interview to be recorded for transcription purposes. After consent was received, the interview began. Participants were asked to give an overview of their academic and work history and experiences, particularly those related to the current roles and positions. Then, participants were asked to discuss where communication enters their jobs, the process of communication that occurs specific to the ERDC workplace, their opinions on the communication practices of others, the development of communication skills, and their recommendations for adequate communication training for new engineers. As the interviews were conducted, certain phrases and word choices needed to be explained, such as workspaces and durable/soft skills. Additionally, some of the interviews were affected by technical issues, such as a poor connection, video restrictions on government computers, and audio quality.

Data Analysis Methods

Interviews were audio recorded with Apple's Voice Memo app and with Zoom's automated transcripts. Final transcriptions were prepared using Otter.ai software and cross-checked against audio recordings. After transcripts were prepared, they were sent via email to participant interviewees for final approval, with the note that the final transcripts could only be accessed by individual participants and the researcher. Approval from all participants was received in January 2023. Prior to analyzing data, participants were given a numerical identifier 1-10 to help ensure anonymity, and audio recordings were deleted from all servers after the research was completed. Interviews provided 148 single-spaced pages of interview transcripts.

Participants were provided with an opportunity to review each of their individual transcripts and make any edits or changes that they felt comfortable. 7 of the 10 participants felt comfortable with the transcripts as they were, with minor edits towards the grammar of the AI transcribers. 3 participants choose to take phrases or slang language out of their work, but all answers to the questions remained the same.

Data was analyzed using an inductive method. Inductive analysis allows for research findings and significant themes to emerge from frequent or dominant theoretical saturation (Thomas, 2006). Coding, which refers to the way research data is labeled and organized, took a manual approach; Interview transcripts were printed, and read multiple times, while colored highlights demarcated each mention of a communication skill, competency, public event, previous training, and training recommendations. Two codebooks were created to address each of the research questions, with insights from RQ1's codebook informing RQ2. The researcher met with the thesis team weekly, and categorized the data until theoretical saturation was reached, which is "the point at which gathering more data about a theoretical construct reveals no new properties nor yields any further theoretical insights about the emerging grounded theory" (Bryant & Charmaz, 2007, p. 611). Five major themes emerged from the data, and a framework was developed.

CHAPTER 4

FINDINGS

While this research focused on identifying what communication competencies engineers need to function in a research engineer organization, the findings included identifying how they define the work that they do. Before focusing on research specific questions, demographic questions provided a foundation to show how the work that they do is supported through communication and durable skills. When describing their work, engineers focused on identifying their research work, which included investigation, experimentation, the creation of prototypes, maintaining equipment, 3D printing, large-scale modeling, and military installations. In addition to these research focused tasks, participants focused on 'knowledge management', which is the efficient handling of information and resources. When asked to elaborate on what knowledge management is, Participant 5 shared a quote made available from ERDC's Online Library, which reads "knowledge management plays a vital role in the successful execution of research projects in the U.S. Army Engineer Research and Development Center (ERDC). Accumulating and building upon knowledge is the cornerstone of the research and development process." The relationship between research and knowledge management is dependent on one another. Participant 3, a mid-level mechanical engineer, shared that

> …we need to have a really good working knowledge of the vast research ERDC is doing because ERDC does not do just computational engineering. It does not do just hydraulic engineering or concrete structures. [ERDC's research output] is so vast and so big.

Participant 7, a trained civil engineer and current communications officer, expressed that she was hired for both a communications role and a knowledge management role, emphasizing the importance the management of knowledge plays. In 2013, the

Commanding General of the US Army Corps of Engineers wanted to get ahead of what would be a 'mass exodus of boomers retiring' and create a more formal framework and process for the keeping of knowledge, so that it can eventually be expanded upon. ERDC indicated that knowledge management plays a vital role in the successful execution of research projects, because accumulating and building upon knowledge is the cornerstone of the research and development process and that maintaining and providing access to knowledge is essential to the successful execution of research programs (ERDC, 2020).

Knowledge management is often separated into three areas (1) Accumulating Knowledge, (2) Keeping Knowledge, and (3) Sharing Knowledge (IBM, n.d.). Interviews showed that these areas correlate with the research process. When asked about the role of communication in her job, Participant 1, an early-career mechanical engineer, shared that communication is everywhere, especially within a research organization. She went on to define this importance by sharing

> …at the end of the day, particularly in research…the whole point is to test something, create something new, and then tell people about it, too. So they can prove you are wrong. Or so they can go off to prove you're right, or to collaborate with different people, different backgrounds and ideas to develop something new. But, the end goal eventually is to publish, to create something and get it out there.

Based on her understanding, both the research process and knowledge management can be broken into three sections: creating or generating knowledge, developing or testing knowledge, and sharing knowledge. Data presented in these findings suggests that research and the management of knowledge is supported through communicative practices.

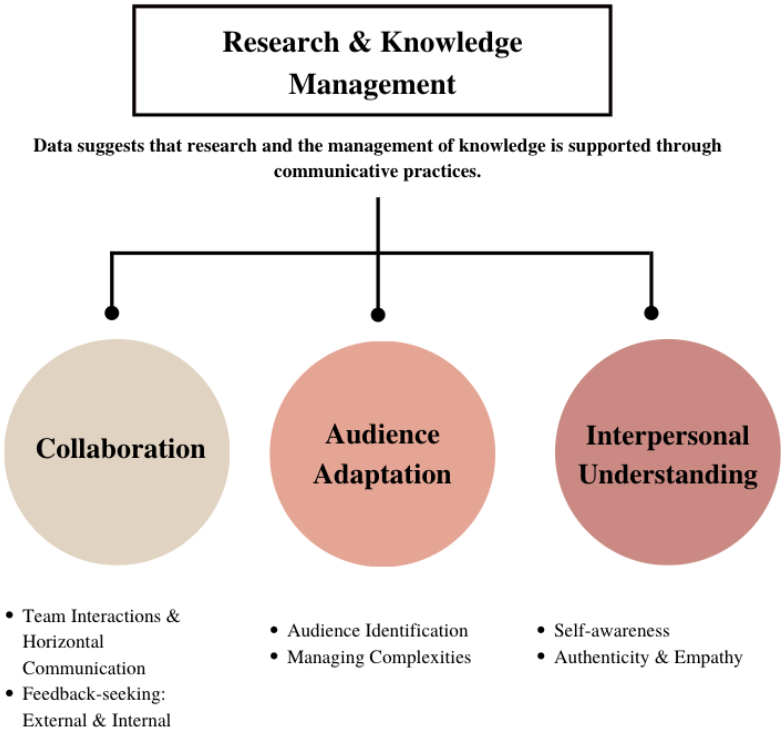
Research Question One

The first objective of this research is to identify which communication competencies are required for engineers to successfully communicate within an engineering research organization. For the purpose of this study, communication competency is defined as the knowledge of effective and appropriate communication patterns and the ability to use and adapt that knowledge (Cooley & Roach, 1984).

