2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #40378

Developing and Scaling Engineering Communication (EC) for New Engineering Education

Dr. Alyson Grace Eggleston, Pennsylvania State University

Alyson Eggleston is an Associate Professor in the Penn State Hershey College of Medicine and Director of Evaluation for the Penn State Clinical and Translational Science Institute. Her research and teaching background focuses on program assessment, STEM technical communication, industry-informed curricula, and educational outcomes for veteran and active duty students.

Dr. Robert J. Rabb P.E., Pennsylvania State University

Robert Rabb is the associate dean for education in the College of Engineering at Penn State. He previously served as a professor and the Mechanical Engineering Department Chair at The Citadel. He previously taught mechanical engineering at the United States Military Academy at West Point. He received his B.S. in Mechanical Engineering from the United Military Academy and his M.S. and PhD in Mechanical Engineering from the University of Texas at Austin. His research and teaching interests are in mechatronics, regenerative power, and multidisciplinary engineering.

Developing and Scaling Engineering Communication (EC) for New Engineering Education

Engineering curricula are being increasingly adapted to foster skillsets in social intelligence, empathy, and professional skills. Revisions to ABET criteria are partly in response to changes in engineering industry culture. Post-graduation, new engineers can expect to function on multidisciplinary teams that may span geographic, cultural, and disciplinary differences. Engineering firms have used remote, international, and hybrid collaborative team structures to be successful during COVID-19, a trend that has gained momentum. Engineering curricula must prepare graduates for this changing workforce dynamic. Aligning the engineering communication curriculum to real-world communication challenges positions engineers-in-training to be adaptive, empathetic, and prepared problem-solvers.

The demand for the engineering mindset to grow and develop as problem-solvers, requires additional skills such as entrepreneurship, leadership, and communications. Engineering entrepreneurship and engineering leadership programs have proliferated in recent years. Despite this, there is less emphasis on communication skills and intercultural competence, which are essential for many additional skills. Approaches to STEM curriculum design in Asia include implementing intercultural awareness and communication competencies, as the relationship between employability and professional skills is well studied, adapted, and implementable.

This paper proposes a process for building an engineering-focused communications course that can be tailored and scaled to program size and needs. Using needs-based assessments and research-based approaches, this paper aims to improve communication and learning outcomes in engineering curricula. This paper also provides case studies for building an engineering communications (EC) class or embedding assignments that are project-based, industry-informed, and produce measurable improvements in student communications competency if implemented early in the curriculum. In this report, we examine several institutional examples involving the integration of EC into existing engineering programs to support ABET and modern General Education learning outcomes, including modular, co-teaching, and entire course implementations. EC assessments can directly support: cultural awareness, audience awareness, and collaborative teamwork and leadership, as specified in ABET criteria 2, 3, and 5, respectively. Effective EC pedagogy and industry partnerships can be an effective and measurable approach to supporting these criteria.

Introduction

International approaches to developing Engineering Communication (EC) skills include careful assays of industry needs, employer expectations, and a continuous cycle of building career-relevant course content [1]. Researchers studying STEM student employability in East Asia highlight written and visual communication modes as key opportunities for curricular development. Not surprisingly, whether internationally or centered in a US context, multi-modal communication is identified by both students and employers as a key opportunity and challenge [2], while engineering faculty's primary concern remains what they perceive to be as a gap in technical skill acquisition [2]. This tension between communicative skill and technical skill development in engineering curricular design is no longer necessary or productive. Remote collaborative work, structurally induced in part by pandemic accommodations has introduced new communication styles, work styles, and projects that arguably better support the engineering- and entrepreneurial-mindset, as reinforced by organizations like STEMNext.org [3] and KEEN's Engineering Unleashed training programs [4].

What is Engineering Communication?

O*NET descriptions of communicative needs for careers in Civil, Electrical, and Mechanical Engineering (occupations 17-2051.00, 17-2071.00, 17-2141.00, respectively) include: active listening, problem-solving and coordination, oral communication and comprehension, problem sensitivity, and communicating with all stakeholders. Discipline-specific vision statements highlight the importance of communication skills for engineers, and EC is positioned to occupy a more central role in engineering curricula because of the role communication plays in professionalization—the process of adopting a professional identity [5-7]. The need for engineering graduates to improve communication skills has been emphasized in multiple disciplines for several decades [8-9]. The American Society of Civil Engineers (ASCE) Vision 2025 suggests that "communications knowledge and skills are embedded in every civil engineer's education and encourage their continued enhancement throughout every civil engineer's career" [10]. The American Society of Mechanical Engineers (ASME) Vision 2030 states that mechanical engineers need enhanced skills, recommending that engineering curricula be designed to produce performance parity between engineering students' demonstrated technical skills and conventional professional skills, such as "effective communication, persuasiveness, diplomacy, and cultural awareness" [11]. Additionally, the report notes that both industry supervisors and early-career engineers emphasize that graduates need stronger professional skills, e.g., interpersonal skills, negotiating, conflict management, innovation, and oral and written communication. The need for effective communication permeates through every engineering discipline. The accrediting board for engineering programs in the US and many schools abroad is ABET, and they define student outcomes as "what students are expected to know and be able to do by the time of graduation." One of the Student Outcomes is (3) "demonstrate an ability to communicate effectively with a range of audiences" [9]. Clearly, discipline-specific vision statements see communication as an essential component in the professionalization of the modern engineer. As educational institutions follow suit, students will need to become fluent in managing personal narrative and mission in online contexts—as their future professional lives may unfold largely online [12].

