The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #41327

Implementation of a Standalone, Industry-centered Technical Communications Course in a Mechanical Engineering Undergraduate Program

Prof. Jenni Buckley, University of Delaware

Dr. Buckley is a Professor of Mechanical Engineering at University of Delaware. She received her BS in Mechanical Engineering from University of Delaware and her MS and PhD in Mechanical Engineering from University of California, Berkeley. At University of Delaware, she teaches a range of courses across the curriculum. She is also the Co-Founder and Board President of The Perry Initiative.

Dr. Amy Trauth, American Instiutes for Research (AIR)

Amy Trauth, Ph.D., is a Researcher at the American Institutes for Research (AIR) and Affiliate Faculty in the Department of Mechanical Engineering at the University of Delaware. Her research focuses on inservice and preservice teacher education and inclusive, accessible learning environments for students in P-16 STEM education.

Dr. David L Burris, University of Delaware
Dr. Alexander John De Rosa, University of Delaware

Alexander De Rosa is an Associate Professor in Mechanical Engineering at The University of Delaware. He gained his Ph.D. in Mechanical Engineering from The Pennsylvania State University in 2015, where he worked on experimental combustion research applied to gas turbine engines, and his M.Eng. in Mechanical Engineering from Imperial College London in 2010. Alex's research focuses on the transfer of learning between various courses and contexts and the professional formation of engineers.

Implementation of a stand-alone, industry-centered technical communications course in a mechanical engineering undergraduate program

Jenni M. Buckley PhD[1,2], Amy Trauth PhD[1,3], Alex De Rosa PhD[1], David Burris PhD[1]
[1]University of Delaware, College of Engineering
[2]University of Delaware, College of Education and Human Development
[3]American Institutes for Research

Introduction

The ability to communicate technical information in written, graphical, and verbal forms is an essential durable skill for undergraduate engineering students to develop and then carry forward into the workplace [1-3]. As practicing engineers, they will be expected to be concise and well organized in their communications and be able to tailor their message to multiple audiences [1, 4]. Beginning in 2000, ABET implemented several student outcomes that align directly with technical communications instruction [5], including "an ability to communicate effectively with a range of audiences" and "an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions." Undergraduate programs have responded to these requirements by providing additional technical communications instruction, either as stand-alone courses or embedded in existing lab or design classes [6]. Despite over two decades of effort to provide better training, feedback from employers indicates that recent graduates still do not meet expectations for communication in industry [6-8]. Literature suggests that the gap between employer expectations and novice engineers' skills may be attributed in part to a misalignment between the communication norms commonly taught in undergraduate courses and those in engineering practice [6].

Engineering programs typically follow one of two models for technical communications instruction, namely, offering a General Skills (GS) course or leveraging Writing Intensive (WI) courses. A General Skills (GS) course [6, 9] is a stand-alone, early-years communications class that may be taught by a communications specialist outside of the discipline. While GS courses provide focused instructional time for communications skills, students view this experience as being "soft" and separate from their engineering training [6, 8]. There has been more focus recently on offering GS courses "in the discipline" with instruction by engineering faculty or industry partners. Writing Intensive (WI) courses teach communications skills by integrating in-depth writing and presentation assignments into disciplinary courses, typically upperclassmen labs or design courses [10-14]. While WI courses provide within-discipline writing experiences, they may focus too narrowly on hypothesis-driven research (lab) reports, which constitute less than 10% of communications tasks in engineering practice [1, 6]. There are pedagogical challenges with the WI model as well, including appropriately balancing new technical content with communications skills [11] and providing students with timely and meaningful feedback on their assignments [15].