Before focusing on research specific questions, demographic and workplace perspective were asked to help develop a frame of reference for what research engineers do at ERDC, and how communication officers support them. Interview data identified Research and Knowledge Management as a core function of the work that is done at ERDC. This function is supported by three additional underlying themes, each addressing different communication capabilities. These include Collaboration, Audience Adaptation, and Interpersonal Understanding. Each of these themes are aided by the building of Communication Skill Sets. Figure 1 illustrated these competencies.

Figure 1

Identified Communication Competencies



It is important to note that every single participant expressed their belief that communication is vital in their engineering workplace, and when asked about where communication enters his job, Participant 5, a senior civil engineer who has worked at ERDC for 23 years, shared:

> [Communication is a part of] every facet of what I do. In fact, that is my primary job is to communicate. So, I spend a lot of time building PowerPoint presentations, which are meant to communicate to customers our capabilities. I talk with the division chiefs, I talk with staff, I talk with my director, I talk with other DoD organizations, I write emails, I write letters, we write technical reports and technical papers, everything that I do is about communication. In fact, I would actually say that probably 90% of my job is technical communications.

Collaboration

Collaboration is the action of working with someone(s) to produce or create something together. For these participants, collaboration was associated with teamwork, horizontal communication, upward communication, and feedback seeking. Each of these subthemes is addressed below.

When asked about teamwork in the workplace Participant 5 stated:

> Well, you don't do anything by yourself once you graduate from college. Nothing is done by yourself. You are always part of a team. So, the earlier that you can learn that and figure out how to be a good part of a team, is crucial.

In an answer to a similar question, Participant 3, a mid-career mechanical engineer, said,

> There is really no work that we do that does not involve some kind of team level execution, and teamwork. It seems like, at least in my circle, there are teams that grow. And, you know, get maintained at larger levels that really inherently function as teams. And then there are individuals and small groups of individuals that can function mostly independently. I'm definitely in the former, where I can't really do anything significant without doing it in a team environment.

As expressed by these participants, collaborative efforts are vital to the creation and development of knowledge at ERDC. Additional interview data revealed collaboration and teamwork include both upward communication and horizontal communication.

Team Interactions & Horizontal Communication. One of the differences between collaboration and teamwork, is that word teamwork focuses on the individual efforts of all team members to achieve a goal, while people working collaboratively complete a project collectively. Teamwork can be required under the umbrella of collaboration. Horizontal communication, which is also referred to as lateral communication, is the communication flow between peers or coworkers. Participant 7 shared that her team thrives on an open environment and constant lateral communication.

The example she shared was that before a project gets sent to a superior, the team gets an opportunity to offer opinions and inputs.

> It's just a very open environment, even with videos. One of my co-workers [created a video for distribution], and asked 'Can y'all come to my cube and watch this? Give me your opinion of it. And so, you know, and several of us gave a lot of input…And so, it's a very collaborative effort.

Participant 4, a mid-level chemical engineer, shared that collaborative efforts are especially vital for entry-level engineers entering the workforce.

> Engineering will teach you the hard stuff, but actually doing it is another thing. And these guys, since they're younger, they communicate pretty well, what they want, what problems they're facing. And they ask for help, which is an important part. A lot of our stuff is collaborative, and you have to ask for help because you don't know everything...But, yeah, knowing how to collaborate is very important. And how and when to ask for help.

Even with this emphasis on collaborative efforts, Participant 3 shared that there is a great deal of autonomy in engineering jobs, which in turn requires more accountability when it comes to communicating, particularly to those higher in the organization and with stakeholders.

Feedback Seeking. Upward communication and accountability are vital at ERDC, as they are a U.S. Government organization which has a strong hierarchy. Upward communication is the process of information flowing from lower levels to the upper levels. Data revealed the most common form of upward communication was feedback seeking, which is the act of employees seeking professional assessments from managers and supervisors to improve work. Data also suggested that feedback seeking is especially vital for entry-level and mid-level engineers. Participant 2, an entry level chemical engineer, shared a story about when his team's upward collaborative effort at ERDC saved time and effort,

> [On] one of our prototyping machines, the pump actually broke on it, and it didn't break the hose line in it, but it got clogged. And we needed to fix that. And we thought of different ideas, you know, a couple of the guys I was working with, and we ended up actually thinking very, very difficult ideas. And we decided that we would just go ahead and ask [our head engineer] what the best solution to fix that would be, and he actually gave us super simple solution the new solution ended up taking me 30 minutes of work and it wasn't near as hard or difficult. We didn't break anything and [were able to] fix it perfectly.

Feedback seeking is an essential part of an organization's ability to develop and update their knowledge and skills and allows for organizations to create and sustain competitive advantage (Crans et al., 2022). Participant 4 shared an example of when he went out of his way to employ feedback seeking efforts outside of the organization, and it created an advantage for him and his team,

> I wasn't asked to or required to set up a meeting with my sponsor that had funded me and our team to execute this work. So, the easy thing would have been to just continue working on it, and then give him a product at the end of the year when the period of performance was over. But I set up an impromptu In Progress Review. And it was actually really helpful. And he had really good ideas for who to coordinate with, and places to kind of send our initial results off to both in industry and academia and in some of these policy roles. [It] felt like that was a positive communication experience in that we set up an engagement with a stakeholder and we will have a stronger project, set of deliverables and likely adoption because of that.

This type of feedback seeking resonated the most with entry level and mid-level engineers. Additionally, several members of the communications team referenced the process of engineer feedback seeking to their communication teams in regard to visual aids for their presentations. This quote also shows the need to be attentive to specific audiences, which is a subsequent theme that emerged from the data.

