Learning from Experience: A Faculty-Led Collaborative Inquiry Exploring Evidence-Based Strategies for Embedding Communication Skills Across Engineering Curricula

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Introduction

Communication skills have long been recognized as critically important for engineers, with the earliest engineering writing courses dating back to the late 1800s (Connors, 1982). Communication training for engineers evolved over the next two centuries, with technical writing curricula forming the foundation for what we now refer to as "technical communication" curricula (Paretti et al., 2014). Historically, technical communication courses have been widely implemented across universities as stand-alone courses disconnected from engineering departments (Paretti et al., 2014).

However, recent research suggests that technical communication courses decoupled from engineering content face two significant limitations in ensuring engineering students develop effective communication skills. First, when taught in isolation from technical content, communication skills may be viewed by both faculty and students as an afterthought of solving "real" engineering problems, rather than as fundamentally central to the problem-solving work of engineers (Matusovich et al., 2012; Poe et al., 2010; Wolfe, 2009). Second, when communication skills are disjointed from technical content, there is often a void of context-specific communication discourse (Paretti et al., 2014), such as training mining engineering students to effectively communicate geotechnical risks with the public (e.g., Conrad, 2009; Hadjigeorgiou, 2020; Noppé, 2014; Stewart & Lewis, 2017).

In addition to these documented limitations of stand-alone technical communication courses, at least three major influences have contributed to an overall shift in engineering education toward embedding communication skills into core engineering curriculum. First, the ABET Engineering Accreditation Commission's inclusion of communication as a core learning outcome required for all engineering students has significantly motivated a collective focus on how to effectively teach communication skills within required engineering curriculum (ABET Engineering Accreditation Commission, 2007; Williams, 2001). A second driver for embedding communication skills across the curriculum is the growing body of research on the school-to-work transition for early-career engineers. Broadly, research on the school-to-work transition suggests that engineering graduates face significant challenges with communication in the workplace and feel unprepared for professional skills more broadly in engineering practice (Ford et al., 2019; Gewirtz et al., 2018; Howe et al., 2019; Lutz & Paretti, 2021). Finally, as summarized in Paretti, McNair, & Leydens' (2014), a robust body of engineering communications research identifies three clear insights to inform best practices for teaching communication skills to engineers: 1) communication instruction should be situated within engineering contexts; 2) communications-intensive courses should be central to major requirements; and 3) engineering content learning can be enhanced with communication assignments.

Despite these cross-cutting insights on engineering communication, challenges remain with the practical work of integrating communication skills across a range of engineering curricula. Toward this point, in their seminal work on engineering communication, Paretti et. al (2014) challenge the

engineering education community to fill a gap in the literature by "expand[ing] our understanding of effective *context-specific and generalizable practices* that foster deep learning of both professional communication and engineering concepts simultaneously" (p. 623, emphasis added). To contribute to this goal, our work focuses on sharing effective strategies for embedding communication skills within specific engineering disciplines. By sharing our collective reflections, our goal is to support engineering educators in drawing connections to their own research and practice.

Purpose and Research Questions

The purpose of this paper is to explore strategies for integrating communication skills into engineering curricula. These strategies are in response to challenges faced in achieving Paretti et al. (2014) vision of context-specific and generalizable practices. Our inquiry is therefore guided by two research questions (RQ):

> RQ1: What challenges do faculty experience when embedding communication skills into engineering curricula?
>
> RQ2: What solutions do faculty forward to better embed communication skills into engineering curricula across a range of engineering departments?

To explore these questions, we leverage a collaborative inquiry approach as a planned process to enable reflection-on-practice and collective sense-making amongst a community of eight faculty members tasked with integrating communication skills into engineering curricula across seven engineering departments. In the sections below, we first describe the conceptual foundation for our study, leveraging Lattuca and Stark's Academic Plan Model as a theoretical lens to enable reflection. We then describe our methodological approaches, rooted in collaborative inquiry approaches. We share the findings from our cross-case analysis (RQ1) to analyze challenges of integrating communication skills into engineering curricula. Finally, we conclude by sharing curricular solutions (RQ2) in the format of six practical case-based examples of strategies implemented in a spectrum of engineering disciplines and learning environments.

Conceptual Framework: The Academic Plan

Our work is underpinned by Lattuca and Stark's (2009) Academic Plan Model, which highlights eight elements and a range of factors that drive decision-making for university curriculum. The Academic Plan Model is an appropriate theoretical framing for our work given its applicability to all levels of a curriculum (e.g., a single class session, a full course, or a cluster of work) and its focus on decisions that shape curriculum planning and implementation. While the full Academic Plan Model includes external, institutional, and internal influences, we chose to scope our exploration to: 1) the seven elements of the academic plan (Figure 1), and 2) a description of the educational environment (Lattuca & Stark, 2009). For practical purposes, and based on the emergent narratives shared during our collaborative inquiry process, we expanded the Academic Plan to explicitly note the ***curricular problem*** that each of us were working to address through our teaching practices, followed by the ***solution***—as defined by elements of the Academic Plan—we have developed through our practices. For our collaborative inquiry, we use these scoped aspects of the Academic Plan Model, along with the problem-solution approach, to provide a consistent set of thinking tools for comparing and documenting communication skills integration across a diverse range of departmental contexts. Practically, sensitizing concepts from the Academic Plan model helped to

ground our data collection and meaning-making processes, supported by Charmaz's (2014) explanation of sensitizing concepts as a tool that "[provides] a place to start inquiry, not to end it." By using a problem-solution approach, along with the descriptive curricular elements of the Academic Plan model, our goal is to enable shared dialogue with practitioners and researchers who may draw connections to their own learning contexts.