How is EC changing and what capacities do engineering students need to build?

Early-career engineers will need to be well positioned to affect change, negotiate solutions, and understand stakeholder perspectives remotely, collaboratively, and documented in real-time. Advances in virtual reality suggest that remote, collaborative work will continue to be normalized. As these technological innovations advance, social and behavioral science can contribute to our understanding of best practices for teaching Engineering Communication (EC). Additionally, EC training also presents a growth opportunity for adult engineering learners who may be uncomfortable with technology, creating developmental opportunities that can improve their work and promotion outcomes. Meanwhile, though younger engineering learners may be familiar with VR and video-based communication outside of a classroom context, this group will benefit from using this technology to improve, iterate, and practice professional communication. This approach to professionalization has the follow-on benefit of preventing younger engineers from addressing colleagues in inappropriate ways or too informally. As the future of the employee-technology frontier looms, the same communicative tasks we used to accomplish in-person will need to be effectively executed online or remotely. These include:

(1) Product pitches;
(2) Client problem-resolutions;
(3) Project management, coordination, and brainstorming sessions;
(4) Progress reports and supervisor briefings;
(5) Interviewing and personnel actions, and in increasingly diverse settings;
(6) Data visualizations and infographic presentations;
(7) Bug reporting, error simulations;
(8) Site inspections

EC necessarily situates itself in the online domain and the mobile, agile work context in which many Civil, Electrical, and Mechanical Engineers (O*NET occupations 17-2051.00, 17-2071.00, 17-2141.00, respectively) increasingly operate [13].

Approaches to Teaching EC

The engineering undergraduate curriculum is largely linear, developmental, and full. Consequently, engineering students and their advisors have little choice, particularly through sophomore year, about course sequencing. Due to increasing technical skill sets, there is little room in the curriculum for EC-focused courses. Most bachelor-degree granting institutions teach EC as a module embedded in existing courses or are outsourced to ambivalent English departments, where the courses are often taught by graduate assistants, adjuncts, or professors with little to no STEM or industry experience [14-15]. A survey of US and Canadian institutions twenty years ago found that about half of US engineering institutions required a stand-alone EC course [15]. A similar study of US engineering-degree granting institutions in 2021 found that for both teaching-focused and R1 institutions, 55-60% of engineering curricula had no stand-alone EC course, and approximately 27-28% did stipulate a stand-alone EC course. A minority of institutions (10% across institution types) opted to embed EC content in existing courses. Embedding EC content is a ‘quick fix’ under tight operating conditions, allowing for some learning exposure to EC content for the students, but it may not be ideal as it does not provide sufficient time-on-task [14].

EC pedagogy has historically drawn on Assertion-evidence (AE) approaches to communication, which are designed to be succinct and persuasive [16]. Drawing upon multimedia studies of learning and engagement, an AE approach requires that the speaker lead with a claim or assertion, immediately followed by visual evidence and keywords or concepts. For example, because the processing and memory integration in the brain prioritize visual over aural signal inputs, it is unhelpful for addressees for a speaker to say and display the same text on a screen [17] especially if the inputs are temporally incongruent [18]. Successful EC hinges on meeting an addressee’s communicative, social, and organizational needs [19]. Communication signals are both linguistic and visual and include features like organized, direct speech, positive affect, and comportment [20-21]. Social metrics for effective visual communication, like presentations, determine if group dynamics are viewed positively, e.g., displaying excellent coordination of work effort or being receptive to a supervisor’s guidance [22-23]. Organizational metrics, if met, signal respect for an addressee's time and awareness of the constraints and expectations of the selected mode of communication.

For these reasons EC practice and performance should be developed at multiple stages in the engineering curriculum, culminating in increased professional knowledge and awareness. Figure 1 illustrates the relationships and mapping between the aspirational professional skills of engineers and the associated communication modes and professional skills.