Audience Adaptation

One of the key tenets of both research and engineering organizations is sharing results and findings with various audiences. The settings in which these engineers share

their results can vary. The data showed that for ERDC employees, the most focused on forums were journal articles, government briefings, stakeholder meetings, and science conferences, though this is not a comprehensive list. When asked if most of their communication was with engineers or those outside of the STEM world, every single participant stated it was split, most often equally proportioned. Participant 5, a senior level Civil Engineer, said that you have to be aware of all the people you are sharing with. He went on to state:

> That's another thing, knowing your audience, right? Who are you talking to? That's fundamental rule number one. In communication, know your audience, and many people don't have a clue. Lots of engineers still don't know that, right.

The process of audience analysis and audience adaptation is a key principle in communication courses, specifically public speaking courses. Audience analysis involves identifying the audience and adapting a presentation to their interests, level of understanding, and attitudes. As noted, the theme of audience adaptation involved two more specific competencies; Audience identification and managing complexities.

Audience Identification. Once audiences have been identified, messages can be tailored to fit communication needs. Several participants explained that a lot of their presentations or briefings are with government stakeholders. Since the Department of Defense is one of the main sources of funding for this organization, there is a large emphasis put on these meetings and visits. Participant 4 shared that these types of briefings can be very pivotal to being effective in their jobs.

Participant 9, a military veteran and laboratory communications liaison, shared that there are several different ways they assist the engineers in prepping for these visits, which include practice briefings with a communications team, to ensure that the correct

message is getting across. When asked about the emphasis on the 'correct message' for this specific type of audience, participants shared that you have to be able to communicate not just about science, but 'in funding,' and in time. Specifically, Participant 6, a dual-service veteran and civil engineer, stated:

> When you bring in like the DOD, like these are people who are brilliant strategists who have not been trained in engineering, and that doesn't make them less or anything at all, but you have to be able to communicate in funding. They care more about funding and in time, they care more about time, it doesn't matter how you get the project out there as much as what can it do when it's out there? How soon can you do it? So, I've used this, I've used that a lot. It is a process for me pitching my research.

In addition to military briefings, ERDC shares knowledge through scientific conferences, published articles, stakeholder meetings, and team meetings. These different contexts or media types create a wide variety of audiences and demographics. Each demographic requires different approaches, such as a focus on message transmission, detail, and organization. Participant 6 shared

> We go to conferences, that's one of the primary ways that we communicate and interact with each other. But I don't think that most presentations at conferences are very effective, because they're mainly focused on sharing how awesome their solution was. And not nearly as focused on sharing why that solution was valuable.

Managing Complexities. One aspect of audience adaptation that several participants focused on was managing the complexity of their message. Several participants shared that when they are tasked with sharing knowledge, they begin by trying to put a complex topic into basic words or simplifying. Participant 3 shared:

> This is almost like a Feynman, Richard Feynman kind of principle of, if you can put a complex topic into really basic words, succinctly, that probably means that you understand it well…if [a researcher is] going to give a brief, it's good to funnel down and not just dig right into the topic in a technical way, but kind of

> give some context as to ‘okay, I, you're here from this office. So let me explain this area that touches your policy in this kind of a way that impacts this part of your portfolio of this magnitude and has the ability to save or improve in this kind of qualitative or quantitative way and kind of finding a way to whittle it down into the technical details.’ Part of that Feynman is part of that awareness as well. But part of that is also just perspective of kind of we're different people.

This principle follows a 4-step process, that follows as (1) Identifying the subject (2) Teach it to a child (3) Identify your knowledge gaps (4) Organize, simplify, and tell a story. Participant 5 furthered the idea of both audience identification and managing complexities when he shared:

> When I'm talking with our staff, or the other division chiefs, or my boss, we're very engineering, technology focused. But a lot of times we're communicating with lawmakers or others that are not necessarily technology focused. And so I think one of the unique attributes [of my] job is that we have to be able to take a very highly complex and difficult process and turn it into something that is very easily understood by the average person on the street so that they're willing to say, oh, yeah, that's why I need that. So, a lot of what I do is taking the difficult problem, breaking it down, so that the complex solution, so that you can make the connection between the complex solution and the difficult problem, but in easily understood terms.

The process of managing complexities also plays out when discussing internal communication within an organization. Within ERDC, Participant 6 expressed that the most important concept in communication to all audiences is to over communicate:

> I try and tell people, my new people, everybody that I mentor or anything like that, I say, okay. If you think you're communicating right, you're probably wrong. If you think you're over communicating to the point where you are a stressed-out ex-girlfriend, going after the boyfriend that you lost, you're probably okay. So that's about the level, you want to take it to.

He went on to state that because many engineers are introverted by nature, what they view as normal amounts of communications are not enough or effective. By the act of deliberately communicating more than what you feel is necessary, you provide more understanding to those working with you. Entry-level engineers and communication

workers expressed that there is sometimes a lack of clarity when it comes to communicating with other engineers. Data shows that this lack of clarity can come from a misunderstanding of questions or responsibilities, lack of personal knowledge of a person, past interactions, or empathy. Participant 10, a trained biologist and strategic integration officer, added to the idea of over-communicating by sharing that another helpful skill is to communicate early. She stated that:

> Effective communication is paramount. And it's so critical to communicate early and often. So that's kind of my motto. I don't believe that we can be successful without effective communication. Because it's so easy for something to get kind of lost in translation. As we are working as hard as we can, and all of us are very professional, very solution driven. And so we all work really hard. And you have to have strong communication.

Strong communication requires the ability to tailor messages to audience types, including external and internal types, which can be learned and developed.

Interpersonal Understanding

Interviews revealed that participants believe interpersonal relationship competencies promote better overall communication in the workplace. The three tenants that respondents focused on most were self-awareness, authenticity, and empathy.

Self-Awareness. In this context, self-awareness refers to the ability to have a clear understanding of oneself, including skills, values, and emotions. This type of self-awareness leads to discovering similarities between oneself and others (Brinck, 2001, p. 12), which can lead to more effective understanding. For example, one participant had this to say regarding understanding:

> But I think engineers tend to think that the technology and their technical solution is important by its nature, and therefore it should be acknowledged and praised. And the reality is, that people don't care…And I think that engineers struggle with the concept that their technical solution is not the real answer. The real answer is

> solving the problem the customer has. I did not understand any of that before I started. That's taken me 30 years to figure out.