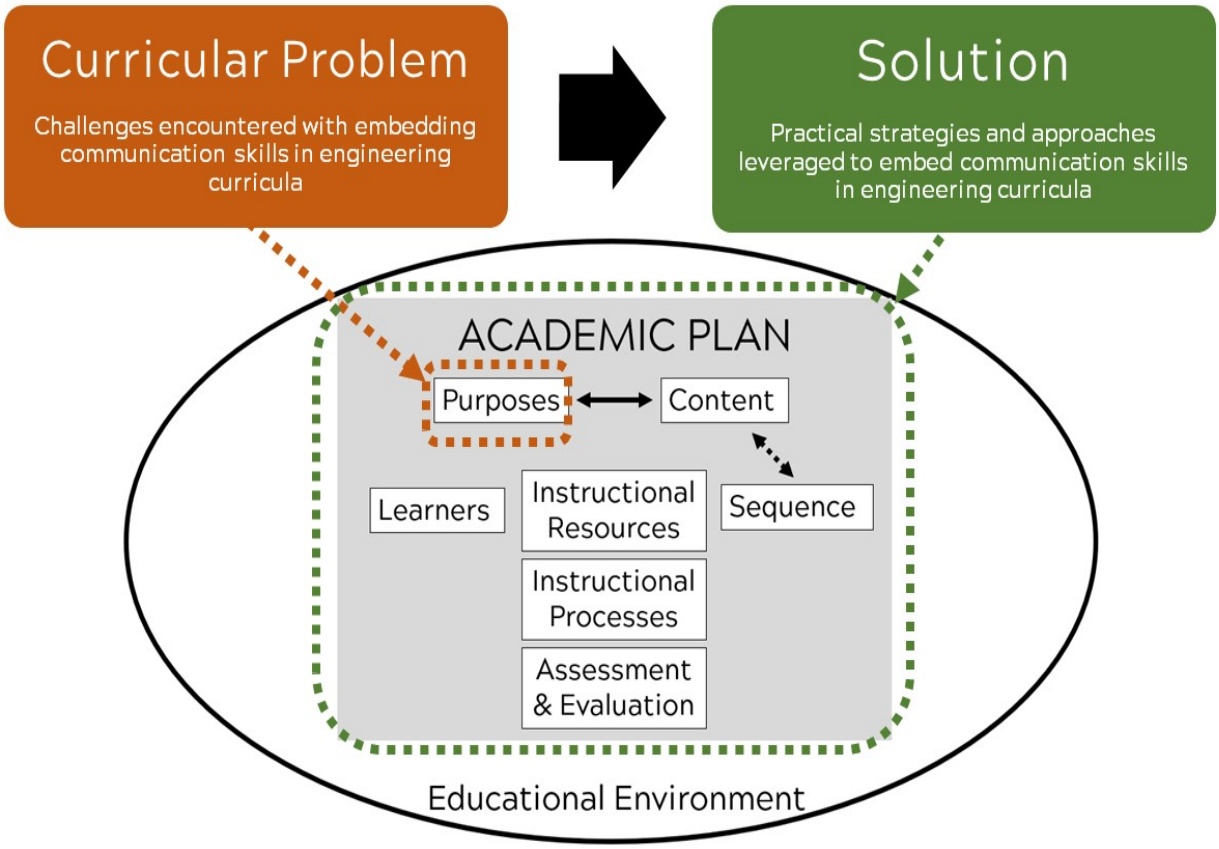

Figure 1. *To describe our solutions to curricular problems with embedding communication skills in engineering curricula, we leverage elements from Lattuca and Stark's (2009) Academic Plan Model as sensitizing concepts to create a shared vocabulary across educational environments.*

Methods: Collaborative Inquiry

We utilized a collaborative inquiry process to systemize our methods for learning from our practical experience embedding communication skills into engineering curricula (Yorks & Kasl, 2002). As shown in Table 1, the seven faculty participants in our collaborative inquiry process were diverse in terms of disciplinary background but all taught courses that met accreditation and curricular requirements. Focused on mutual learning across expertise, our faculty team is an active partnership between experts in communication and engineering, aligning with recommendations for designing effective communication curricula (Harran, 2011; Jacobs, 2010). Practically, the process of sharing experiences and reflecting together through collaborative inquiry enabled our team to engage in cycles of reflection about our teaching experiences and collective sense-making (Charmaz, 2014; Coso Strong et al., 2023). Our data collection process occurred through a series of monthly knowledge-sharing meetings and individual reflections over the course of two consecutive semesters. Collective sense-making occurred through group discussion as we interrogated our experiences and worked to identify themes, in alignment with Charmaz's (2014) recommendations for making sense

of reflections using a constructivist grounded theory approach. Ultimately, our cyclical reflection processes provided a platform for connecting research-to-practice, with collective learning from experience rooted in the reflections of faculty who teach communication skills across seven distinct engineering departments and a variety of curricular contexts.