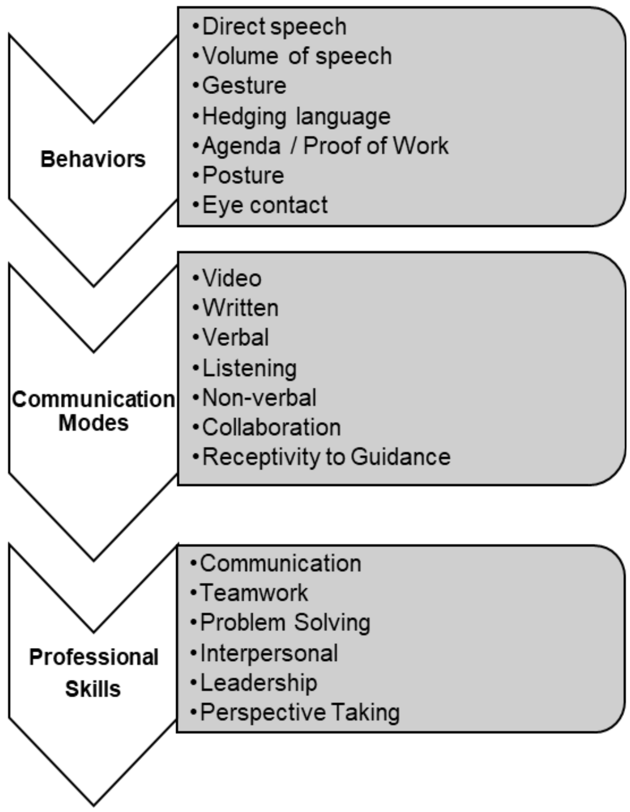

Figure 1: Communication Behavior Mapping to Professional Engineer Skills

Current EC Pedagogy in Practice

Engineering professionals and faculty agree and support EC-focused initiatives to strengthen communicative capacity in engineering students, as evidenced by KEEN's entrepreneurial mindset (EM) faculty development seminars [4] and NSF's investment in REU programs, such as Purdue's EM program [24]. However, fewer than 30% of sampled bachelor-degree granting engineering programs provide a stand-alone engineering-, STEM-, or technical-focused communications course [14]. Another 10% embed EC training and projects within other courses. The remaining engineering programs outsource EC to humanities departments, where faculty members are often lukewarm to teaching Technical Communications (TC) and lack the STEM-focused background to meet the students' subject matter interests [14]. These findings were corroborated in an earlier survey of engineering programs, completed almost 20 years ago, with similar findings: less than 10% of surveyed schools had a stand-alone EC course.

This trajectory is set to change rapidly with the rise of interdisciplinary, remote engineering teams, increasingly visually-focused publication modes [25], and ChatGPT [26] and other AI-powered writing tools. It is beyond the scope of this paper to detail communication-supporting approaches to integrating AI- and non-AI-powered tools in the EC course context [27]; however, selected emerging apps show clear promise for students for visual and presentation contexts (Tome.ai, Orai) [28-29] and written contexts (WordTune, ChatGPT) [30].

The New EC Curriculum

Ideally introduced in the second year of engineering curricula, an EC course is able to scaffold and develop authentic communicative capacity grounded in students' interests and emerging subject matter expertise. Studies show that today's students want coursework that increasingly aligns with their future professional experiences. What does that look like? Students want hands-on projects that are solution-focused and skill-building, requiring stakeholders beyond just the professor as a source of knowledge. Increasingly, students are questioning inference-based modes of instruction that are abstract or connected to obscure rhetorical concepts that students have very little knowledge base with which to assimilate. Traditional approaches to teaching communication—for example, a lesson in Greek rhetorical approaches to persuasion—will not be received as immediately applicable to EC presentations that convey major points through assertion-evidence logic. An applied approach to teaching EC must include exposure to communication apps and tools beyond Word and Google Slides. Below, Table 1 provides an example project organization broken out by tool exposure and stakeholder accountability. Table 2 shows how projects and assessments are mapped to ABET learning outcomes. Without over-specifying content, these two tables can provide a guide to developing an EC course for a variety of majors and programs.

Curriculum Components

Table 1: Curricular Components

Project	**Tools**	**Skills**	**Stakeholders and Partnerships**
Professional Portfolio	Templates (Cover Letter, Resume, Memo, Email, Progress Report)	Entrepreneurial Mindset (KEEN Framework) Stakeholder Communication	Industry
Team-based Project Documentation; Repair or Design Guide	Overleaf iFixit HTML Photography Video Templates (Proposal, Meeting Agenda, Progress	Entrepreneurial Mindset UX Design Teamwork & Problem-solving Collaboration Leadership Project Management Problem-solving	Industry, Community Client

	Report, Repair and Design Guides)	Oral Communication and Comprehension Problem Sensitivity Stakeholder Communication Interpersonal Skills Negotiating Conflict Management Innovation, Written, Verbal, and Visual Communication	
Technical Report	Overleaf Expresso WordTune Grammarly ChatGPT Canva	Pain Point Recognition Problem-solving and Coordination Problem Sensitivity Stakeholder Communication Written and Visual Communication Infographics	Individual, Lab Instructor, Fellow SMEs
Technical Presentation	Tome Google Web Conferencing Virtual Meeting Platforms	Audience Awareness Active Listening Project Management Oral Communication and Comprehension Stakeholder Communication Persuasiveness Diplomacy	STEM Departments, Fellow SMEs, Industry Mentors

Table 2: ABET Mapping of Student Outcomes to Major Assessments

ABET Student Outcome	Assessment
(3) an ability to communicate effectively with a range of audiences	Project 1: Professional Communication Portfolio Project 2: Industry partner or "Instructables / iFixit" Technical Writing and Repair Guide Project 3: Research Report Project 4: Presentation
(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	Project 2: "Instructables / iFixit" Technical Writing and Repair Guide Project 3: Research Report

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	Project 2: “Instructables / iFixit” Technical Writing and Repair Guide Project 4: Presentation

As summarized in previous studies in 2004, 2021, EC has historically been accomplished in engineering curricula in ways that accommodated historical curricular priorities, faculty interest and expertise, and the constraints of credit-hour loads and time-to-degree completion rates. Crucially, both foregoing studies were developed from pre-COVID-19 institutional data, suggesting that now is the time to restructure our approach to teaching EC, as ‘mindset’ developing initiatives gain momentum [3-4] and students themselves express a desire for course content that more closely matches the concepts [31], technology and experiences [32] they are likely to encounter early in their career.

Where the Field is Going

Evolving technology creates uncertainty for the future and uncertainty of the relevance of past technologies. We may have emerging technical fields that have still-developing vocabulary such as Artificial Intelligence and Machine Learning (AI/ML). According to a 2018 report from the Institute for The Future, 85% of the jobs that will exist in 2030 have not been invented yet [33]. The ability to gain, apply, and communicate new knowledge may be even more valuable than the new knowledge itself. This requires continuous learning with certainty in diversity and opportunities to employ technical communication skills.

