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Engineering Is Personal: Interpersonal Communication for the 21st-Century Engineer

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Abstract

In 1996, the Accreditation Board for Engineering and Technology (ABET) adopted Engineering Criteria 2000 (EC2000). EC2000 was revolutionary for its time and its implications for engineering education paradigms rocked engineering programs around the United States. Communication in engineering continues to be an important element of engineering education, especially in terms of future employability. Universities are continually measured, ranked, and evaluated for performance-based funding based on their students' employment numbers following graduation. However, a divide exists between the level of communication competency employers expect from recent graduates versus their actual competency. Despite over two decades of Communication (and English) faculty efforts, extensive research, and grant investment by the National Science Foundation (NSF) in engineering communication education since EC2000, the calls for universities to teach communication competence to engineering undergraduates has only grown louder.

At its core, communication is a process of shared meaning making that relies on the relationships between communicators. In this paper, we discuss how communication as a theoretically and empirically rich discipline has been largely bypassed in favor of pursuing teaching engineering students how to develop technically sound written messages and visually appealing presentations. As a result, the calls for improved communication competence among new engineering graduates has become more persistent as engineering students continue to enter the workforce without the myriad communication competencies employers are seeking. We argue that including interpersonal communication training, including teamwork, collaboration, intercultural competence, and audience centered communication will afford students with the competencies necessary to navigate the challenges faced by 21st Century engineers.

The authors' experiences teaching interpersonal communication in technical engineering courses offers a roadmap for how professional communication instruction can be effectively implemented even in large-section engineering courses to further discussions around diversity, equity, and inclusion. Furthermore, the authors' research and experiences working in and developing integrated communication programs in engineering and other STEM fields provides three unique cross-disciplinary case studies at three different institutions that offer clear and transferrable recommendations for how communication instruction can be collaboratively integrated into engineering programs to attend to justice and equity. In short, interpersonal communication instruction presents an expanded understanding of communication competence, as well as how communication training can inform and transform undergraduate engineering education and professional practice.

Finally, we contend that the goals and impacts of cross-disciplinary communication instruction extend beyond preparing undergraduate students for professional success, and that a cross-disciplinary approach can provide an avenue for the integration of a broad education that prepares students for global citizenship and civic engagement. In short, we outline the ability of communication to strengthen engineering education and to help meet the growing calls within

engineering for civic engagement, diversity, equity, inclusion, and social and environmental justice.

Introduction

An engineering instructor recently told us, "For those of us who were trained as engineers in the 1980's and have taught the past 20 years, there's a bit of a Pavlovian response that communication means writing." Indeed, "communication = writing" is a widely accepted proof among engineering instructors and is confidently echoed by engineering students when asked, "*What is communication*?" Those with broader perspectives include "and presenting" to the equation, but even some of the most experienced and open-minded engineers and engineering professors we have met stop there. Engineering students, becoming competitive in their responses to the prompt "*What is communication*?" begin to shout out things like "Conveying a message in writing or verbally," while a handful of cheeky students offer an all-encompassing, "Everything!"

At the risk of sounding overwrought and grandiose, of the responses typically offered, "everything" comes closest to describing communication as the theoretically and empirically rich discipline it is; while it is true that writing, presentations, and speaking are all forms of communication, communication cannot be not defined by any of these individual components. Unfortunately, the decades-long focus on teaching engineering students how to develop technically sound written messages and, more recently, visually appealing presentations *as* communication has pushed most of communication's "everything" out of engineering education. As a result, the Pavlovian response in engineering that "communication" means "writing" is widespread, and the definition of "good communication" is frequently based on one's proficiency in forming grammatically correct, cogent sentences with "good flow."

But the challenges we face in the 21st century require engineers who bring more to the table than technical competency and readable technical reports. Engineering federations and accreditation agencies around the world recognize the complex, interdisciplinary, and multicultural nature of these challenges, and have issued calls for engineering education to equip aspiring engineers with a range of intercultural and interpersonal competencies. ABET, the European Network for Engineering Education (ENAEE), and the Federation of Engineering Institutions in Asia and the Pacific (FEIAP) highlight the need for engineers to recognize and account for the impacts of engineering practice and design in broad contexts that impact human and environmental conditions throughout their guidelines. ABET (2021) mandates that engineering graduates have "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors," and "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" (p. 8). FEIAP (2019) stipulates that "Engineering practice must consider economic, public health, safety, legal, social, environment and sustainability factors" (p. 2). Similarly, ENAEE (2021) states that Bachelor Degree Graduates must demonstrate an "awareness of the wider multidisciplinary context of engineering," an "awareness of non-technical - societal, health and safety, environmental, economic and industrial - implications of engineering practice (p. 11) the “ability [...] to recognise the importance of non-technical [...] constraints” (p. 9), and the “ability to develop and design complex products (devices, artifacts, etc.), processes and systems in their field of study to meet established requirements” with consideration for those non-technical aspects (p. 10).