For both technical communications course models, there are several pedagogical strategies that are well established in the engineering education literature. First, prior work has shown that student self-confidence and/or performance for technical communications tasks is enhanced by: (a) use of templates and exemplars for different technical writing formats [16-18]; (b) use of detailed grading rubrics that are shared with students before writing assignment submission [19]; and (c) timely and meaningful feedback, either from instructors [6, 15] or through peer review [20, 21]. Secondly, most undergraduate programs currently follow some version of writing across the curriculum (WAC) [6, 9, 22-24] where communications skills developed in early-years courses are reinforced through later lab, design, and capstone classes. Ideally, instructional elements like templates, exemplars, and rubrics are kept consistent throughout WAC courses. Lastly, there is strong evidence to suggest that situated learning activities – that is, instruction and assignments that relate to real-world situations in the discipline – improve learning outcomes and skill transfer in technical communications courses [6, 25]. Industry-aligned capstone design projects are often cited as examples of authentic, situated technical communication [6]. Although this is true, capstone design is one of the last courses in the undergraduate program, which leaves little room for growth and refinement prior to graduation. There is clearly a need to embed industry-aligned, situated communications experiences earlier in the program of study.

In this paper, we build on prior work in engineering education by introducing a within-discipline, large-enrollment GS technical communications course, called *Technical Communications*, for first-year mechanical engineering students. *Technical Communications* features situated experiences in which students take on the role of product design engineer at a commercial company. Students engage in a range of industry-relevant assignments, including composing emails to colleagues and superiors, interpreting data sets from sales associates and vendors, and composing memos and technical briefs. In addition to writing composition, the course emphasizes graphical representation of data, experimental design and statistics, and presentation skills. Following recommended pedagogical practices in the field, *Technical Communications* is the foundational course in our program's WAC thread; and it features templates, exemplars, and rubrics designed to be carried forward into future courses.

The primary purpose of this study was to conduct a preliminary evaluation of the course by measuring pre- to post-course changes in self-confidence for specific communications tasks. In addition, we present the curriculum for *Technical Communications* as open-source content, with the intention that others will adopt and modify elements of this novel GS course. The results of this study may be of interest to other programs seeking to create an early-years technical communications course that features situated industry experiences and engages students in communication strategies used in the workplace.

Methods

Curricular Design

Technical Communications was designed as a standalone course for first-year mechanical engineering students, to be taken prior to any laboratory courses within the major and concurrently with an introductory design course. As a 2-credit course, *Technical Communications* met in-person twice weekly for approximately one hour per session. The course was a single large-enrollment section (ca. 200) taught by one instructor who is a faculty member within the discipline. Class sessions were approximately 70% lecture and 30% small group activity that had a required, online group submission (15% course grade). Students were randomly assigned to groups of three and instructed to sit next to these individuals during class time. All other course assignments were completed individually, and these included: (1) weekly assignments (35% course grade) designed to take approximately 2-3 hours each; and (2) two major summative assignments (two at 25% each) that integrated content from multiple weeks in the course. In order to provide timely feedback to students, all assignments were graded within two weeks by a team of undergraduate teaching assistants. Teaching assistants were high course performers from prior years of the course and were selected through a competitive application process. They received a one-time two-hour instructional coaching session at the start of the semester along with weekly 30-min check-ins to review assignment rubrics and grading instructions. The instructor created detailed grading rubrics and examples for all assignments and was directly involved in grading summative assignments.