EC is concise, inclusive, industry-specific, and increasingly visual
Engineering Communication is necessary to enable technology adaptation through documentation, visuals, and verbal interaction. This field produces content necessary for business and engineering success. A redesigned EC course that is sensitive to the recent technological pivot toward remote work, VR, and AI-assisted tasking should accomplish an expanded set of tasks, while providing students with novel tool exposure [34-36]:

1. Focus on audience’s values and preferences

EC can add value to the organization by providing support through structured and high-quality documentation. Think of the end – did the audience learn or take away what was expected? An engineer’s solution or innovation has reduced impact if others do not understand its purpose and cannot execute on its basis. Organization leaders and decision-makers expect professional communications. Spelling mistakes, unclear speech, and unfamiliar terms may make an executive doubt an engineering design team’s reliability and accuracy. With so many tools available, careful curation and selection of appropriate apps is recommended. Expectations are getting higher – clients and supervisors expect increasingly polished content that concisely conveys key data, takeaways, and actionable information. Communication mediums (verbal, written, visual, infographics, and data visualizations) should be created based on audience analysis. Attunement to audience needs and priorities will help in developing rapport and necessary communication skills.

2. Be inclusive

As multidisciplinary engineering teams collaborate remotely – and more frequently – it is useful to acclimate students to working with teams equipped with diverse strength, expertise, racial, and gender profiles. Team science is a burgeoning field of research and has demonstrated that more diverse organizations (gender, age, ethnicity) – are associated with better performance, outcomes, profits, increased innovation through more accurate risk assessment that arises from varied experiences [37]. Much of this research also underscores diversity, equity, inclusion, and belonging initiatives – an important learning outcome for ABET program assessment and a value affirmed by many institutions.

3. Infographics and visual aids

EC is vital for presenting designs, concepts, and ideas using graphics and visual aids for a better audience experience. Audience requirements are also evolving, with enhanced expectations for inclusion and diversity, e.g., picture-capturing for the visually-impaired and meeting transcripts for the hearing impaired. EC skills require a vast array of tools and skills to employ the accommodations and troubleshooting associated with creating documents that are enriched with graphics and visual aids and are also in compliance with UX Design best practices [35].

4. Field-specific Terminology

As fields evolve and blend, staying current with field-specific terms is mandatory. For example, automotive engineering has seen a proliferation of new terms thanks to disruptive technologies like alternative fuel, hybrid and electric vehicles, and autonomous drive. We should also expect engineering fields to continue to blend and become more multidisciplinary.

5. EC and organizational styles

Organizations undergo changes in report and writing formats periodically to work with different customers, comply with industry standards, or to work across disciplines. EC writers should be aware of changes and implement them to ensure future project success. Engineers can learn to effectively write documents (proposals, progress reports) and improve presentation skills (public speaking, visual aids) to deliver information to technical and non-technical audiences [36].

6. Dashboards

One visual aid that has become increasingly common is a dashboard. Dashboards are visual displays to monitor conditions or quickly assist with user understanding. Dashboards may contain data to convey a story to a specific audience, leveraging human's cognitive preference for visual information. Some dashboards have broad audiences, but most are tailored to specific people or roles. These roles have different needs and uses for the data. Dashboards enable engineers to share their findings, plans, and projects with peers who understand specific data and technical language as well as with executives in business meetings, who are interested in broad longitudinal trends over time. EC must take the visual dashboard and technical material and focus the audience on the relevant information. Summarizing and translating technical concepts into simple language in an engaging, confident manner can vary for each target audience. Traditional dashboards feature static displays of icons that hold data in arrangements like graphs and charts. Dashboards that are more sophisticated include interactive functionality to allow real-time monitoring. Dashboards typically track key performance indicators (KPIs) and choosing the right dashboard design and the essential metrics help the organization align behaviors, strategies, and measure success. In the example engineering project management dashboard in Figure 2, audience awareness dictates how information is organized. Immediate information on job completion, job accountability, and project schedule is given in the first cluster of data visualizations. The second layer conveys longitudinal data on run-times, project costs, and user behavior. The third layer summarizes productivity metrics, including number of jobs completed, and percentage of successful product testing.