Additionally, engineering graduates are expected to have the ability to “communicate effectively on complex engineering activities with the engineering community and with society at large” (FEIAP, 2019, p. 27), and to “communicate effectively with a range of audiences” (ABET, 2021, p. 8). These three organizations also call attention to the importance of engineering education to prepare engineering graduates to work on multidisciplinary and multicultural teams with a high degree of competence and awareness for others, stipulating that engineering bachelor degree graduates have the 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, p. 9), to “demonstrate knowledge and understanding of engineering management principles and economic decision making and apply these [...] as a member and leader in a team [...] in multidisciplinary environments” (FEIAP, 2019, p. 27), and to “gather and interpret relevant data and handle complexity within their field of study, to inform judgements that include reflection on relevant social and ethical issues” in teamwork contexts (ENAEE, 2021, p. 12). The communication-based competencies outlined by ABET, ENAEE, and FEIAP above are so important to engineering practice that 63% of employers are willing to hire employees with proficiency in these non-technical competencies and provide on the job training to get them up to speed on the technical aspects of the job (Smith, 2022).

The need for interculturally competent engineering graduates is apparent, and employers increasingly expect to hire engineers who are proficient in this and other areas of communication. However, the implementation of communication training in engineering education continues to face many challenges, including that, in engineering schools, Communication is frequently essentialized to “writing and speaking skills,” and as a result, the empirical and theoretical richness of the Communication field is rarely recognized or incorporated into engineering communication training programs.

Below, we outline and discuss specific attributes of interpersonal and intercultural communication, our experiences developing communication programs in engineering and other STEM disciplines, and how integrating a fuller and more complex model of communication training in engineering programs can enhance STEM efforts toward diversity, equity, inclusion, sustainability, civic engagement, and justice. We conclude with a discussion about what the field of engineering can learn from our examples of how communication training is implemented in three unique universities across two different STEM disciplines and suggestions for how engineering colleges can better integrate and accommodate broad communication training in their programs.

What is Communication?

Communication is the process of exchanging information to arrive at shared meaning and construct social realities within a particular context. Figure 1 is a representation of the transactional model of communication depicting communicators exchanging messages via particular channels (spoken, written, verbal, nonverbal, face-to-face, mediated, virtual) with the goal of arriving at shared meaning in context. A key element related to this model of communication is the communicators' environments, which broadly encompasses factors such as physical space and place, individual backgrounds and experiences, and the context, including the setting and related organizational, cultural, and relational dimensions. This conceptualization encompasses communication at various levels including interpersonal, team, organizational, and public communication and acknowledges the impact of cultural, relational, and social dynamics that inform each communicator's perspectives, thus illustrating the complexities inherent in communication and shared meaning-making.