Table 1. *Faculty Participants in Collaborative Inquiry Process*

Collaborator	Disciplinary Training	Department of Faculty Appointment
Angelo Biviano	*MA, English* *BA, English*	*Mining & Minerals Engineering*
Caroline Branscome	*PhD, Human-Centered Design* *M.S., Curriculum & Instruction* *M.S., Communication & Media Studies* *B.S., Mechanical Engineering*	*Civil & Environmental Engineering*
Christine Bala Burgoyne	*MA, English* *BA, English Studies: Language*	*Materials Science & Engineering*
Kathleen Carper	*Ph.D., Leadership & Social Change* *MA, Education* *BA, English*	*Industrial & Systems Engineering*
Josh Iorio	*PhD, Linguistics* *MA, English* *BA, English Literature*	*Construction Engineering & Management*
Kelly Scarff	*PhD, Rhetoric & Writing* *MFA, Creative Writing* *BA, English* *AA, Graphic Design*	*Mechanical Engineering*
Ashley Taylor	*Ph.D., Engineering Education* *MPH, Public Health Education* *M.S., Mechanical Engineering* *BS, Mechanical Engineering*	*Biomedical Engineering & Mechanics*

Results

Below, we begin our results section by highlighting emergent themes across our data related to challenges faculty described with embedding communication skills into engineering curricula (RQ1). Following, we provide six descriptive case studies highlighting strategies and approaches for integrating communication skills into engineering curriculum in response to these challenges (RQ2).

Our case studies represent curricular integration across seven distinct engineering departments at Virginia Tech, including both undergraduate and graduate education. From a total of 11 case studies discussed in our collaborative inquiry process, six case studies were selected for this paper based on relevance to RQ1.

Using the Academic Plan Model (Lattuca & Stark, 2009) as our foundation for discussion, these case studies provide context for the learning environment and implementation strategies for embedding communication skills. By examining results for our research questions, our goal is to support faculty in drawing connections to their own challenges and teaching strategies to enable effective integration of communication skills across engineering curriculum.

Challenges with Embedding Communication Skills Across Engineering Curriculum (RQ1)

We began our analysis by examining the challenges described by faculty that can impede effective integration of communication skills, visually presented in Figure 2. A clear theme that emerged was

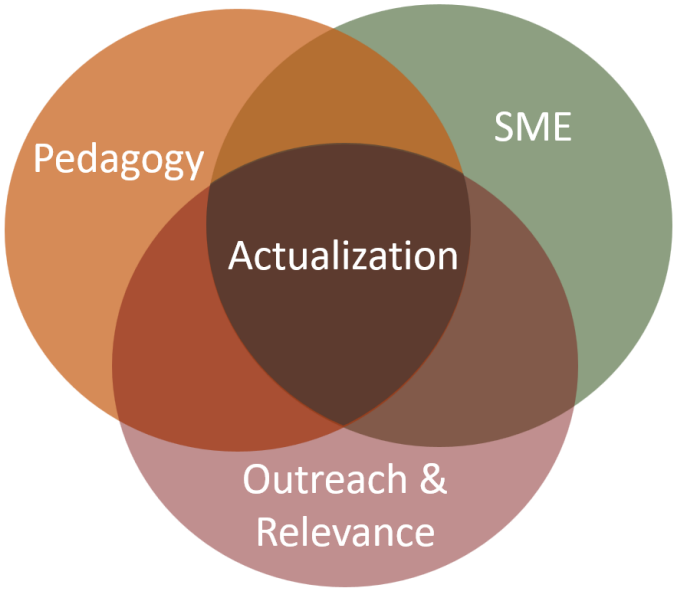

Figure 2. *Three groups of challenges emerged in our result that can impede* ***actualization****—students' achievement of desired communication learning outcomes. These included challenges related to how we elevate the importance of communication skills (****outreach and relevance****); how we teach engineering communication skills* ***(pedagogy),*** *and how we navigate as communication subject matter experts* ***(SME)*** *in engineering departments.*

the challenge of ***"actualization"*** of students' communication skills, which we define as students achieving desired learning outcomes related to communicating effectively in engineering contexts?. As Angelo Biviano aptly noted during one of our collaborative reflections, "most people in my department strongly support the idea that communication is important for our students. But there are often questions on how to achieve those skills through the curriculum." Broadly, our reflection processes identified three groups of shared challenges across our engineering departments and distinct educational environments. First, **"outreach and relevance**" of communication skills is a challenge shared across our contexts. Faculty face challenges with increasing the visibility of communication skills in engineering practice and connecting the bridge between academia & industry. Though literature and accreditation standards support the need for effective communication skills, faculty describe the ongoing need to build a case, to both students and faculty peers, for how communication skills connect to effective engineering practice. A second group of shared challenges centered on navigating engineering departments with **"subject matter expertise (SME)"** as communication experts. In order to effectively influence and implement curriculum within our respective contexts, faculty described challenges with sharing communication SME with colleagues and students. Finally, many challenges described in our reflections related to **"pedagogy"—**fundamentally how we teach communication skills situated within diverse learning environments. Based on our reflections, we concluded that **outreach and relevance**, **SME**, and **pedagogy** must work together to help students actualize the communication skills needed for their engineering careers. Table 2 provides a cross-case analysis to identify themes that emerged with challenges across our cases.