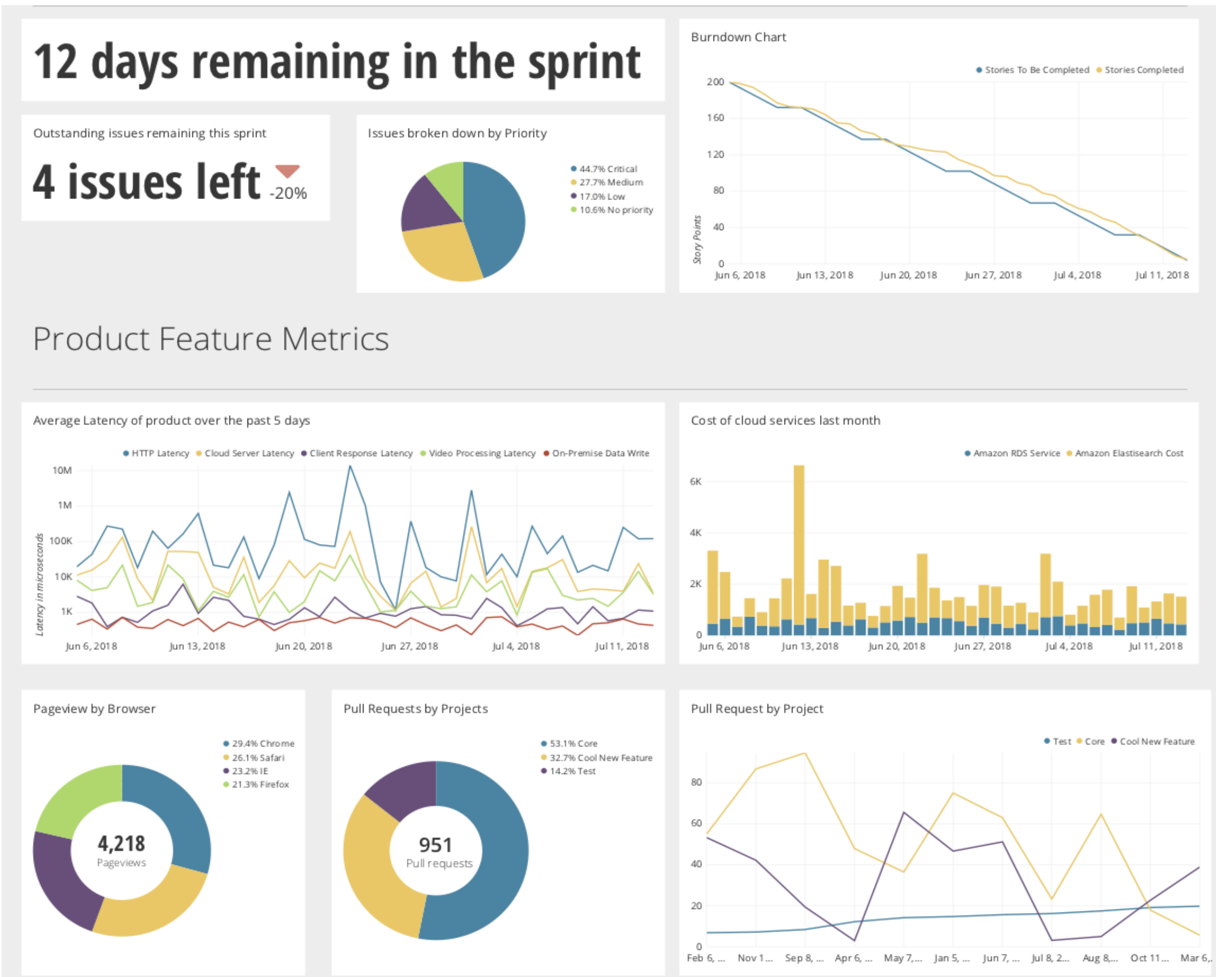

Figure 2: Basic Engineering Data Visualization for Multiple Audiences [38]

Figure 3 is a student enrollment dashboard. Note the pull-down menu in the upper left where one can select an academic term or particular campus to isolate areas of interest and monitor outlier events (e.g. Covid enrollments). Other links at the top of this dashboard (removed for blind review of the academic institution) allow the user or analyst to gather information on demographics and level of degree. Even though Figure 3 may not be indicative of specific engineering work, these dashboard examples require a level of interpretation and audience awareness to convey pertinent information, either in writing or in presentation.