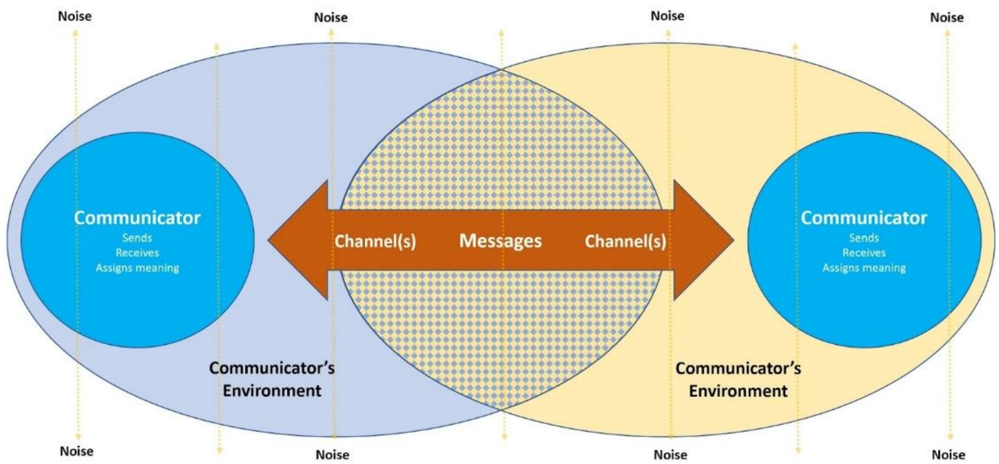

Figure 1. Transactional model of communication

With this model, we can more easily see that communication is not merely a tool that is used to convey information; rather, it is how our social realities are negotiated and how information is produced and circulated. As is true of all fields and professions, engineers first come to understand their professional field by how it is communicated to them educationally: through the definitions, facts, formulas, and descriptions of theories and processes in textbooks; in the format and content of lectures; through the manner in which teachers engage the subject matter and students; and in the way students are required to demonstrate comprehension. Thus, in the context of engineering, the communicator's environment includes their educational background, including the information they learned, as well as the contexts in which they learned it and how the information was communicated to them. In addition to their background of engineering education, the communicator's environment includes the aforementioned perspectives, expectations, attitudes, beliefs, values, etc. that are informed by their experiential and cultural backgrounds.

What is Interpersonal Communication?

Interpersonal Communication is widely misunderstood, and while this is perhaps especially true in STEM disciplines, STEM is not alone in their misconceptions. Outside of Communication Studies, Interpersonal Communication (IPC) tends to be treated as a personality trait (Okoro, Washington, & Thomas, 2017; Pert, 2019), and on popular career websites and in professional contexts alike, is most often defined in terms of "people skills," "personal skills" (Doyle, 2021), or even “friendliness” (Indeed, 2021). IPC is also frequently discussed as a set of traits that are inherent to a person.

However, the role of IPC in everyday professional communication is much deeper and more complex than cordiality; it is essential to functionality and effectiveness across disciplines and organizations. Furthermore, IPC and the concepts that fall under its purview are backed by bodies of research spanning multiple areas of communication, such as science-, health-, and organizational-communication. Common IPC concepts that competent communicators routinely engage in the workplace, and are thus directly relevant to engineering education, include verbal and nonverbal communication, listening, empathy, conflict resolution, feedback, and culture and diversity. The ability to competently engage these aspects of IPC is learned, and can be taught, practiced, and improved over time. When embedded in a curriculum alongside other professional training, students are provided the opportunity to learn necessary and transferable communication competencies that align with the professional needs and expectations of their specific fields.

Collectively, these concepts offer a framework for cultivating 21st Century engineers who are capable of communicating with diverse audiences (wherein an audience is 1 or more person that a message is directed to), including multidisciplinary colleagues, and who have the tools they need to productively participate as part of diverse teams. An engineer who is able to competently navigate interpersonal communication concepts will have the capacity to think critically about the parameters of a given context, and will be able to appropriately contextualize their verbal and written communication in a way that meets the needs of their specific audiences.

Although the ability to competently navigate these concepts is integral to professional effectiveness, practice, success, growth, and promotion across professional contexts, including engineering, these concepts and how to practice them are almost never explicitly taught as part of engineering education. Rather, engineering students are generally expected to passively acquire proficiency from classroom activities, group assignments, and lab work.

What is Intercultural Communication?

Intercultural communication is interlinked with interpersonal communication and is often described as culturally focused IPC. While the IPC concepts listed above include “Culture and Diversity” as an IPC proficiency, the specific focus of culture-impacted communication deserves special attention, as cultural norms and expectations directly impact the other IPC concepts listed.

Intercultural communication (ICC) is the study of cultural impacts on communication and communication across cultural contexts. This area of communication research is important in STEM education given the increasingly intercultural and international nature of STEM work (Rico-García & Fielden Burns, 2020). Indeed, “a growing number of employers expect to hire engineers who are well versed in intercultural communication,” and calls from ABET, ENAEE, and FEIAP reflect demands from all corners of the engineering field for “graduates with effective communication skills that enable them to collaborate with a diversity of people in a globalized professional environment” (Handford et al., 2017).