Table 2. *Cross-Case Analysis for Emergent Themes in Challenges Described by Faculty*

	Outreach & Relevance: How do we elevate the importance of communication skills?	**Subject Matter Expertise (SME)** How do we navigate as communication SME in engineering?	**Pedagogy:** How do we teach communication skills?
Case 1: Presenting to Write Construction Engineering Management		✓	✓
Case 2: Podcasting Mechanical Engineering	✓	✓	
Case 3: Debate Mining & Minerals Engineering		✓	✓
Case 4: Flipped Classroom, Civil & Environmental Engineering		✓	✓
Case 5: Style Shifting Materials Science & Engineering	✓	✓	✓
Case 6: Teaching Assistants, Industrial Systems Engineering		✓	✓

Case Study Solutions Described for Embedding Communication Skills into Curriculum (RQ2)

Case Study 1: Present to Write - Using Presentations to Teach Argumentative Writing
Josh Iorio, Myers-Lawson School of Construction at Virginia Tech

Educational Environment. Graduate students from a variety of undergraduate disciplines across colleges are required to enroll in a 3-credit course that focuses on the development of soft skills, including writing and presenting. The students are diverse in terms of national and disciplinary background.

Problem. Argumentative writing is a common (albeit not often well-known or studied) professional competency in many engineering disciplines. Daily, engineers use argumentative writing to explain how evidence supports their decision-making. Many students who enroll in the course are not able to effectively structure a written argument but are able to write grammatically. Based on observation during writing workshops, students spend a disproportionate amount of time focused on correcting grammatical errors in their writing before ensuring that their writing is effectively structured. Grammatically correct and stylistically appropriate writing is important, but well-structured and logical reasoning is fundamental to creating effective (written) arguments.

Solution. The approach adopted in this case study situates presentation design as an initial component of the writing process rather than as an outcome. By starting the writing process with presentation design principles, students focus their attention on the structure and logic of their writing before focusing on grammar and style.

This case approach builds on the Assertion-Evidence Model (Alley, 2013) of presentation design. In Alley's model, slide content is limited to two key elements: 1) an assertion or claim, and 2) supporting evidence. The presenter is then responsible for providing: 3) an oral explanation of how the evidence supports the assertion, and 4) an oral transition to the next assertion. In the case approach, Assertion-Evidence is extended directly to the structure of argumentative paragraphs with each of the four components represented as discrete, sequential sentences in a paragraph.

Students are asked to select a topic of interest that is intrinsic to the course content, e.g. the ethical implications of new technologies on engineering practice. Ultimately, the student will produce a 1-page written argument in support of a rhetorical goal related to their topic. Before they start drafting their written argument, students prepare and deliver a 2-minute presentation in 2 slides using the Assertion-Evidence structure. Students receive feedback on their assertions, the verbal explanations for how evidence supports their assertion, and how they logically transition to the following assertion. Students then use the feedback they receive on their presentation to develop their written argument, often as an initial outline. Students finish the writing process by reviewing their work for grammar and style, in which discrete sentences containing assertions, evidence, explanations and transitions can be combined through grammatical mechanisms without risk of losing the structure and logic of their argument.

Case Study 2: Developing an Engineering Communication Podcast
Kelly Scarff, Mechanical Engineering Department at Virginia Tech

Curricular Problem: Engineering undergraduate students struggle to actualize the amount of writing and other forms of communication that engineering careers often require.

Solution: Interview-based podcast that focuses on the communication aspects of engineering

Educational Environment. I am a faculty member in Virginia Tech's Mechanical Engineering department where I also serve as the director of the department's Technical Communication Program (TCP). The department awards an average of 400 undergraduate, 40 Master of Science, and 30 Doctoral degrees annually (Virginia Tech, 2023). As TCP Director, I offer writing workshops, guest lectures, and other similar events to help students gain different skill sets outside of the classroom.

Purpose. After attending a National Humanities Center's Podcasting Institute, I began thinking about how I could develop a podcast for engineering students that would highlight the practical communication components of engineering careers in a way that also showcased potential careers and research available to them in the future. I started The Engineering Communication Podcast (available on Spotify) in fall 2022, as part of the TCP. While the podcast is situated in a mechanical engineering department, its main goal is to provide engineering communication advice and information that is useful and relevant to engineers across all engineering fields.

Content. In engineering departments, podcasts have been used for a wide variety of applications, including teaching students how to research and discuss engineering education topics, such as global views and information dissemination (Alpay & Gulati, 2010); teaching students how to assess and solve problems (Berger, 2007); and helping engineering students with language acquisition skills (Chaikovska et al., 2019). Based on the literature, podcasts are proving to be a common and effective tool for providing content to myriad engineering audiences.

The Engineering Communication Podcast is managed by me with the help of an undergraduate assistant (UA) that changes each academic year. The UA is responsible for editing all podcast

episodes and interviewing participants when possible. We post two episodes per month during both fall and spring semesters; we take a hiatus over winter and summer breaks.