A common issue that participants brought up throughout the interviews was the idea that engineers are introverted, which can make interpersonal communication difficult. This was specifically addressed when several participants discussed networking. Participant 5 shared that

> I think there's another component to effective communication that I would actually say is the biggest weakness that most engineers have, is they do not know how to, or how to effectively network. That is a crucial communication skill, that it's not difficult to learn. But people are, you know, they get paranoid and freaked out about it. But that's a skill that can be taught just as well as any of the other skills, how to network, how to follow up. Those are just interpersonal communication skills that are professional, so interpersonal, professional communication skills are a crucial thing that [we] should be training on. You know, a lot of engineers tend to be introverted in nature, not that it's not exclusive, but that personality trait tends to run pretty deep. And so forcing yourself to do things that are difficult, like learning how to network and practicing networking, and learning those skills are something that I think could be taught. And quite frankly, I wish I had recognized the importance and value of networking when I was much younger, and earlier in my career.

Authenticity and Empathy. One of the tenets that several of the communication employees focused on was the idea of authenticity. One of the principles that several of the communication employees focused on was the idea of authenticity. Being authentic is the quality of being genuine and trustworthy. Participant 7 expressed

> …once they are themselves, and they're truly authentic, and it is when I see that passion. And so I think a lot of times, people are intimidated, or they feel like they can't be themselves, they need to fit into a certain role or a researcher. And I really like talking to researchers who are totally comfortable in their skin of knowing who they are, and who are authentic. I think that if you're wanting to communicate with other people, the more authentic you are, I think the more it builds trust, and therefore better communication.

The third focus was on empathy, which involves both accepting and allowing different perspectives and emotions in other people, and also sharing it with them to enable encouragement and support. It's also the practice of actively listening, in an effort to understand the emotions of whom you're communicating with. When asked about what durable skill they wished everyone in the workplace had, Participant 10, a strategic communications officer, shared that she believed their organization would benefit from everyone "having a little bit of empathy for people when we're in the workplace. And I know that's extremely soft. But I still believe that it's necessary. I really do. So, just being empathetic." By establishing an ability to be self-aware, authentic, and empathetic, engineers can learn how to adapt their communication styles to build beneficial professional relationships. Participant 6 shared that:

> Most of what my job is, at this point, is facilitating others to be able to do their job more appropriately. So it's, you know, connecting people or getting some information from somebody and talking to different people and trying to build relationships. And, and I'm a big believer in that whole empathetic process as well, you know, you have to have a, you have to let them think that you know, or at least feel that empathetic response so that they will build a stronger bond with you.

Learning to recognize your own and other's skills can lead to being able to find people who can complement your projects and make functioning within this workplace more enjoyable and efficient.

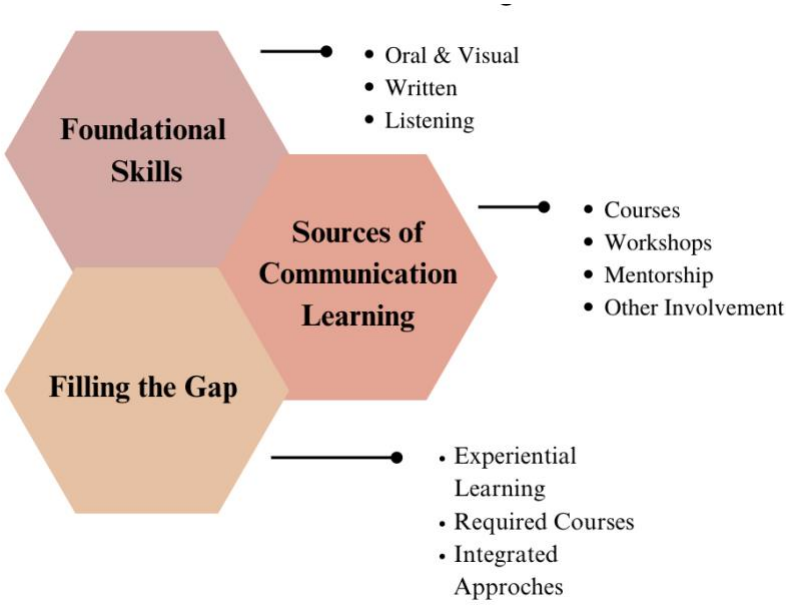
Research Question Two

Research question two is focused on identifying whether there is a need for future science communication training curriculum at either the university or professional level. Each of RQ1 themes were supported by the building of foundational skill sets, and thus

needed to be included within training. This section includes an overview of the participants' opinions about communication training, including sources of communication learning and their direct suggestions of the implementation of communication training.

FIGURE 2

Recommended Training Considerations



Foundational Skills

Foundational communication skills serve as a basis for all other technical and operational tasks to be carried out effectively. Two of the participants shared that they have participated in hiring and promotion meetings within the ERDC organization, and both emphasized the importance of developing durable skills. Participant 6 shared:

> When I'm actually looking at people to hire or something of that nature, it's a lot of the [durable] skills…Not anybody can sit there and have those [durable] skills automatically. Because all of that is based on that, that next level of stuff, that next level of, of understanding, right, it's digging deep into yourself at that point and understanding that.

Similarly, Participant 5 recounted that these durable skills are identifiable from the initial interview:

> I would like people to listen and respond to the question, not to their interpretation of the question. So having the ability to ask for clarification, to interpret to make sure that if there are two level questions that they answered both parts of the question. So, those are simple things. From the written standpoint, it is, you know, it is really important that their resume conveys the impact of their work. So, being able to articulate that and being able to write that those are all factors that are very crucial to an interview.

The four skill sets that were focused on the most in the interview were Oral and Visual, Written, and Listening skills.

Oral and Visual. When asked about the role of presentations in the workplace, each participant expressed that they are involved in presentations on almost a weekly basis, whether it be creating a visual aid and delivering a presentation or sitting in on another coworker's presentation. Participant 8 shared:

> Presentations are just a way of life. I mean, it's a very basic way of how we communicate information, how we communicate data as a result. And so that is something that is very, very frequently done.

Because ERDC employees are often conveying information to others, without the same technical knowledge, there is a large reliance on visual aids, particularly slide deck presentations. Participant 9, a strategic communications officer, shared:

> Engineer presentations are huge. And another thing that I helped do is I helped prepare our director and our Deputy Director, and sometimes our leadership team, to go to different conferences, and, you know, prepare their slides. And, in the government, as you know, we love PowerPoint for some reason…And so creating, you know, that message and understanding that presentations are actually really powerful.