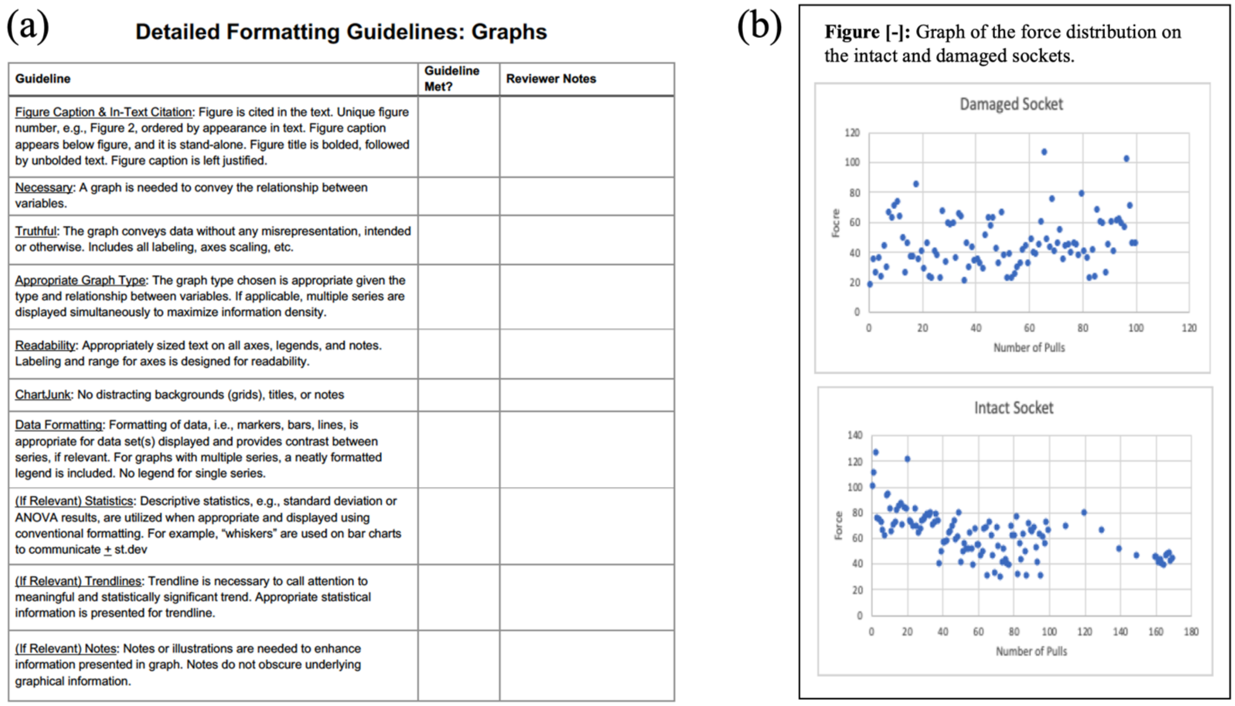
There were six overarching learning objectives for *Technical Communications* (Table 1). These learning objectives balanced writing composition and formatting with specific skills like ability to generate tables, graphs, and in-text equations. There were also substantial data management and statistical analysis components to the course, which were added to better prepare students for future engineering laboratory classes in the program. In the course, students were expected to write or critique four types of technical communications, namely: (1) product-centered design reports, (2) hypothesis-driven research studies, (3) technical presentations, and (4) technical briefs and/or memos. Students also practiced composing emails to technical supervisors with an executive summary and hand-off of written reports. While there was no required course textbook, two texts were recommended as supplementary material, including Jeter et al. [26] for learning objectives A and B and Tufte [27] for objective C (see Table 1).

The overarching course learning objectives were mapped to specific communications skills (Table 1) that were introduced and reinforced with three steps. First, in the weekly workshops, students were introduced to a communications skill, e.g., creating a table, and specific guidelines for content and formatting associated with that skill (Figure 1). Then students critiqued an instructor-provided example of technical communications according to these guidelines, first in class as small group activity and then as part of the weekly individual assignment. These examples largely included de-identified design reports, research studies, presentations, and email correspondence from various courses, including capstone design, upper class laboratories, and technical electives. Excerpts from peer reviewed journal papers, TED talks, and select popular press articles were also used for this purpose.

After critiquing the work of others, students generated original content focused on that particular communications skill as part of their weekly individual assignment. This exercise generally followed a theme in which students were to imagine that they were product engineers at Melissa and Doug®, an international toy company that regularly partners with our program. As an engineer at Melissa and Doug®, they had to synthesize and communicate technical information to their supervisors. Contrived background documents and/or data sets were provided as part of the assignment. Weekly assignments were structured as 30% critique and 70% generating content and were designed to take 2-3 hours per week.