The podcast is in an interview format with common questions for each participant, with the idea that the answers to those common questions will change with enough frequency that each episode will offer a different perspective on engineering communication. We open by asking each participant about their educational background, any relevant past experiences, and their current position. Then, we ask about the communication components of their job, how their communication requirements have changed over the course of their careers, and how they approach writing and other forms of communication. Lastly, we ask them if they have any advice for engineering students about how to instill productive communication habits, such as writing, presenting, or interviewing. We strive to keep each episode between 20-30 minutes.

Learners. The primary audience for The Engineering Communication Podcast is undergraduate engineering students; however, I've received the most feedback from graduate engineering students and industry professionals in their mid-careers, leading me to believe that I am off target for my primary audience. To account for this, I am sending out a survey to undergraduate engineering students to better understand what topics they're interested in to see how I might pivot the podcast to make it more attractive to undergraduate engineering students while staying true to the core goal of the podcast.

***Instructional Processes*:** Currently, The Engineering Communication Podcast is not linked to any specific course; rather, I market each episode via social media outlets and email. However, I plan to incorporate the podcast episodes into my undergraduate engineering discourse class this spring as part of a writing analysis assignment. To record the podcast episodes, we use Virginia Tech's podcasting studio, housed in the Technology-enhanced Learning and Online Strategies division offices. The equipment includes a Yeti microphone, a desktop computer, and a sound-proof room with adjustable table and camera heights. To edit the episodes, we use Audacity, a free, open access editing software that both my UA and I find to be fairly intuitive to use.

***Assessment & Evaluation*:** We are currently in the second season of The Engineering Communication Podcast and are just now hitting a saturation point where the answers to the questions are becoming a bit similar and, thus, predictable. In spring 2024, I plan to work with my UA to create a new list of questions for the podcast guests that I will then implement into the fall 2024 episodes at the start of Season 3. My goal for the podcast is to elucidate the various communication components of engineering while keeping listeners engaged and continually learning about new aspects available to them across engineering careers and research fields; therefore, a fresh set of questions is a necessary adjustment for the upcoming season.

Case Study 3: Developing Mining Engineers' Communication Skills with Non-technical Stakeholders through Op-eds and Oxford Debates.

Angelo Biviano, Department of Mining and Minerals Engineering at Virginia Tech

***Curricular Problem*.** Developing communication skills that target non-technical audiences, particularly the general public and community stakeholders impacted by mining operations.

Solution. Integrating a communications-based "Sustainability Project" into a sophomore level course on leadership, ethics, and responsible mining. The project consists of two deliverables: a written op-ed and an Oxford style debate.

Educational Environment. Virginia Tech's Department of Mining and Minerals Engineering initiated its "Writing and Communications Program," in the mid 1990s to develop critical spoken, written, and visual communication skills that its graduates will quickly rely upon early in their careers. The program is led by a "coordinator" who collaborates and co-teaches with mining engineering technical faculty in designated courses. Hence, there are no strict communication courses in the mining engineering curriculum per se, but instead communications-focused assignments are integrated into technical courses.

Purpose. The case study discussed here was integrated into the course *MINE 2544 – Leadership for Responsible Mining*, a sophomore level class aimed at exposing students to leadership principles critical in their professions. A heavy emphasis is placed on engineering ethics, sustainability, and the need for social license, or a community's buy-in for a proposed mining operation. The communications portion of the department's curriculum adheres to guidelines set forth by ABET as well as an active advisory board composed of alumni and mining industry leaders. Both of these entities emphasize the need for mining engineers to communicate technical information to a variety of audiences, including both technically-trained supervisors and subordinates as well as non-technical members of the work force and the general public. Given the number of technical courses in the curriculum, students have ample opportunities to develop effective communication skills through laboratory reports, design and feasibility projects, and technical presentations. However, creating opportunities to develop communication skills aimed at non-technical audiences has not always been feasible or achievable.

Content & Sequence. A written Op-ed and Oxford debate comprise the overarching "Sustainability Project." The Op-ed assignment requires individual students to write a 1000-word opinion piece on one of three contemporary, significant, and controversial mining projects as selected by the course technical instructor. Students must either defend or discredit continuation of the mine based on principles of sustainable development and ethical practices as covered in the course. The op-ed serves as a springboard for the second Oxford debate assignment where students are split into three debate categories based on their chosen mine projects. Within each, members are grouped into a "for" or "against" panel, largely derived from their op-ed positions.

Instructional Processes and Resources. Skills for op-ed writing and debate are identified and delivered to students in advance of the deliverable deadlines. Prior to the op-ed assignment, students are provided with lectures and small group workshops on op-ed writing strategies (bottom line, diction, integrating/research, editing). Students are exposed to modes of persuasion and logical fallacies, and they conduct a rhetorical analysis of actual op-eds from major publications. To prepare students for the Oxford debate, instructors teach about debate format as well as effective debate and public speaking strategies. Resources and approaches, which enhance the debate and amplify student engagement, include a debate timer, a bell, name plates for panel members, and a suitable classroom or small auditorium that allows panel seating to face the audience. Every attempt is made to create a real and effective debate environment, with additional department faculty invited as jury members.