Participant 10, another a strategic communications officer, furthered the idea of the importance of visual aid when they said:

> A lot of the presentations are done out here…but actually conducted within the lab space. And some briefings are in a meeting setting around a table, or in a classroom setting with big monitors. But those tend to be a little dull. So we like to take our visitors into the laboratory so they can actually touch and feel and really get an idea of what's going on with the research. The federal government loves a PowerPoint presentation.

Participant 5 conveyed that while visual aids can be useful, learning how to craft and share a message is more important.

> And it's not about just making pretty PowerPoints. It's about how to get the message across how to use the medium to show, to articulate your message, to convince other people [Participant 5].

Participants conveyed that in addition to being informative, research engineers need to also be persuasive. Participant 3 shared that the ability to give a good briefing, no matter the setting, is a pivotal skill.

> We give a lot of briefings…And then there's briefings that are very important because they lead to decisions that are funding at a level that is within our stakeholder environment, that can help us secure the work that we want to do or transfer the results from work that we've done. So briefings can be a nuisance, or they can be very pivotal to us being effective in our jobs.

The overall consensus was that having the ability to speak and convey your ideas well across different visual media, is crucial to succeeding at this research engineering organization.

Written. Participant 4 shared that one thing they did not realize before entering an engineering organization was how much writing was involved. When asked about what specific training they would encourage young engineers pursue, each engineer shared that they would emphasis more writing classes, including a variety of writing styles. Participant 5 expressed that they would:

> …strongly encourage young engineers to go and to take courses on record writing, go to effective writing, that's a crucial skill that most can't do well. That

> doesn't have to be once, that can be done every four or five years, you want to go take a course, and practice and make sure that you're getting an expert to evaluate your writing, and your speaking is crucial. The other thing that I would do, I think, is at the mid level career. At that point in your career, you're supposed to be publishing, presenting, you know, getting out in our field, and supposed to be at conferences sharing the results of your research, interfacing with customers in those are all components of effective researchers within our organization.

When talking about the importance of writing skills, Participant 10 stated that her education had,

> …such a huge emphasis on the writing part of it. And that's where I say, in my current job, and in previous jobs, a lot of people cannot write. And a lot of people think they can. But a lot of a lot of times, I mean, it goes back to just writing mechanics and writing basics. So I would say that was probably my greatest lesson learned in my education is the writing.

Writing doesn't just come in the form of journal articles, but with internal communications. Participant 2 shared that before joining the ERDC workforce, there was never an opportunity to learn how to professionally email coworkers, while other participants shared how they had to learn how to keep record reports throughout a project. Participant 1 believes that an increase of writing communication skills would benefit the organization and their ability to share information as a whole.

> And then after that, I'd probably say, writing skill we do, or at least I do. My goal is to publish, and I want to publish. But if everyone had the ability to write better or write faster that would help with people getting their ideas out.

The use of written communication skills is used in a variety of settings, across the workplace, and have to be developed and adapted to each situation.

Active Listening. Both senior level engineers shared how vital listening skills are at an engineering organization, in external and internal settings. Participant 1 defined active listening as going beyond your interpretation of what they said, and understanding what they mean and why. She shared that:

> …with listening, make sure you actually listening to what people are saying. And you've got the whole concept of you got what's going on your head, you say it, you got other people's filters, what's going on their head?

When discussing the importance of listening skills, Participant 5 shared

> Probably the most important skill is being able to listen and understand what the customers are really saying. That does not come easy. Some people don't ever figure it out. It's a challenge. Because most people will not actually tell you what's really going on. They may not have enough money to pay for something, they may have been told that they need to work with somebody else, because that happens, right? There may be a conflict, an internal conflict, that they're fighting for resources, and you don't know. So being able to listen to both the spoken and unspoken needs of your customer. That is a soft skill that quite frankly, I wish I was better at. That is a very hard, soft skill to learn. Some people are intuitive, other people aren't. But that's a skill that more engineers need to be able to do [Participant 5]

Participants believe that listening skills are needed in every aspect of an engineering job, from understanding a problem to working as a team to listening and adapting to feedback. Active listening and understanding are vital to employees at ERDC Participant 7 shared that:

> Part of communication is the ability to listen and listen to your customers on what problem do they have, instead of going to them and saying, I have your solution of listening to them and saying, Oh, this is the problem you have. And then working with a team of people to come up with a solution that is faster, better, cheaper than what the customer had? I don't know how you do that if you're not good at communication

Active listening helps engineers solve problems, work in teams, and build professional relationships inside and outside of the organization.

Other Skills. Each participant was asked the hypothetical question ‘if you could wave a magic wand, and grant one durable skill to everyone in your workspace, what would it be? Table Three summarizes each participant’s chosen skill,

Table 3

Additional Identified Durable Skills

Identifier	Skill
Participant 1	Effectively Communicate
Participant 2	Timely Responses
Participant 3	Professional Patience
Participant 4	Knowing when and how to ask for help
Participant 5	Active Listening
Participant 6	Articulate WHY you are doing something
Participant 7	Be Authentic
Participant 8	Empathetic Responses
Participant 9	Visual Media Skills
Participant 10	Be Personable

These skills show the variety of communication needs and knowledge of effective communication patterns. Mastering durable skills can allow for the development of adaptability, which in turn can further an engineer's professional relationships and career.

Sources of Communication Learning

Participants mainly focused on two different settings for communication learning, University and Organizational. Each participant expressed that communication training would be beneficial to all engineers and those who work in engineer workplaces. Each participant was asked what they would recommend for future training, and the most prevalent points for any type of engineer-specific communication training were 1) to

offer in-person training over online training, 2) a focus on writing, 3) developing public speaking skills, 4) learning how to set communication standards for a team, and 5) an overall emphasis on professional development. Participant 6 shared one of the greatest sources of communication learning comes from practice.

> For undergraduates that are coming out, I honestly think the more you practice to get out in front of people and get out of your comfort zone, the better you'll be. So if there were multiple opportunities, like for instance, my capstone, I had two opportunities to essentially get out in front of the individuals that sponsored our capstone, to be able to talk with them about the project itself, one in the beginning of the project, or one at the end of the project. Now, I also went on study abroads [sic], and we were able to communicate in multiple languages as well. I feel like that was highly beneficial to be able to understand the cultural differences in a lot of things as well. So something of that nature, and being able to have more focus on those soft skills would be highly beneficial for engineering students coming out.