Table 1: Course learning objectives and associated communications skills for *Technical Communications*. The week(s) in which skills were covered are also shown.

Course Learning Objective	Communications Skills	Week(s)
A. Document Organization & Structure Create technical documents that follow professional conventions	• Compare and contrast common norms for technical communication, including audience, style, organization, and elements • Deconstruct technical writing into their core organizational structure, and explain how this structure is adjusted for different audiences • Apply workplace communication norms to emails and other common correspondences. • Recognize and apply the three major goals of all technical presentations • Plan content for a presentation using the storyboard method	1, 7, 14
B. Document Formatting Edit and format technical documents and presentations	• Describe the fundamental grammatical elements of engineering writing • Recognize when references are required to support written claims • Apply relevant style standards for in-text citations and references section in technical writing • Utilize professional reference manager software to create in-text citations and references section • Recognize when appendices are necessary and create them following formatting standards • Incorporate appropriate document organizational elements, like title pages and table of contents, depending on document length and audience • Apply common elements of style to create high quality technical presentations	2, 3, 6, 7, 14
C. Graphical Elements Design and format graphical elements that complement written reports and presentations.	• Justify the use of different graphical elements to support engineering writing • Use standard software (MS Word, MS Excel) to generate professionally formatted tables • Recognize the three principles of graphical excellence, namely, necessity, design, and honesty • Select the most appropriate graph type for a given dataset • Recognize and apply appropriate graphical elements for all graph types • Use standard software (MS Excel) to generate scatterplots, line graphs, bar charts, stacked bar charts, and pie charts that meet formatting guidelines • Recognize technical communication situations where images are needed to support the text • Use standard software to compose images that meet technical communication standards • Recognize communication scenarios in which in-text equations are needed • Use standard software (MS Equation Editor) to create and embed equations in text	3, 4, 5
D. Data Sets Organize and manage data sets and generate appropriate graph types for a given data set.	• Apply formatting guidelines for spreadsheets and data sets • Explore advanced functionality of MS Excel • Recognize the operational and legal necessity behind good data management practices • Create digital archives with logical organizational hierarchies.	5, 13
E. Experimental Design & Statistics Apply basic principles from experimental design and perform statistical analyses on experimental data to determine trends and make comparisons between groups.	• Recognize and understand the purpose of common elements of experimental design including repeated measures, sample size, experimental protocols, and use of controls • Differentiate between accuracy and precision in the context of experimental design • Apply propagation of error to determine principal sources of measurement error in an experiment • Define and apply common descriptive statistical measures, like mean, standard deviation, median, range, and percentile • Use standard software (MS Excel) to calculate descriptive statistical measures • Apply one-way ANOVA to determine differences in numerical outcomes between groups • Use standard software (MS Excel) to run one-way ANOVA	10, 11, 12
F. Career Development Create a professional resume and online presence.	• Create or revise a resume to get started on building your engineering career experiences • Recognize common communication platforms that are used in the workplace, e.g., LinkedIn, and their associated purposes • Set expectations and timeline for seeking engineering-related summer internship or supplemental skills training • Practice inquiring about internship opportunities in research labs and in industry	9,15