Through intercultural communication instruction, engineering students can learn to recognize and appreciate one another's culturally and experientially influenced perspectives, methods, and problem-solving approaches. With thoughtful and intentional ICC instruction, students learn to understand cultural variation not as differences that need to be overcome, but as strengths that can be intertwined and leveraged as they navigate their work on multidisciplinary teams. The acceptance and appreciation of various ways of thinking, perceiving, and doing leads to increased creativity, improved critical thinking, innovative problem-solving, and dynamic solutions to complex issues.

Interpersonal Communication, Intercultural Communication, and Student Learning Outcomes

Interpersonal and intercultural communication concepts and principles are at the heart of other forms of professionally valued communication, including written and oral communication, teamwork, and communicating with diverse audiences (Donnel, Aller, Alley, & Kedrowicz, 2011; Woodin, Carter, & Fletcher, 2010). However, these communication-rooted concepts and principles are rarely expressly taught in engineering education (Kedrowicz & Nelson, 2007), where teamwork training tends to instead focus on process, organizational, and assessment elements such as team contracts and peer-assessment (Chowdhry & Murzi, 2019). In such settings, engineering student teams are often told to create a team contract that outlines expectations for team participation, communication, behavior, and task completion. Drafting a meaningful and effective team contract requires that students negotiate, listen, understand conflict resolution, and carefully consider diversity regarding attributes such as work styles, ways of organizing time, group participation, and perspectives on teamwork and team membership. The diverse perspectives and approaches that students bring to the table are borne from students' varied experiences, upbringings, and cultural and co-cultural memberships, and are beneficial to STEM innovation, ingenuity, and problem solving. However, STEM students are rarely asked to even think about these common, normal human factors, never mind provided instruction that teaches to the positive impacts of diverse thinking in STEM and how to negotiate diversity to the benefit of a team, project, or product. The same students may then be instructed to use number-based peer-assessment tools that compare team member task completion to the details of the team contract. The expectation is that such assessment will address team discord, despite the students never being expressly taught about conflict types, resolution strategies, or the constructive aspects of well-managed conflict in communication and team settings. Such an approach invites well-organized complaining based on a narrowly structured and poorly understood team contract from students who may have little to no understanding of or patience for perspectives and ways of being that are different from their own.

However, the direct instruction of IPC and ICC concepts and principles in undergraduate engineering classrooms would aid in achieving the spirit and the letter of multiple engineering federation and accreditation student learning outcomes. Looking specifically at ABET (2021) student learning outcomes (see Table 1), we can see that the direct instruction of IPC and ICC can be of great benefit.

Table 1

ABET SLOs and Associated IPC and ICC Competencies

ABET Student Learning Outcomes (2021)

Student Learning Outcome	Most Relevant IPC and ICC Competencies
SLO 2 "ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors"	Culture & Diversity Listening Framing Perspective Taking Beliefs and Values Problem Solving
SLO 4 "ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts"	
SLO 3 "ability to communicate effectively with a range of audiences"	Verbal & Nonverbal Communication Listening Empathy Conflict Resolution Feedback Culture& Diversity Perspective Taking Beliefs and Values
SLO 5 "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"	

Although it may seem that interpersonal and intercultural instruction will require the addition of undergraduate courses, STEM students do not need to minor in communication studies to benefit from IPC and ICC concepts, theories, and practices. While clear, direct instruction of communication topics is necessary for students to effectively develop the professional competence necessary for the 21st Century engineer to successfully navigate 21st Century challenges, such instruction has been successfully integrated into STEM programs and courses in a variety of program specific ways that achieve desired student learning outcomes.

Below, we outline three integrated communication programs in engineering and veterinary medical colleges at three different universities. The communication programs in the engineering colleges at the University of Utah and the University of South Florida demonstrate differences in how communication training is often integrated in engineering education. The communication program at North Carolina State University's College of Veterinary Medicine showcases how a well-developed and thoroughly integrated communication program that highlights how interpersonal and intercultural communication can lead to measurable outcomes that enhance professional identity and practice.