By incorporating communication skills into technical courses, engineers can build workplace specific skills. Another emphasis was the idea of requiring these courses. As engineer study loads tend to be heavy, there is limited available time to seek out non-required courses. One suggested way to counter this was by making the courses required or integrated. Participant 10 shared that in a research organization, writing and public speaking courses need to be required.

> I know that there are technical writing classes, that I don't know if they're a part of the engineering curriculum, but there are technical writing classes that happen here, and I don't know if they're required, or just greatly encouraged to participate in, that's a necessity. Because, you know, their research here needs to be published. And they're all about that. And we partner with so many universities, on our research, so I think the technical writing skills should be required. I think, even if it's just a general public speaking course, I think that should be a requirement.

Other participants shared that while writing and technical writing was covered in their university courses, there was still a learning curve when it came to writing a completed research paper or an executive summary, instead of lab notes.

Another source of communication learning is short term training courses. Several participants shared that they have taken a leadership development course provided through the U.S. Army and USACE. This includes several units of study, spread over the course of several weeks, and becomes a part of their Curriculum Vitae. Participants believe that other workshop training could be offered at ERDC, starting even at new employee orientation. Participant 9 shared:

> Once these folks are hired, you know, we kind of give a quick spin up of, especially if you're coming in, and you're brand new civilian, right, you don't have any military experience, you never work with military before, this critical of understanding how to communicate with your people around you and your customer, and just giving kind of a crash course in how to communicate with that demographic. And then also, if we can stop bad PowerPoint habits before they start, would be lovely. You know, just kind of a welcome to the government, here's how we do PowerPoint. You know, it's not like the academics do PowerPoint, you know, in a crash course. And that I think it'd be great. So that way, again, we can stop bad habits before they start [33:26].

Participant 8, a strategic integrations officer, shared that orientation would be,

> …a perfect opportunity to present some type of communication, training. And I'm not sure if that's going on, but that would be helpful I would think. And, and again, it would just be to show them the different forms or the different types of communication mechanisms that we have here. Just like to say we have podcasts we have, you know, just wiki, Wiki pages, just everything. So maybe just kind of laying it out there for everyone. Conferences, everybody's going back to conferences now. And workshops, and just the whole shebang. All of that, to me, is under communication.

By incorporating foundational skills into different sources of communication learning and training, engineers are better equipped to function and succeed within a research organization.

CHAPTER 5

Discussion

This case study sought to first identify what communication competencies engineers believed are needed to function at a research engineering workplace and develop recommendations for future engineering communication training at both the university and professional level. Three themes emerged from the data to describe what communication competencies would be needed: Collaboration, audience adaptation, and interpersonal skills. Each of these themes were supported by the building of foundational communication skill sets, which can be taught through inclusionary curriculum and specific training.

Answering RQ1

The themes of collaboration, audience adaptation, and interpersonal understanding echo the research presented in the literature review of interpersonal communication skills, teamwork, and public speaking (Mercer-Mapstone & Kuchel, 2016; Cruz et al., 2021; Itani & Srour, 2016; and Masduki & Zakaria, 2020). Engineer research is also unique in the realm of science research, as engineering seeks to create new things, such as products, environments, and experiences over studying how things work. How engineers communicate with one another and how they communicate with clients and stakeholders are specific to the creation of new knowledge or a new product. Participants noted that these skills were needed both before hiring and in the case of career advancements.

Collaboration is the process of working together to create something, and it was repeated throughout the previous research and the current study (Itani & Srour, 2016;

Masduki & Zakaria, 2020). Unique to this study, was the focus on feedback seeking, both internally and externally. The U.S. Army Corps of Engineers is an organization within the United States Army, and therefore has a strict hierarchical setting. This can be seen in the need to receive confirmation from supervisors and clients, which allows for a more effective working relationship within teams. Learning how to be both independent, and responsible for your tasks, while being interdependent and complementary to a team or project is a necessary competency that is needed at all engineer levels and across this entire organization.

Previous research focused mainly on public speaking as a whole, defining it as specific events such as presentations, formal speaking, public seminars, and technical presentations (Dannels, 2003). The process of audience adaptation takes this idea one step further and focuses on a variety of situations that require any mutual communication, including things such as meetings, conversations, email correspondence, posters, and research publications. Each event, both oral or written, requires the ability to adapt a solution, idea, message, or product to different audiences. ERDC as a case study created a unique finding, as one of the main roles of research is to share information with others, including a variety of audiences from engineers to stakeholders, to Department of Defense strategists. This research identified managing complexities as the core idea of audience adaptation: knowing what to share, how to share it, including/excluding jargon, etc. This competency was demonstrated as a vital skill for functioning and succeeding at this organization. Participants shared that upon promotion, they were informed that their ability to communicate and adapt messages at an effective level were key components to their advancement.

Interpersonal skills have been seen in previous research as important for knowing how to communicate and work with groups and individuals in a professional engineer setting (Darling & Dannels 2003; Hirudayaraj et al., 2021). Understanding how to develop and use interpersonal skills to further workplace relationships were demonstrated as necessary to a productive work environment. Participants mainly focused on self-awareness, authenticity, and empathy. Self-awareness was described as knowing your personal limitations, specifically within durable skills, and how to either work around or through those limitations. The main focus of self-awareness was surrounding the idea that engineers are introverted by nature and have to work around that factor when it comes to functioning in this work environment. Authenticity was a focus of the participants with communication-specific roles. In their work with engineers, they noted that there was a clear difference when engineers were authentic to their work, and it allowed for better connection in both large and small public settings. Empathy was focused on when it came to working directly with people and encompassed the idea that by being empathetic to those around you, you created greater workplace relationships, with allowed for more effective work. Participants believed that these three interpersonal skills could be developed further with practice.

Answering RQ2

Every single participant expressed their belief that communication is vital in their engineering workplace. The ability to build foundational skill sets, including oral, visual, written, and listening skills were shown to be needed in collaborative settings, in audience identification and adaptation, and in using interpersonal communication principles to facilitate strong working relationships. Previous research supports the ideas

that oral communication and writing skills are needed skills within engineering organizations (Darling & Dannels, 2003), and that engineers have communication tasks that require oral communication, written communication, interpersonal communication, and visual communication (Maduski & Zakaria, 2020). This study corroborates the need for these communication skills and adds the idea of active listening to them. This research also found that engineers believe that there has been a lack of training, or deficiency, in the teaching of communication basics needed to excel in the engineering professional space (Riemer, 2007).