(a) **Detailed Formatting Guidelines: Graphs**

Guideline	Guideline Met?	Reviewer Notes
Figure Caption & In-Text Citation: Figure is cited in the text. Unique figure number, e.g., Figure 2, ordered by appearance in text. Figure caption appears below figure, and it is stand-alone. Figure title is bolded, followed by unbolded text. Figure caption is left justified.		
Necessary: A graph is needed to convey the relationship between variables.		
Truthful: The graph conveys data without any misrepresentation, intended or otherwise. Includes all labeling, axes scaling, etc.		
Appropriate Graph Type: The graph type chosen is appropriate given the type and relationship between variables. If applicable, multiple series are displayed simultaneously to maximize information density.		
Readability: Appropriately sized text on all axes, legends, and notes. Labeling and range for axes is designed for readability.		
ChartJunk: No distracting backgrounds (grids), titles, or notes		
Data Formatting: Formatting of data, i.e., markers, bars, lines, is appropriate for data set(s) displayed and provides contrast between series, if relevant. For graphs with multiple series, a neatly formatted legend is included. No legend for single series.		
(If Relevant) Statistics: Descriptive statistics, e.g., standard deviation or ANOVA results, are utilized when appropriate and displayed using conventional formatting. For example, "whiskers" are used on bar charts to communicate ± st.dev		
(If Relevant) Trendlines: Trendline is necessary to call attention to meaningful and statistically significant trend. Appropriate statistical information is presented for trendline.		
(If Relevant) Notes: Notes or illustrations are needed to enhance information presented in graph. Notes do not obscure underlying graphical information.		

Figure 1. Throughout the course students conducted structured critiques of sample technical writing: (a) structured critique worksheet for x-y scatterplots and line graphs and (b) scatterplot from a technical writing sample.

Two major summative assignments were designed to integrate multiple communication skills (Figure 2). These were multi-week assignments (6-7 weeks) with a mandatory draft submission (due week 4-5, 5% grade) with feedback from teaching assistants followed by a final submission (95% of grade), which was graded by the instructor. Like weekly assignments, the summative assignments required students to take on the role of product engineer at Melissa and Doug®. They were required to compose a technical brief (4-5 pages) to management about a particular product issue. Students also composed an email to management handing off the technical brief and recommending a particular action.

For Summative #1 (Figure 2a), students were asked to develop a production schedule for a new toy component, the "Tower Topper," that required immediate production on an in-house fleet of 3D printers and eventual outsourcing for injection molding. Given the 3D model of the part (an .stl file), students had to use a combination of online software and background research to determine 3D printing and injection molding costs, production time, and volume. Students then integrated this information with instructor-provided sales projections to advocate for a particular production schedule. This assignment particularly emphasized communications skills in composition, use of references, graphical elements like tables, line graphs, and images.

Summative #2 required students to make design recommendations for a new Melissa and Doug® product that would launch rubber bands a specified target distance. The benchmark product was a popular rubber band shooter by another manufacturer (Model PL7920, Funtime; Figure 2b), which was physically on hand for students to work with. Students were asked to derive from first principles the expected target distance based on rubber band stretch, to redesign the rubber band stretch mechanism to achieve desired target distance, and use propagation of error to determine which parameter needed to be most tightly controlled to minimize target distance variability. Three different rubber band manufacturers were considered, and tensile test data was provided for each manufacturer for students to determine rubber band length and stiffness. This assignment heavily emphasized data management, statistics (i.e., descriptive statistics, linear regression), and principles of experimental design: experimental controls and propagation of error.

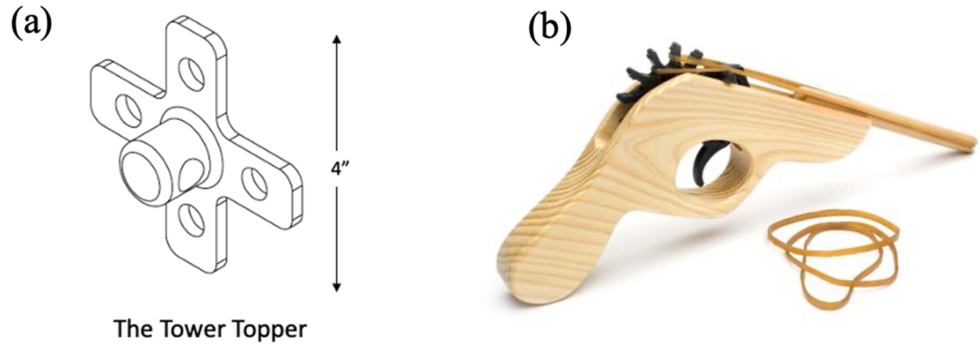


Figure 2. Summative assignments for *Technical Communications* required students to address an industry-themed technical problem. (a) Summative #1 involved creating a production schedule for this new toy component. (b) Summative #2 had students determine the design parameters for a rubber band launcher based on this benchmark design (Model PL7920, Funtime).