Experiences in Engineering
Program 1: University of Utah (2003-2013)

Engineering Criteria 2000 resulted in the incorporation of communication and writing instruction as part of engineering graduation requirements. Dedicated learning outcomes related to communication, writing, teamwork, and ethics necessitated that engineering departments demonstrate continuous improvement/development of these competencies. As a result, a pilot program was launched in the Department of Mechanical Engineering that paired two graduate teaching assistants (one from Communication and one from Writing) to work with the senior design course to enhance students' ability to prepare and deliver design proposals, project, updates, and reports orally and in writing. The success of this small-scale initiative resulted in the development of a college-wide engineering communication program in 2003 led by a program director with a doctorate in Communication (Kedrowicz) and staffed by a team of graduate (PhD level) teaching fellows from Communication and Writing. The goal of this program was to prepare engineering graduates for leadership. As such, the program included training on communication, writing, teamwork and ethics as core components of the undergraduate curriculum in every department in the College of Engineering. The program director worked with faculty from each department to develop an integrated, scaffolded curriculum that was delivered by the two graduate teaching fellows per department as part of the core undergraduate curriculum. The thrust of the program was to incorporate teaching and learning of context-specific communication, exemplified by the communication-in-the-disciplines (CID) (Dannels, 2001) approach that positions the standards of professional communication within the norms of engineering work. Collaboration occurred in at least one required course for each engineering student from Freshman through Senior year. The courses typically included a team design project, thus necessitating some instruction on team communication, oral presentations, writing, and ethics.

This program began with College-wide, dean's level administration and support. The communication lab and consultations space was centrally located in the main College of Engineering building. It was in this space that the director, administrative assistant, and graduate teaching fellows also occupied office space. PhD students from the College of Humanities with interests in instructional communication, writing/composition, and communication across the curriculum served as strong ambassadors for the importance of disciplinary expertise. In addition to classroom instruction, communication laboratories, and student consultations, the program director and graduate teaching fellows offered monthly workshops targeting engineering faculty on topics related to communication, writing, teamwork, ethics, assignment design, and feedback. These sessions served to both increase awareness of the program and provided training on best practices related to teaching and learning communication. Dedicated end-semester instructional team meetings included engineering and communication faculty and graduate students, culminating in written year-end reports to document activities and recommend changes.
The program director also led beginning and end-of year retreats with Humanities graduate students which served to strengthen the program. The program director and graduate students cultivated an active research agenda dedicated to scholarship of teaching and learning including travel support for graduate students to attend conferences and showcase this innovative cross-disciplinary communication program. Finally, the program director gathered and compiled assessment and outcomes data each year to evaluate program impacts. Outcomes include measurable improvement in students' communication competence over time and an appreciation for the interdisciplinary collaboration characterizing this work (Kedrowicz, 2007a; 2007b; Kedrowicz, 2010; Kedrowicz et al., 2011; Kedrowicz & Nelson, 2007; Kedrowicz & Sullivan, 2006). While the thrust of the program was speaking and writing deliverables related to engineering design projects, students worked collaboratively on almost every project, so instruction related to team communication and collaboration served to enhance the interpersonal processes required to produce effective products (designs and deliverables).

Program 2: University of South Florida (2018 – Present)

To keep pace with rapidly evolving accreditation criteria and calls by employers for broad communication competence among new engineering graduates, the College of Engineering (CoE) at the University of South Florida (USF) implemented a scaffolded communication program in 2018 and hired communication PhD holding faculty to lead the program. Burchfield was embedded into two traditional, mid-level engineering courses, Engineering Economics (Econ) and Probability and Statistics (P&S), which each serve approximately 450-550 students/semester. These courses are required for most engineering undergraduate students across departments. Communication faculty were also embedded in an engineering elective course, Globalization and Technology (G&T), which serves 100 students/semester and is open to all university students. In total, approximately 1100-1300 students cycle through these courses per 16-week semester (Spring and Fall), and approximately 300 students in the summer. All three courses are certified to meet General Education (GenEd) student learning outcomes (SLOs); Econ and G&T are certified to meet Human and Cultural Diversity GenEd SLOs, while P&S is certified to meet Data Literacy SLOs.

The CoE took a communication-in-the-disciplines (CID) approach that integrates communication training into existing engineering courses and focuses on context specific communication topics (Dannels, 2001). The communication component of the two core courses, Econ and P&S, accounts for 20% of students' final grades, with the other 80% dedicated to technical engineering content; the communication component comprises 40% of the final grade in the elective G&T course. The CoE has provided support to communication faculty by providing up to three TAs per 550 students to help grade communication assignments.