Evaluation. For both the written and debate portions of the project, students are evaluated by both the technical instructor and the communications coordinator via separate rubrics. The communication rubric for the op-ed focuses on elements presented in earlier lectures to include a

clearly identifiable position, effective structure and transitions, appropriate rhetorical mode, and avoidance of fallacies. Likewise, the communication rubric for the debate evaluates effective debate skills and public speaking, as demonstrated by the entire student team. In addition to the technical and communication instructors' evaluations of the debate, the jury (student audience) votes on which panel makes the most compelling argument—or wins. Based on this input, the winning team receives additional bonus points.

Reflection. Integrating the op-ed and Oxford debate assignments into the department's Leadership for Responsible Mining course has proven to be a successful means of enhancing students' communication skills aimed at non-technical audiences and public stakeholders. Feedback from students is generally positive, with most appreciating an opportunity to practice and refine public speaking on topics that are not strictly scientifically based. Though it is well received by students, the instructors have identified issues that may be changed in the future, and are summarized as follows:

- Difficulty evaluating students' spoken communication skills in debate given the division of labor among team members (some take on roles as speakers, others play a part in research). An alternative approach may be to assign the team equal grades.
- For the Op-Ed assignment, some students fail to "come down on a side" or offer a more resolute position. This results in an op-ed with a hidden or unclear bottom line and a random or disconnected structure. It also impacts the panel debate since debating teams are not really in opposition to each other.

Case Study 4: Switching to Inductive Learning to Increase Student Motivation
Caroline Branscome, Civil & Environmental Engineering, Virginia Tech

Educational Environment. CEE 4804: Professional and Legal Issues in Civil Engineering (P&L) is a three-credit course that enrolls approximately 100 students. P&L is a seminar taught by a professor of practice or instructor and a handful of graduate and undergraduate teaching assistants with several lectures being taught by guest speakers. Course topics include business etiquette, construction delivery methods, ethics, discourse, goal setting, interviews, leadership, legal principles, professional licensure, public policy, salary negotiation, and societal and environmental considerations in engineering design. Deliverables are assignments related to the topics, in-class quizzes on lecture content, and a final project that incorporates as many course topics as possible.

Problems. Students tend to value P&L less than their technical courses. Students dislike jumping from topic to topic and struggle to see the importance of learning about communication, ethics, professionalism, and social issues; therefore, attendance is poor. Of those who attend, many spend class time doing other things. The lack of student attendance and motivation informs three overarching problems in the class. First, teaching and course-objective evaluation scores are consistently below the department and college averages. Second, instructors prefer not to teach P&L every semester because they prefer to have higher evaluation scores, motivated students, and a less logistically challenged course. Last, rotating instructors means a rotating curriculum and an inconsistent student experience, reducing motivation and perpetuating the cycle of problems. The department thought these problems were endemic to P&L and kept the status quo. In spring 2023 the rotating pool of P&L instructors shrank to zero, and I was assigned the course. The department and I were all hoping I would hold the current status quo.

Solution. I rejected the status quo and wanted to improve students' experiences. I collected anonymous feedback twice during spring 2023. Over the summer, I attended a workshop on active learning in STEM. Then I pooled what I learned from students, the workshop, and my teaching degrees to redesign the fall 2023 version of the course for inductive, activity-based learning. Changes for fall 2023 included:

- Grouping and sequencing the topics to build on one another, explicitly tying each topic to a course objective. (Established guest speaker schedules precluded major schedule changes.)
- Switching two lectures out with pre-readings, which created more time for student activities.
- Adding realistic and/or actual case studies as examples, choosing cases from regions close to the university, and bringing in guest speakers with lived experience in diversity and leadership.
- Adding engaging individual and group homework and activities that required creative and critical thinking.
- Adding graded draft versions for major writing assignments and allotting class time for revision.
- Giving students choices on activities and homework and adding more open-ended homework.
- Grading some assignments myself instead of having the GTAs do it.
- Collecting students feedback three times during the semester and responding to it within days by improving course materials and/or logistics.

Quantitative evaluation. Students anonymously evaluated how well the course met the following eight objectives: Professional licensure, ethics, project delivery methods, legal principles, public policy, broader contexts, and leadership. Student evaluations for six topics changed by less than 3%. For project delivery methods, scores were 20% worse in the fall than spring. For project delivery methods, scores decreased by 20% in the fall; however, this drop may be due to an extenuating circumstance on behalf of the instructor. For advanced discourse, evaluation scores increased by 10%. I gave students trickier problems, more choices, and more feedback on their communication-related assignments.

After the course revamp, teaching evaluation scores increased an average of 10%. The largest increases were for me providing quality feedback (19%), helpful readings (19%), effective teaching (13%), stimulating their interest in the subject matter (13%), and clear course objectives (12%). Student average grades were higher in the fall of 2023 (95.8) than the spring (91.1, $p<0.001$). That held true for assignments I kept the same and those I updated to encourage more critical thinking. The fall assignments were more challenging, but students used the extensive feedback on their drafts to improve their finals.