Course Evaluation

The primary aim of the *Technical Communications* course, as described in the previous section, was for first-year engineering students to develop multiple, industry-aligned communication skills. A preliminary evaluation was conducted to determine if the course was meeting this goal. The study setting was a large-enrollment introductory design course taken by second semester, first-year, mechanical engineering students at a mid-sized university in the Mid-Atlantic region. Most students in the course had already taken a university-required general composition course the prior semester. The course was taught as a single lecture section that met twice weekly for approximately one hour. This study took place in the second year of face-to-face implementation of the course, with a version being taught online for two semesters due to the COVID-19 pandemic. One faculty member from within the discipline (mechanical engineering) taught the course, supported by eight undergraduate teaching assistants who assisted with grading the weekly assignments.

Several data sets were collected as part of this study. Student participation in formative and summative assignment was documented, as well as course completion rates. The primary data set was a voluntary skills self-assessment survey (Qualtrics XM) that was completed by students at two time points during the semester. The survey was first administered during the first week of class (pre-course) and again during the last week of class (post-course). On the survey, students were asked to rate their level of self-confidence on a 5-point Likert scale (very confident to very unconfident) on 29 different skill-specific items aligned to five of the six course learning objectives (A-E, see Table 1). On the post-course version of the survey, students were asked whether various course elements like in-class group assignments and video tutorials were beneficial to their learning. There were also open response questions that asked students how the course could be improved, what was their most valuable take-away skill, and what advice they would have for future students in the course.

Students' responses survey items from pre- to post-course was compared using repeated, paired Chi-Squared tests (p<0.05 for significance; JMP Pro 17). When considering changes in self-confidence for entire skill categories (A-E) that encompassed multiple survey responses, students' responses were mapped to integer values and averaged by individual to yield numerical scores. Descriptive statistics, pairwise correlations, and one-way ANOVA for pre- to post-course aggregate measures were then performed (p<0.05 for significance; JMP Pro 17). Students' responses on items related to the utility of various course elements were analyzed using descriptive statistics. Thematic analysis was used to analyze students' constructed responses on open-response items [28].

Results

Technical Communications was offered as a single section, large-enrollment (N=198) course in Spring 2023. Participation in all course elements was fairly high, with 86%-96% of students completing weekly formative assignments, and 95.0% and 89.9% completion for summative assignments #1 and #2, respectively. The majority of students (89.4%) completed the course with a grade of C- or higher. Response rates on pre- and post-course surveys were also high with 74.2% (n=147) students completing both surveys.

At the beginning of the course, students reported the highest self-confidence for skills in Category B: Document Formatting, followed closely by Category C: Graphical Elements (Table 2). They were least confident with skills in Category A: Document Organization and Structure. With regards to specific skills, students came into the course with relatively high self-confidence for generating descriptive statistics; formatting graphical elements like tables, graphs, and images; recognizing plagiarism; composing reports free of spelling and grammatical issues; and composing professional emails. Pre-course self-confidence was low for composing both technical reports and design reports, using more advanced MS Excel features, organizing experimental data, and conducting more advanced statistical tests like one-way ANOVA.

From pre- to post-course, there were statistically significant improvements in students' self-confidence for every skill that was assessed (Table 2). Gains in self-confidence were most pronounced for Category A: Document Organization and Structure and least for Category B: Document Formatting. At the level of individual technical communications skills, students showed the largest increase in self-confidence in composing technical reports and design reports, organizing experimental data, applying one-way ANOVA, and incorporating mathematical equations into technical writing. Gains were less pronounced, although still statistically significant, for awareness of plagiarism, editing for grammar and spelling, producing poster presentations, and generating neatly formatted tables.