Burchfield revised the communication content and assignments in the Engineering Economics course over the first three years to more meaningfully achieve Human and Cultural Diversity SLOs. An interpersonal and intercultural approach was implemented and provided explicit instruction on the influence of culture and co-cultures on communication, audience-centered communication (where an audience is one or more person, such as a client), teamwork, perspective-taking, and diversity and inclusion. A key element of the implementation is critical/analytical reflective writing and reporting, where students are required to examine how their perspectives and expectations, extended from their backgrounds and experiences (the "environment" in the Transactional Model of Communication from Figure 1), influences how they engage in situations and with others, and thus how their participation may impact the people they interact with and the outcomes they experience. Throughout the semester, the terms "interpersonal-" and "intercultural communication" are used and defined, as are specific terms for IPC and ICC concepts, such as "audience."

Following the implementation of these changes, students began to demonstrate improved learning outcome achievement and began to report personal/professional growth and development of perspective in terms of engineering practice, ethics, and professional identity (Burchfield, Akintewe, & Chilton, 2022). Based on these findings, a pilot study was conducted in the mandatory first year Foundations of Engineering course that all incoming students are required to take (~800-900 students per semester, 100 students/section). This project-based course requires students to work in teams throughout the semester to complete a project, however no teamwork instruction is provided to the students. In the pilot study, a 30-minute IPC/ICC lecture that focused specifically on teamwork was integrated into one section. The inclusion of the lecture led to a decrease in dysfunctional teams, clearer expectations among students regarding teamwork, and new tools for navigating team negotiations, team member roles, and team conflict (Burchfield, Akintewe, & Chilton, 2022).

In addition to program development, Burchfield has provided support to other undergraduate engineering courses through guest-lectures, and to the graduate student community via guest-lectures and communication workshops and seminars. Burchfield has also teamed up with engineering faculty members to develop a 1.0-credit spring-break engineering study abroad program as well as to advise engineering undergraduate students in the national Lockheed Martin annual ethics competition. In each of these touch-points, IPC, ICC, and other communication concepts have been explicitly taught in an effort to help students understand how communication competency is professional engineering competency.

Experiences in Other STEM Disciplines (2013-Present)

Other STEM fields also acknowledge the importance of communication to professional success, including biological sciences, and medicine. Cross-disciplinary communication instruction is on the rise in veterinary medicine. Communication is a core clinical competency that enhances veterinarians' relationships with their colleagues and clients. Beyond relationship development, veterinarians who communicate competently reap the benefits of greater well-being and job satisfaction. Recognition of the importance of communication to the practice of veterinary medicine is evident through incorporation of communication as an educational outcome by the American Association of Veterinary Medical Colleges (AAVMC) Council on Education (COE). This is further acknowledged through the addition of communication training that is now a part of many veterinary schools' curriculum.

In veterinary medicine, communication activities include collaborating effectively as part of a medical team and efficiently coordinating efforts to provide medical care to patients, communicating with clients during veterinary appointments, and communicating with the public. Genres of communication include both face-to-face team and individual interactions, as well as written communication in the form of client educational materials, medical records, discharge instructions, and social media postings. Standards for success are ultimately tied to patient and client outcomes, such that a veterinarian's communication is integrally tied to their ability to diagnose and treat patients. It is through communication that veterinarians are able to build professional relationships with clients that enhance information gathering, client education, and decision making that ultimately influences patient care through client adherence to recommendations. As a result, knowledge and application of interpersonal and intercultural communication is especially important.

A curricular change initiative was instituted in 2014 at the NC State College of Veterinary Medicine developed by Kedrowicz. A key component of this initiative was to provide students with professional communication training and development. The structure is such that the development of communication competence follows a situated, developmental approach (Lave & Wenger, 1990) spanning the three pre-clinical years. Students participate in four required courses beginning their very first semester of the Doctor of Veterinary Medicine (DVM) program. The first course is the teams in veterinary medicine course where students learn how to communicate as part of a medical team. This includes instruction in competent communication, collaboration, coordination, safety culture, feedback, diversity, well-being, and conflict management. Students apply the knowledge learned in this course to their authentic team experiences in concurrent and future courses. During years two and three, students participate in the introductory and advanced clinical and professional communication courses where they learn how to interact with clients during routine wellness visits (introductory course) and more advanced, problem appointments (advanced course). The thrust of these courses are the simulated client communication laboratories. In addition to practicing their interpersonal communication, students participate in modules relating to well-being, professionalism, and Diversity, Equity, Inclusion and Justice (DEIJ). Finally, the capstone communication course includes instruction related to medical team communication, patient handoffs, professional identity management, and another advanced simulated client interaction.