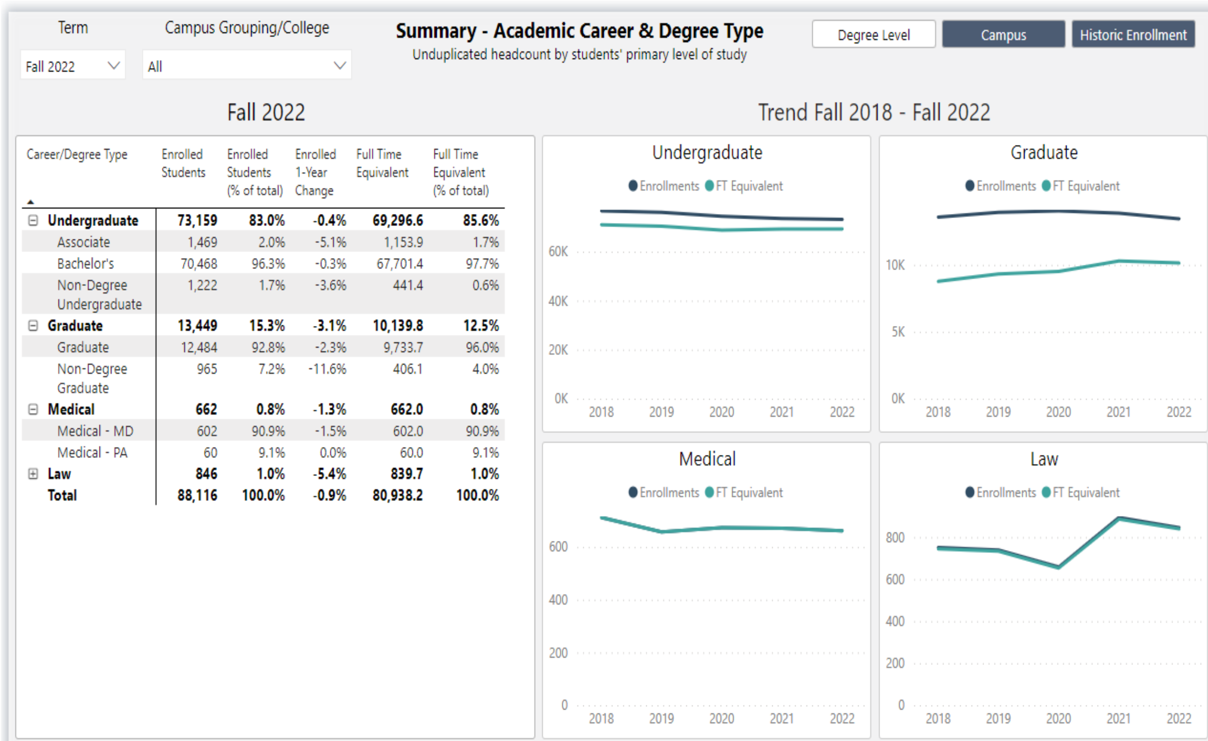

Figure 3: Student Enrollment Dashboard

Discussion

Engineers drive innovation, improve processes, and solve problems. A well-rounded engineer not only has a deep understanding of engineering and project management but can also collaborate well with other engineers and non-engineers alike. The engineer with well-developed communication skills can add more value to the organization by conveying the technology and innovations to a broader audience. These are not just aspirations, but necessities specified in discipline-specific documents and practiced in industry today. The work of tomorrow is characterized by diversity: disciplinary, linguistic, cultural, and audience-rich diversity.

The higher education landscape in engineering education is internationalizing in other important ways. Engineering programs are expanding and developing new sub-disciplines as AI/ML technology matures and operationalizes old tasks in new ways. Additionally, US-based graduate engineering programs are increasingly composed of international students, for whom industry-relevant course content is likely already the norm. We need near-term solutions to expand these course offerings with content-rich, industry-relevant content.

Operating Challenges

At the time of this writing, the authors estimate that 55-60% of engineering programs offer stand-alone EC courses. The majority of those courses are taught in humanities departments, where they may not be highly valued in terms of content rigor and their applied communications focus. Incidentally, this disciplinary devaluing of applied scholarship in the humanities is very well documented [39-40] and more recently has resulted in ‘divorce workshops,’ wherein EC program directors housed in humanities departments learn about tools and resources needed to standup an EC program and be free or at least distanced from some of the documented programmatic interference encountered in some humanities departments [40].

Going forward, academic engineering leadership may pivot toward a modernized EC that employs project components similar to those detailed in Table 1. Whether engineering leadership ultimately employs stand-alone or embedded modular EC courses, all will encounter structural challenges: cloning and scaling. Below are more details on the Cloning or Scaling options to build EC courses. However, program and student outcomes are paramount to instructor preference and convenience.

Clone

First, a modern redesigned EC course or modular must be cloneable, i.e., departments and programs must be able to resource-share materials and lesson plans that support a finite list of projects. Once these EC projects are developed and led, often by STEM-passionate communications faculty in conjunction with engineers, engineering departments can provide ‘train the trainer’-style events to create replicable and assessable courses or course materials across departments and even affiliated institutions. To effectively clone EC project materials that contain the features described in Table 1, ask the following questions:

(1) Who among the faculty already teaches this material as part of a traditional engineering course?
(2) Are there any adjunct faculty with deep industry experience?
(3) Which faculty have already created resource-sharing networks and storage space for project-based learning?

Essentially, asking these questions will help the engineering leadership to identify likely allies, resource management infrastructure, and faculty who would be interested in teaching and collaborating in the modern EC effort. Finding allies also allows engineering leadership to move through the next phase of course development, where execution, ABET and institutional assessment, and evaluation are necessary restraint conditions that will guide how the course is delivered.

Cloning Case Study

An EC Course, developed over several years by an experienced instructor at a teaching-focused institution, was adopted by several STEM departments, resulting in a sharp increase in section demand. Additional instructors were hired and provided the cloned course, complete with supplemental materials, lectures, rubrics, assessments, Canvas site, and example projects. An advantage of this cloning effort was that a centralized course offering was made to be accessible by a variety of STEM majors.

However, challenges to the cloning approach emerged. As additional instructors were hired to meet section demand, instructors preferred to teach the course with more autonomy, resulting in increased group work, hybrid class structures, and fewer assignments. While none of these outcomes are inherently bad, a new Computer Science department seeking ABET accreditation found it difficult to extract individual student work exemplars that matched ABET learning outcome criteria due to the increase in group work instituted by some of the instructors. Additionally, by the second semester, students were aware that different sections demanded varying time-on-task and practice commitments, resulting in instructor preferences when building their semester schedule. Fundamentally, the cloning approach provides great centralization of effort and materials if reinforced with regular lesson conferences; however, instructors may seek more autonomy over time at the cost of shared (group) learning outcomes and assessment. Continuous course improvement is difficult without shared assessments—and this may negatively impact student learning of EC.

Scale

At campuses with strong community college pipelines, cross-institutional affiliations, or even hybrid campus offerings, the modern EC course can be scaled to offer to a larger engineering student cohort. At the scaling stage, the modern EC course curriculum developers should consider the following features:

(1) Structure the EC course within the curriculum such that it aligns with a corequisite that will reinforce the applied focus of the EC course.
(2) Structure learning outcomes, activities, and assessments such that they provide insight for selected ABET and programmatic learning goals.
(3) Allow for increased specialization and disciplinarity with regard to projects. For example, develop communication projects relevant to a specific engineering sub-discipline and offer the course when those majors can schedule it.
(4) Break larger classes into smaller cohorts to allow for increased scaling of impact. Use fewer projects and assign teaching assistants where appropriate.