In addition to sharing the belief that communication is vital, each of the 10 participants expressed support for more communication specific training to be incorporated into engineering programs. The most prevalent points for any type of engineer-specific communication training were to offer in-person training over online training, to focus on learning how to write a completed research paper or an executive summary, to develop public speaking skills, to work on how to set communication standards for a team, and to develop an overall emphasis on professional development. There was a clear division in answers when asked if these courses should be taught by a communications expert or by an engineer with communication skills, though the overall focus was that experiential learning needed to be prioritized. This type of learning has been shown to generate engagement, deeper learning, improved outcomes, and enhance professional skills (Experiential Learning, 2022). Previous research has shown that an integrated approach is more often used over stand-alone approaches, and that communication competencies are taught by science academics over communication scholars (Mercer-Mapstone & Kuchel, 2016).

Participants in this study believe that it would be more beneficial to practice communication skills as it relates to their degree and technical training but would prefer if there was a mix of both technical and communication-centric instructors who can help bridge the gap in learning. This study found a significant emphasis placed on going further than just developing a technical solution, but thoroughly understanding and solving the problem your client has presented to you, within the boundaries of time and funding. An additional idea of seeking out professional development was discussed in these interviews, with each of the engineers and communication specialists taking part in a Leadership Development program provided through the U.S. Army Corps of Engineers. Participants were more likely to participate in optional workplace training when they would receive recognition or certificates that can build resumes and experience.

Theoretical Implications

This study was grounded in constructivism, communication across the curriculum (CXC) and communication in the disciplines (CID). The findings are consistent with constructivism, most notably that engineers at ERDC construct their knowledge through experiences and time. Constructivism communication theory is the idea that learners use their previous knowledge as a foundation and build on it with new things that they learn, and the more they learn and practice, they develop the ability to be more effective and skilled. The most clearly communicated constructivist theme is that the engineers understand that a more complex understanding of the different audiences they face will facilitate their job performance. Competent communicators are those who can see things more complexly. Senior-level engineers stressed the importance of learning communication skills while in the earlier stages in their career that can be adapted by the

communicator to various situations. As theorized, adaptation is an important communication function. As time passes, those who have developed the most adaptable and effective foundational skills and the ability to apply them to collaboration and relationship building succeed professionally.

CXC and CID frameworks both focus on the integration of communication skills within the STEM discipline. CXC includes the idea of incorporating durable skills into courses offered within the STEM discipline, while CID develops this idea into including the training of durable skills into discipline specific assignments and contexts that require durable communication skills. By incorporating the development of communication skills within technical courses, engineers can learn how to better utilize these skills specific to their work and discipline. Participants noted that a clear distinction could be made when introducing these foundational communication topics, as well as an emphasis on the importance of these, to show younger generations of engineers that these are needed skills and can further the development of professional identity (Linvill et al., 2019). Participants believe that specific practice and training would be beneficial, particularly in the early and mid-career stages of entering the workplace.

Practical Implications

The findings of this study also have practical implications for future communication training. Communication courses across undergraduate and graduate studies should place an emphasis on teaching foundational skills and provide opportunities for students to develop those skill within their course work. Students should have opportunities to work within groups that they select as well as into groups that are

assigned, so they can develop skills across a wide variety of audiences, including those with research similar and different than their own. Additionally, engineers should be trained on giving a wide variety of presentations, geared to different audiences, and be given feedback from subject matter experts in technical and communication fields. The data illustrate the importance of collaboration. For that reason, these courses should include explicit training in teamwork and feedback seeking. As audience adaptation was so central in the data, learning activities should help engineers practice communicating to a variety of audiences, both in theory and in practice. Interpersonal skills can be taught through learning exercises, including role playing, practice interviews, working with non-experts, receiving feedback and generating feedback, observe yourself talking. Engineers would benefit from these activities being structured. Workplaces should also take the opportunity to provide organization specific training upon orientation, which participants believe can stop bad habits and skills before they are even started.

Engineers should take time and effort to develop these skills inside and outside of classroom settings. Participants shared that some of their most formative durable skill experiences came from participation in clubs, particularly with leadership positions. Other participants shared that through mentorship experiences, they developed skills in maintaining professional relationships and increased their ability to network. Engineers should also prioritize their experience in working within team settings. Each participant shared that almost all work conducted in the professional level relied on collaborative efforts. Communication educators and learning design instructors can assist engineering academics and professionals in the development and teaching of these courses and training.

Limitations and Future Directions

Limitations of this study include a lack of diversity in the background and the gender of the participants. The ten participants went to a total of five different undergraduate colleges, and engineering participants went to only 3 different graduate programs. Of the 6 engineers who currently work in engineering research interviewed, only 1 was a female. As men make up a large majority of STEM disciplines, a focus on differences in gendered communication could introduce research worthy elements of study, such as the male-centric culture and persistent stereotypes of women in STEM industries face. This study provides groundwork for research in creating and implementing engineer specific communication training. Using Tracy and Hinrichs (2007) criteria for qualitative quality this research offers a significant contribution to engineering communication research. Each participant remarked that this information was significant and interesting to the current workplace experience and is therefore relevant. This study uses an appropriate set of theoretical constructs, samples, and provides a specific context, which allows this to be considered rigorous (Tracy & Hinrichs, 2017). Research findings provide a contribution both theoretically and practically, while achieving what the study purports to be about and uses methods that fit the stated goals (Tracy & Hinrichs, 2017). Participants repeatedly expressed that they believe that communication research for engineers, or engineering communication research was necessary and vital to furthering engineering education. Future research should investigate a wider variety of participants, as well as more significant numbers of participants. Due to the small number of participants, no large generalizations could be made about participants' perception of communication competencies in an engineer

research and development workplace. Yet, this work, like others before it, does provide important insights based on small sample sizes. Additionally, future research should use both quantitative and qualitative research means, to add additional understanding and to yield more complete evidence. As teamwork and relationship building were main themes in this research, additional research can be done to determine what collaborative approaches work to create thorough work as well as develop skills used in industry. Future research should also focus on the effectiveness of communication in engineering courses.