Developing and implementing this scaffolded communication curriculum requires collaboration and support from clinical faculty members and technical staff who help deliver the instruction, develop the clinical cases that are used during simulations, and provide coaching and feedback during simulated client communication labs. So, in addition to communication instruction targeting students, communication training is also provided in the form of seminars and “lunch and learn” sessions for faculty, technical staff, and house officers (veterinary interns and residents). Not only does this training provide them with the requisite communication knowledge to serve as coaches during communication labs, it also enhances their ability to provide communication-related feedback to students during clinical rotations, and positively impacts their own interactions with colleagues and clients, thus enabling consistent role modeling of competent communication.

Additionally, a full-time staff person supports the communication curriculum by providing instructional support including searching the literature for instructional resources, maintaining course web pages, and managing all communication simulations (scheduling students, facilitators, and actors, recording all simulations and archiving data for all students in the program), as well as research support including literature reviews, data gathering and analysis, and presentation development. Beyond personnel, an integrated clinical and professional communication program requires unique structural considerations including flexible scheduling with other faculty to accommodate communication laboratory experiences for 100 students each semester, as well as dedicated training rooms equipped with secure video recording and archiving equipment. Results from this program include measurable student improvement in communication competence over time, enhanced student confidence with client communication, and greater self-awareness related to communication (Kedrowicz, 2016; Kedrowicz et al., 2017; 2018; 2019).

Integrating Interpersonal and Intercultural Communication in Engineering Education

As discussed in the introduction, engineering federations and accreditation bodies across the world have set standards for undergraduate engineering education to include training that develops graduates’ abilities to work toward multidisciplinary solutions for complex global issues in multidisciplinary, multicultural, and diverse contexts, as a productive part of diverse teams, and with awareness of and concern for public health and safety, environmental impacts, and the broad effects on the surrounding community. Integrated instruction of interpersonal and intercultural communication in undergraduate engineering education can help engineering students develop the proficiencies required to meet the requirements of accrediting bodies and the professional demands of employers. Additionally, the critical thinking, perspective taking, and systems thinking approach that IPC and ICC cultivate in intentional practitioners will broaden and strengthen students' abilities to facilitate diversity, equity, inclusion, and justice (DEIJ), both in engineering education and in professional engineering contexts. While DEIJ outcomes may not necessarily be the focus of IPC and ICC integration in engineering education, direct IPC and ICC instruction has been shown to broaden student perspectives such that they independently begin to connect topics of DEIJ and engineering ethics to their engineering course content and even to their own engineering identities (Burchfield, Akintewe, & Chilton, 2022).

ABET accreditation revisions over the past 20 years, employer demands, engineering education research trends, and changes within engineering colleges regarding DEI-related initiatives point to an ongoing evolution in the engineering field. The integration of DEI and justice (DEIJ) based training in engineering education is integral to good engineering design, public health and safety, improved product outcomes, client satisfaction, and ethical engineering practices. Joy Buolamwini (2016) discusses some of the implications of developing technologies and products based on datasets and research compiled by non-diverse engineers and computer scientists, and notes that "Calls for tech inclusion often miss the bias that is embedded in written code." Buolamwini explains the difficulties that people with dark skin-tones – especially Black women – have with facial recognition software, and recounts her experience of having to wear a white mask while conducting her research so that the facial recognition code she was using would recognize her face as a face: "A lack of diversity in the training set leads to an inability to easily characterize faces that do not fit the *normal face* derived from the training set" (2016). As Buolamwini states in her byline, "Whoever codes the system, embeds her views."

In addition to facial recognition software, the history of cameras and film development poorly capturing and rendering dark-skinned features and accounts of infrared soap dispensers and sink sensors failing to respond to dark-skinned hands provides a glimpse of the issues caused by a lack of diversity and inclusion in STEM. While the soap and water not working or having to key in your passcode instead of unlocking your phone with facial recognition may be brushed off by some as mere inconveniences, there are broader and much more dangerous implications of these technological failures. For example, "Facial-recognition systems are more likely either to misidentify or fail to identify African Americans than other races, errors that could result in innocent citizens being marked as suspects in crimes" (Garvey & Frankle, 2016). The potential risks to citizens associated with technological failures that could mark them as suspects include undue stress, financial hardship, loss of job and/or reputation, and even loss of life.