With curricular innovation comes change, and sometimes that change meets resistance. Larger institutions may have departmental-level stakeholders (English, Rhetoric, Communications) that have individuals who may want to support the professional skill development of engineers. However, these departments and individuals are often already teaching maximum course loads and cannot react quickly enough to meet the volume of engineers and other STEM disciplines that desire specific technical communication courses. Some cloning and scaling within engineering units will help close the gap between what is already supported and what will be needed. Ultimately, we all want better students who meet the student outcomes and are better prepared to meet expectations after graduation.

Scaling Case Study

An experienced instructor developed and refined course materials at a large institution resulting in a successful course with high enrollments. Adopting a 'train-the-trainer' model, the instructor recruited high performing engineering students in the class to serve as classroom experts, so-called 'learning assistants' in future iterations of the course. Learning assistants in a high-enrollment course are regarded by students as being low-threat and can provide guidance during small group work, while providing cursory feedback.

The advantage of this course model is that enrollments can increase without the need to hire more instructors. Challenges emerge with the need to constantly recruit and rotate high performing past students to serve in the learning assistant role, especially as upper level engineering students' schedules become busier.

Conclusion

The medical field has relied on mobile facilities, requiring healthcare workers to interact with a range of patients in different communities. Telehealth has allowed healthcare workers to practice worldwide, improving and saving lives. As engineers' work will evolve with innovation, the engineering skillset will increasingly rely on remote communication skills to leverage the application of the innovations to broader audiences, regionally and globally. The demand for engineering graduates will continue to grow, and the vision for many of the engineering disciplines is for graduates to have enhanced communication skills [41]. EC courses exist in about half of the major engineering curricula and there is some anecdotal support to grow more. As the demand for more engineers and more EC courses grows, cloning and scaling well-prepared and relevant EC courses are ways to meet the impending demand.

This paper provides guidance for EC teaching priorities, learning activities, and industry-informed projects. Whether an engineering program opts to build a stand-alone course or embed engineering-focused communication content and skills in an existing course, instructors and program directors are well positioned to shift EC pedagogy, practice, and assessment toward content that matches future work styles, career trajectories, and agile work teams.

References

[1] V. A. Kulkarni, A. K. Bewoor, P. Malathi, and B. S. Balapgol, "Employability skill matrix for engineering graduates of tier-II institutes*," Journal of Engineering Education Transformations*, 30(3), 71-76, 2017.

[2] A. Eggleston, A., R. Rabb, and R. Welch, "Employer and Student Mismatch in Early-Career Skill Development, Paper presented at *2022 ASEE Annual Conference & Exposition*, Minneapolis, MN., 2022. [Online]. Available: https://peer.asee.org/40895.

[3] STEMNext. [Accessed Feb. 26, 2023]. [Online]. Available: https://stemnext.org/wp-content/uploads/2020/04/Engineering-mindset-brief_Final.pdf

[4] KEEN. [accessed 26 February 2023]. [Online]. Available: https://engineeringunleashed.com/mindset.

[5] N. K. Schlossberg, "A Model for Analyzing Human Adaptation to Transition. *Counseling Psychologist*, 9(2), 1981, pp. 2-18.

[6] N. K. Schlossberg, *Counseling adults in transition*. New York, NY: Springer Publishing, 1984.

[7] A. E. Guskin, "Learning More, Spending Less." *About Campus*, 2(3), 1997, pp. 4-9.

[8] F. Munir, "More than Technical Experts: Engineering professionals' perspectives on the role of soft skills in their practice," *Industry and Higher Education*, *36*(3), 2022, pp. 294-305.

[9] ABET. [Accessed May 1, 2020]. [Online]. Available: http://www.abet.org.

[10] American Society of Civil Engineers, "The Vision for Civil Engineering in 2025." [Accessed May 1, 2020]. [Online]. Available: https://www.asce.org/vision2025/.

[11] American Society of Mechanical Engineers, "ASME Vision 2030: Creating the Future of Mechanical Engineering Education," Executive Summary, ASME Board on Education, September 2012. [Accessed April 29, 2020]. [Online]. Available: https://www.asme.org/asme-programs/students-and-faculty/engineering-education/strategy-vision-2030.

[12] Z. Friedman, "Work from home for rest of year? Some tech companies say "yes,"" *Forbes*. [Accessed May 8, 2020]. [Online]. Available: https://www.forbes.com/sites/zackfriedman/2020/05/08/google-facebookamazon-work-home/#3b93f6abeaea.

[13] O*NET OnLine. [Accessed February 28, 2023]. [Online]. Available: https://www.onetonline.org/.

[14] A. Eggleston and R. Rabb, "Survey and best Practice Identification for Course Development and Integration of Technical Communications for Engineers," *The Technology Interface International Journal*, 22(1), 2021, pp. 37-43.

[15] L. Reave, "Technical Communication Instruction in Engineering Schools: A Survey of Top-Ranked U.S. and Canadian Programs, *Journal of Business and Technical Communication* 18, 2004, pp. 452-490. DOI: 10.1177/1050651904267068.