Qualitative evaluation. The GTAs and I were repeatedly impressed by the quality of student work compared to prior semesters. Class time was a buzz of movement and activity. Student work was introspective, creative, and well-written. Fewer groups blew off assignments, and fewer groups had internal issues. Because I changed the seating three times during the semester, students got to know each other instead of sticking with their largely homogenous friend groups; they complained less about the assigned seats than we anticipated.

Student feedback, both anonymous and not, was mostly positive. Students preferred the pre-reading > in-class activity > in-class work over having to listen to lectures. Students appreciated getting

substantial feedback on their drafts before submitting the final version. They also appreciated the timely response to student feedback.

Adjustment. For spring 2024, the instructional team planned content that builds upon itself and scheduled guest speakers to fit around the course progression instead of the other way around. In fall 2023, only two lectures had pre-readings. In spring 2024, I implemented the pre-reading > in-class activity > in-class work on homework progression for as many topics as possible. Pre-readings include content, context, and controversy to help students think critically. I am adjusting in-class activities to have the appropriate level of complexity and realism, which I've discovered is a trial-and-error process. I look forward to collecting student feedback, both informal and formal, to continually improve P&L.

Case Study 5: Joining the Conversation: Providing Novice Engineering Students the Relevant Research and Communication Tools as they Begin Navigating their Technical Field
Christine Bala Burgoyne, Materials Science and Engineering at Virginia Tech

Educational Environment. The Engineering Communications Program (ECP) is a discipline-based, integrated communications program that provides communications (written, oral, and visual) instruction within the Department of Materials Science and Engineering (MSE) undergraduate curriculum at Virginia Tech. As program director, I manage a team of graduate and undergraduate teaching assistants, partner closely with technical instructors, and work with six core MSE and professional development courses across the sophomore, junior, and senior cohorts.

This case study focuses on ECP's integration with MSE 2044: Foundations of Materials Science and Engineering, a 4-credit introductory course for MSE sophomores. At Virginia Tech, engineering students do not declare their majors and join their departments until the fall of their sophomore year.

Integration Problem. A decontextualized approach to writing instruction proves a long-standing view that writing instruction as a remedial and disconnected task does not yield the desired actualization of learning-to-write/writing-to-learn outcomes within specific contexts (Poe et al., 2010), more so for novice learners who are entering their specific discipline. To fulfill ABET requirements, MSE 2044 instructors initially required students to produce a 10-page research paper on any material they wanted to write about. This end-of-the-semester assignment, which was 10% of their final grade and focused only on "an end product," had no instructions or guiding questions other than reminders that they had to use scholarly sources. We found that most students were unfamiliar with specific research writing protocols in MSE (e.g. databases, documentation style) and because students were just learning the technical foundations of their field, they still had a difficult time understanding the highly technical scholarly sources that they used in their paper. Assessment of these early attempts of integrating communications instruction in an introductory technical course showed the disconnect of writing instruction from the course itself. The results were essays still in draft mode that lacked logical organization and technical explanations. Additionally, many essays regurgitated exact language from journals, resulting in several papers being flagged for plagiarism. Perhaps because of these challenges, students found the paper to be "a waste of their time." At the end of the semester, students still could not use MSE-relevant research databases, implement proper engineering documentation style, and or effectively explain relevant foundational MSE concepts.

Solution. By using the sociocognitive view and situated learning models of learning, in which social interaction and gradual guided instruction is emphasized while students learn within a discipline, we found that novice learners discover meaningful space and time to participate in the knowledge-making process, whether as static receiver of knowledge or an active shaper of new meanings (Lave & Wenger, 1991; Leydens, 2008; Vygotsky, 1978). By encouraging authorial agency and focusing on process, feedback, and audience, it is possible to structure an introductory research writing assignment that allows the students to join the technical conversation, learn relevant research skills specific to their discursive practices, and use their acquired skills to new and unfamiliar contexts.

Content and Sequence. Our revisions to this communications integration in MSE 2044 morphed into an introduction to research work (i.e. literature review) in MSE and aimed to provide sophomores with tools for unpacking MSE jargon and writing in a collaborative context. As their first immersion within the field, students entered the "MSE conversation" in which they were introduced to fundamental MSE concepts and, thus, technical language, that they would be using their entire engineering career. We worked with the MSE instructors by heavily emphasizing process and feedback as the students wrote their collaborative paper, focusing on the structure, processing, properties, performance, and green engineering impacts of a material of their choosing. In this iteration, which was 30% of the final grade, students were required to attend weekly ECP workshops that addressed various aspects of research writing and complete a series of scaffolded communications deliverables leading to their final paper, written for a general, nontechnical audience (Critical Review of A Material for *Scientific American*).

Evaluation and Feedback. Students' deliverables were evaluated throughout the semester by the ECP Team and the technical instructor using the following guides: audience and jargon, organization, style and grammar, integration of sources, document design, and contributions to collaborative writing. At the end of the semester, technical instructors confirmed that not only have the students "entered the MSE conversation" with their newfound confidence to talk the "MSE way," but also have formed a sense of camaraderie and community from their continuous discussions throughout the semester. Students' feedback on the communications component of the class showed different opportunities for actualizing the learning-to-write/writing-to-learn process in their field. They indicated a high appreciation of how they were provided enough time to learn the nuances that accompany the research process in a specific field. Several students in the subsequent MSE courses talked about using their research paper as a means of explaining their preliminary interests in MSE. Students also mentioned how they were able to talk about their material in their internship interviews while still taking MSE 2044 courses. A few students, after a semester, joined a research group and worked on the topic that they wrote for their research paper. Lastly, students reported back on how they were able to use the communication tools to explain technical concepts in nontechnical contexts, such as outreach activities and professional engagements.