Direct IPC and ICC instruction in engineering classrooms, especially when paired with examples such as Boulamwini's, helps undergraduate engineering students better understand not only how to navigate engineering contexts, but also the broader implications of the work they do and how that work is done. Additionally, highlighting the positive impacts of multiple and diverse perspectives on engineering products, projects, and outcomes encourages students to invite the inclusion of different perspectives as well as helps underrepresented students feel that their perspectives and contributions are both wanted and needed.

However, despite broad engineering accreditation, federation, and industry/employer insistence, the acceptance and support by engineering colleges of communication integration in engineering education is still limited. Disciplinary constraints (required core and elective courses) impact the likelihood that students will be exposed to dedicated courses on DEIJ and other traditional liberal arts courses designed to enhance civic education. As a result, it is imperative to capitalize on the cross-disciplinary collaboration and expertise that Communication scholars bring to these initiatives. Further, by “couching” DEIJ, environmental justice, ethics, etc. discussions within the engineering curriculum, students will be more likely to see the relevance of such topics to both their professional success and personal well-being. Moreover, stressing the civic responsibilities associated with professional competence serves to enhance student’s professional identity development.

An expanded view of communication to include instruction in interpersonal and intercultural communication can be the vehicle for DEIJ, ethics, and civic engagement in STEM disciplines broadly and engineering, specifically. Communication scholars teaching within STEM disciplines can and should develop learning opportunities that integrate interpersonal communication, attention to ethics, and DEIJ issues. Instructional modules should be developed that encourage students to engage in discussions related to these topics within the engineering context, followed by a deliverable requiring students to account for these issues. For example, this could include a design report that must address stakeholder needs for a civil engineering project impacting housing and community development in a low-income neighborhood. It might also include engagement with case studies followed by an oral presentation where students must grapple with ethical issues. It could also include a critical self-reflection designed to enhance self-awareness. Service-learning opportunities are another avenue for student immersion in real-world problem solving, stakeholder engagement, and debate and decision making related to DEIJ.

Lessons Learned and Moving Forward

Scaffolded, integrated, discipline-specific instruction works best to prepare students for both professional success and civic engagement. While we acknowledge that communication includes presentations and writing, the broad communication training necessary for success in professional engineering practice reaches beyond these two common genres of communication to encompass teamwork, interpersonal interactions, and attention to cultural diversity, and thus, all these areas should be appropriately leveraged as part of a broad-based engineering communication curriculum. In short, it requires a shift from emphasizing the product of communication (presentation, proposal, report) to emphasizing the process of communication (interpersonal communication, collaboration, consideration for and critical reflection of how culture impacts communication and teamwork).

Successful cross-disciplinary collaborations of this kind require support from college and departmental leaders, as well as faculty collaborators and an openness to innovation in instruction, assignments, courses, and curricula. Attention to a broad approach to communication pedagogy need not require additional courses per say; rather, a more nuanced approach to assignment design could accomplish multiple objectives with one deliverable. What *is* required, however, is commitment to educational innovation to enhance the development of engineering students' communication competence. Just as we expect our students to be lifelong learners, so, too, should we make a commitment to learning more about best practices for communication pedagogy and interdisciplinary collaboration. Moreover, these collaborations as exemplified by communication instruction can enhance students' learning of their engineering material in that communicating and writing about engineering content facilitates student understanding.

In summary, Engineering undergraduates will benefit from more nuanced communication training that will both prepare them for engineering work, and also prepare them to be engaged citizens. They will become members of an organization that will demand collaboration with diverse individuals with different backgrounds, experience, and expertise. They will grapple with solving real-world problems that have ethical considerations and often competing stakeholder needs. A broader communication education that includes attention to interpersonal communication, teamwork, DEIJ, ethics, and professional communication will prepare them for these responsibilities. Employers will reap the benefits of better prepared graduates which means less time and money spent providing additional communication training on the job. The industry as a whole will see enhanced problem-solving and greater credibility and trust among the general public.

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