[16] M. Alley, *The Craft of Scientific Presentations*, 2nd ed, Spring-Verlag, New York, 2013.

[17] J. Sweller, P. Chandler, P. Tierney, and M. Cooper, "Cognitive Load and Selective Attention as Factors in the Structuring of Technical Material," *Journal of Experimental Psychology: General*, 119, 1990, pp. 176–192.

[18] M. J. Crosse, J. S. Butler, and E. C. Lalor, "Congruent Visual Speech Enhances Cortical Entrainment to Continuous Auditory Speech in Noise-free Conditions," *Journal of Neuroscience*, *35*(42), 2015, 14195-14204.

[19] L. S. Bohannon, A. M. Herbert, J. B. Pelz, and E. M. Rantanen, "Eye Contact and Video-mediated Communication: A review," *Displays*, *34*(2), 2013, pp. 177–185

[20] Y. Onishi, K. Tanaka, and H. Nakanishi, "Embodiment of Video-mediated Communication Enhances Social Telepresence," In *Proceedings of the Fourth International Conference on Human Agent Interaction*, 2016, pp. 171-178.

[21] A. F. Monk and C. Gale, "A Look is Worth a Thousand Words: Full gaze awareness in video-mediated conversation," *Discourse Processes*, 33(3), 2002, 257-278.

[22] M. Groen, M. Ursu, S. Michalakopoulos, M. Falelakis, and E. Gasparis, "Improving Video-mediated Communication with Orchestration," *Computers in Human Behavior*, *28*(5), 2012, 1575–1579.

[23] R. B. Kvavik, "Convenience, Communications, and Control: How students use technology," *Educating the Next Generation*, Eds. Oblinger, D. and Oblinger, J. Educause Center for Applied Research, 2005. https://www.educause.edu/research-and-publications/books/educating-net-generation/convenience-communications-and-control-how-students-use-technology

[24] L. Bosman and J. Ostanek, NSF RE: "Growing Entrepreneurially-Minded Undergraduate Researchers with New Product Development in Applied Energy," Purdue University. National Science Foundation Award #2050451, 2021. [accessed Feb. 28 2023]. [Online]. Available: https://sites.google.com/view/purdue-university-reu-site/home.

[25] C. Nikolian, C. Vahagn, and A. Ibrahim, "What Does the Future Hold for Scientific Journals? Visual abstracts and other tools for communicating research," *Clinics in Colon and Rectal Surgery* 30(4), 2017, pp. 252-258.

[26] ChatGPT OpenAI. https://chat.openai.com/auth/login. [accessed 28 February 2023].

[27] H. H. Thorp, "ChatGPT is Fun, But Not an Author," *Science*, *379*(6630), 2023, pp. 313-313.

[28] Tome. https://beta.tome.app/. [accessed 28 February 2023].

[29] Orai. https://orai.com/. [accessed 28 February 2023].

[30] Wortune. https://www.wordtune.com/. [accessed 28 February 2023].

[31] E. Leyva, C Walkington, H. Perera and M Bernacki, "Making Mathematics Relevant: An examination of student interest in mathematics, interest in STEM careers, and perceived relevance," *International Journal of Research in Undergraduate Mathematics Education*, 2022, pp. 1-30.

[32] P. Pantzos, L. Gumaelius, J. Buckley, and A Pears, "Engineering Students' Perceptions of the Role of Work Industry-related Activities on Their Motivation for Studying and Learning in Higher Education," *European Journal of Engineering Education*, 2022, pp. 1-19.

[33] L. Salemi. "85% of Jobs that will exist in 2030 haven't been invented yet." Linkedin. [Accessed Feb. 26 2023]. [Online]. Available: https://www.linkedin.com/pulse/85-jobs-exist-2030-havent-been-invented-yet-leo-salemi/.

[34] Ohio University, "Engineering Communication Guide: Skills, Tips, and Tools [Accessed Feb. 26 2023]. [Online]. Available: https://onlinemasters.ohio.edu/blog/engineering-communication/.

[35] G. N. Vilaza, P. Bækgaard, "Teaching User Experience Design Ethics to Engineering Students: Lessons Learned," *Frontiers Comput. Sci.*, *4*, 2022, pp. 1-8.

[36] A. Siddartha, "The future of Technical Writing: 7 ways to consider to work in the industry." LinkedIn. [Accessed Feb. 26 2023]. [Online]. Available: https://www.linkedin.com/pulse/future-technical-writing-7-ways-consider-work-amit-siddhartha/.

[37] L. E. Gomez and P. Bernet, "Diversity improves performance and outcomes," *Journal of the National Medical Association*, 111(4), 2019, pp. 383-392.

[38] ChartIO. [Accessed Feb. 26 2023]. [Online]. Available: https://chartio.com/learn/product-analytics/software-engineering-dashboard/.

[39] E. Tebeaux, "Whatever happened to technical writing?," *Journal of Technical Writing and Communication*, 47(1), 2016, pp. 3-21. https://doi.org/10.1177/0047281616641933.

[40] CPTSC: Ilyasova, K. A, "Leaving English: Factors to Consider in Separating and Building a Stand-Alone TC Program," In *Proceedings for 2019 CPTSC Annual Conference*.

[41] National Academy of Engineering (NAE). *Educating the Engineer of 2020: Adapting engineering education to the new century*, Washington, DC: National Academies Press, 2005.