Conclusion

Engineers believe that they need communication competencies to function and be successful in an engineering communication workplace. Competencies are not just a knowledge of the skill itself, but a developed ability to use and adapt that knowledge to fit the needed setting. Experience and practice allow for engineers to gain durable skills, but with specific training and development, these skills can be developed into adaptable competencies that allow them to succeed. This research established three communication competencies that allowed for research and knowledge management to occur, and each competency was supported by the building and development of foundational communication skills. Those skills were identified as oral, visual, written, and active listening. Additionally, this research demonstrated the need for communication skills to be included in the engineering discipline, particularly when integrated within required courses.

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APPENDIX A

INTERVIEW GUIDES

ENGINEER- SPECIFIC

Opening Questions

- How old are you?
- Are there particular pronouns that you prefer to use throughout the interview and in published material?
- What type of engineer are you?
- What type of degree and academic experience do you have?
- Can you tell me about your current job?
    - Can you tell me a little bit about your responsibilities and role here?
    - Can you tell me a little bit about what that job entails?
    - How long have they had this job/been in this role?
- What is your previous [engineering] job experience?
- What else should I know about you to understand what you do? (Needs prompting material)

So, I'd going to transition into a little more research focused questions now:

Research Questions

- I'd like to ask you about the kinds of communication that are important in the work you do here. Think about the range of things you do…. Where does communication enter your job?
- Would you say that most of your communication is with people in engineering fields or people outside engineering fields?
- Would you be able to give me a specific example of when communication was important? Positive and Negative
- What did you not know or not realize regarding communication that you wish you had known previously to entering the engineering workspace?
    - Can you give me an example of a time when that kind of communication was important?
    - Can you describe a time when lack of communication affected your job? **
- One of the ways that literature talks about communication competencies is to define them as, soft-skills or durable skills. Would you be able to tell me about specific skills that stick out in your mind that are important in your work
    - Some ideas could be communication across age groups, or with diverse groups of people, oral speaking and public presentation, teamwork, the ability to articulate problems in a 'jargon less way, and leadership

Can you tell me about the role of presentations in your workplace?

Can you tell about the role of group work in your workplace?

- If you could choose what communication and soft/durable skills are most important in your workplace, what would you choose and why? (Make hypothetical)
- Can you tell me about any communication training you received while earning your degree?
    - Was this through courses and class curriculum?
    - Did you seek out any other opportunities to develop communication skills? Were you encouraged to?
    - Can you tell me about any non-training specific circumstances that lead to the development of skills (i.e. school clubs, mentorships, making mistakes)
- How well did these courses or experiences prepare you for the communication activity you are asked to conduct while at work?
- Can you tell me about any additional communication training you received since leaving school?
    - Can you tell me a little about the format of the training
        - Were they online, in-person courses? Which do you find most helpful to you communication needs now?
- Do you feel as if communication skills played in role in any career advancements?
- What changes would you recommend to the communication training new graduates should receive before they come to work?

NON-ENGINEER SPECIFIC

Opening Questions

- How old are you?
- Are there particular pronouns that you prefer I use throughout the interview and in published material?
- What type of degree and academic experience do you have?
- Can you tell me about your current job?
    a. Can you tell me a little bit about your responsibilities and role here?
    b. Can you tell me a little bit about what that job entails
    c. How long have they had this job/been in this role?
- What is your previous job experience working with engineers?
- Do you work with a specific type of engineer?
- What else should I know about you to understand what you do?

So, I'd going to transition into a little more research focused questions now:

Research Questions

- I'd like to ask you about the kinds of communication that are important in the work you do here. Think about the range of things you do…. Where does communication enter your job?
- Would you say that most of your communication is with people in engineering fields or people outside engineering fields?
- Would you be able to give me a specific example of when you observed positive communication with engineers? Negative communication?
- What did you not know or not realize regarding communication that you wish you had known previously to entering the engineering workspace?
    - Can you describe a time when lack of communication affected your job?
- One of the ways that literature talks about communication competencies is to define them as, soft-skills or durable skills. Would you be able to tell me about specific skills that stick out in your mind that are important in your work and the work of engineers that you see
    - Some ideas could be communication across age groups, or with diverse groups of people, oral speaking and public presentation, teamwork, the ability to articulate problems in a 'jargon less way, and leadership

Can you tell me about the role of engineer presentations in your workplace?
Can you tell about the role of engineer group work in your workplace?

- If you could choose what communication and soft/durable skills are most important in your workplace, what would you choose and why? (Make hypothetical)
- Can you tell me about any communication training you received while earning your degree?
    - Was this through courses and class curriculum?
    - Did you seek out any other opportunities to develop communication skills? Were you encouraged to?
    - Can you tell me about any non-training specific circumstances that lead to the development of skills (i.e. school clubs, mentorships, making mistakes)
- How well did these courses or experiences prepare you for the communication activity you are asked to conduct while at work?
- Can you tell me about any additional communication training you received since leaving school?
    - Can you tell me a little about the format of the training
        - Were they online, in-person courses? Which do you find most helpful to you communication needs now?
- Do you feel as if communication skills played in role in any career advancements?

- What changes would you recommend to the communication training new engineering graduates should receive before they come to work?

APPENDIX B

IRB DOCUMENTATION

IRB > Engineering Communication

Approved

STUDY00016580: Engineering Communication

Entered IRB: 10/19/2022 8:50 PM
Initial approval: 11/3/2022
Initial effective: 11/3/2022
Effective: 2/21/2023
Last updated: 3/31/2023 1:10 PM

Principal investigator: Vincent Waldron
Submission type: Initial Study
Primary contact: Vincent Waldron
PI proxies:

IRB office: ASU IRB
IRB coordinator: Susan Metosky
Letter: Correspondence_for_STUDY00016580.pdf(0.(
Regulatory authority: 2018 Requirements

ASU Knowledge Enterprise Development

EXEMPTION GRANTED

Vincent Waldron
NCIAS: Social and Behavioral Sciences, School of (SSBS)
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Dear Vincent Waldron:

On 11/3/2022 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	USACE Case Study: Communication Competencies for Engineers
Investigator:	Vincent Waldron
IRB ID:	STUDY00016580
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• Consent Form , Category: Consent Form; • Email Correspondance w/ ERDC, Category: Off-site authorizations (school permission, other IRB approvals, Tribal permission etc); • Protocol, Category: IRB Protocol; • Question List - Oct20, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Recruitment_Methods_Email_10-28-22.pdf, Category: Recruitment Materials;

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2)(ii) Tests, surveys, interviews, or observation (low risk) on 11/3/2022.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).