Case Study 6: Leveraging Undergraduate Teaching Assistants to Support Communication Skills Integration

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Educational Environment. ISE 3034: Technical Communications for Engineers is a required technical communications course at Virginia Tech that is embedded within two different

departments. Because of this, the population of students is fairly diverse, especially in terms of writing and speaking abilities. This course is housed in the Industrial and Systems Engineering (ISE) Department and taught by the same instructor to ISE and Biological Systems Engineering (BSE) junior-level students. Each course section has 60 to 70 students. ISE's graduating classes average around 200 students, most of whom take the course in the fall semester each year. BSE's graduating classes average around 50, all of whom take the course in the spring semester each year. Students work in groups of 6 to 7 throughout the semester. Undergraduate teaching assistants (UTA) grade coursework and provide in-class support via workshopping.

Problem. This course was implemented in Fall 2020 to better help students prepare for the written and oral communications skills needed for their careers. The goal of all curricula is to help students polish skills around common documents and presentations within engineering as well as to prepare them for their capstone course in their senior year. This course originally used graduate teaching assistants (GTA), most of whom spoke English as their second language; therefore, grading writing and speaking skills was challenging for them. Additionally, most GTAs did not appreciate being assigned to a communications course when pursuing a graduate degree in engineering. The grading support received by GTAs was not effective; the instructor spent more time teaching and re-grading than receiving grading support. Separately, there was a College of Engineering initiative to increase the use of UTAs. Simultaneously, several undergraduate students asked the instructor if they could TA the course. It made sense to be able to hand-pick the best and brightest former students to grade and support students in the course. The desire was to improve the grading and student experience in the course.

Theory and Framework Used to Solve Problem. Lattuca and Stark (2009) define many elements of the instructional process. The UTA implementation was based on some of their ideas. Specifically, UTAs work with the instructor on the **content**. UTAs help to grade all assignments in ISE 3034 with the supervision of the instructor. They use categorized rubrics within the learning management system (LMS) of Canvas to annotate documents and provide feedback. As noted previously, they are hand-chosen by the instructor, so there is an assumption that they have a good understanding of the content based on their performance when they took the course; however, they are also chosen for their interpersonal skills. Additionally, all UTAs help with the **instructional processes**. As noted, ISE 3034 is delivered in a hybrid modality. This specific hybrid design involves half of the course enrollment attending class on one day while the other half meets asynchronously with their assigned groups. The course is organized via weekly modules with resources and deliverables. UTAs are trained at the start of the semester, and they are also provided with a UTA handbook with detailed instructions about each assignment and how many points to deduct for each type of assignment. Additionally, UTAs attend all class meetings to provide feedback. Finally, UTAs work with **instructional resources**. While Canvas (the LMS) is the most common tool to deliver content, other resources, such as Google Drive, One Drive, and email are used for regular communication and curriculum design. UTAs communicate with students via email and Canvas and with the teaching team via email, Canvas, and text messaging.

Reflection. The implementation of UTAs to the course has been an overwhelmingly positive experience; they are an excellent, underutilized resource that could be used for many courses. If the UTAs being considered have taken the course previously and excelled in the content, chances are

high that they will be a good grader and support to students and the overall course. Further, there are a few other benefits:

- If they can be hired early enough in their undergraduate career, they can serve as TAs for multiple semesters/years, which allows them to train new UTAs.
- They can help you improve the Canvas site/grading system with their ideas.
- Many of them have teaching aspirations, and this allows them to have a highly pragmatic experience in higher education.
- It (should) lessen the work load on the instructor.
- Perhaps one of the greatest benefits was that there was a significant cost savings for the department due to hourly wages versus assistantships; therefore, there is great support for this change from the department perspective.

Overall, at present, the UTA implementation is going very well; however, there will continue to be refinement of grading practices, rubrics, and training.

Discussion and Conclusion

Despite widespread recognition that communication skills are critically important for engineers, supporting students in achieving learning outcomes related to communication remains a challenge. With a team of eight faculty across seven distinct engineering departments, we leveraged a collaborative inquiry process, underpinned by the Academic Plan Model (Lattuca and Stark, 2009) to explore the curricular challenges and associated solutions for integrating communication skills into existing engineering curricula. Across educational contexts, cross-cutting themes identified included challenges with how we teach engineering communications (pedagogy), how we navigate as subject matter experts (SME) in communication, and how we elevate the importance of communication skills within our engineering department. To describe solutions for navigating these challenges, we shared six case studies of embedding communication skills across engineering curricula. While the number case studies may be a limitation of our study, they do highlight various approaches to engineering communication as well as lay the foundation for and allow us to build on future research in this area. By sharing these results informed by our iterative reflections on our teaching practices, our collective goal is to support engineering communication educators in drawing connections to their own work.

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