Table 2. Pre- vs post-course responses to survey prompts aligned course learning objectives A-E (paired Chi-Sq N=294, DF=4).

Learning Objective	Survey Prompt	Timepoint	Very Confident	Somewhat Confident	Neither	Somewhat Unconfident	Very Unconfident	Chi-Sq	p-value
A	I can compose a full length (5-10 page) technical report related to a laboratory or research experiment.	Pre	9.5%	26.5%	19.7%	33.3%	10.9%	155.1	<0.0001
		Post	61.2%	34.0%	1.4%	1.4%	2.0%		
	I can compose a full length (10+ page) engineering design report describing how I created a new product or process.	Pre	6.1%	18.4%	23.1%	35.4%	17.0%	158.8	<0.0001
		Post	41.5%	50.3%	3.4%	2.7%	2.0%		
	I can distill technical reports or engineering design reports into shorter summary documents (1 page).	Pre	8.8%	34.7%	26.5%	26.5%	3.4%	145.3	<0.0001
		Post	57.1%	38.1%	1.4%	0.7%	2.7%		
	I can compose professional emails related to engineering or technical issues.	Pre	15.6%	38.8%	28.6%	16.3%	0.7%	111.5	<0.0001
		Post	63.9%	30.6%	2.7%	0.7%	2.0%		
	I can present my technical work clearly and concisely as an oral presentation (10-15 min) with slide visuals (MS PowerPoint).	Pre	11.6%	24.5%	29.3%	24.5%	10.2%	75.5	<0.0001
		Post	43.5%	38.1%	11.6%	4.8%	2.0%		
	I can highlight my technical work in a poster presentation [with a poster and brief talking points]	Pre	13.6%	31.3%	29.9%	20.4%	4.8%	56.8	<0.0001
		Post	40.1%	42.9%	12.2%	3.4%	1.4%		
B	I can clearly communicate through my writing the "why, what, and how" of engineering design or research projects.	Pre	8.2%	36.1%	32.0%	19.7%	4.1%	129.3	<0.0001
		Post	58.5%	30.6%	2.0%	3.4%	5.4%		
	I know when and how to cite references in my work.	Pre	11.6%	28.6%	29.9%	23.1%	6.8%	120.8	<0.0001
		Post	59.2%	29.9%	1.4%	4.1%	5.4%		
	I am aware of what constitutes plagiarism.	Pre	41.5%	34.0%	4.8%	8.8%	10.9%	27.8	<0.0001
		Post	70.1%	19.0%	1.4%	2.0%	7.5%		
	I can use a reference manager to create in-text citations and bibliographies.	Pre	19.7%	36.1%	23.8%	11.6%	8.8%	92.7	<0.0001
		Post	67.3%	21.8%	0.7%	4.1%	6.1%		
	I can neatly format a written report and ensure that it is free from grammatical or spelling errors.	Pre	23.1%	40.1%	19.0%	12.2%	5.4%	83.0	<0.0001
		Post	69.4%	20.4%	0.7%	4.1%	5.4%		
	I can incorporate graphical elements into my reports that complement written text.	Pre	22.4%	46.9%	23.1%	7.5%	0.0%	133.0	<0.0001
		Post	77.6%	17.0%	0.7%	0.0%	4.8%		
C	I can create neatly formatted tables in written reports using standard software, e.g., MS Word or Excel.	Pre	22.4%	37.4%	25.2%	14.3%	0.7%	115.9	<0.0001
		Post	71.4%	22.4%	0.7%	0.7%	4.8%		
	I can incorporate mathematical equations into reports using standard software, e.g., MS Equation Editor.	Pre	12.9%	24.5%	34.7%	22.4%	5.4%	164.6	<0.0001
		Post	74.1%	18.4%	2.7%	0.0%	4.8%		
	I can create neatly formatted graphs using standard software, e.g., MS Excel.	Pre	20.4%	36.1%	26.5%	13.6%	3.4%	118.9	<0.0001
		Post	76.9%	15.0%	2.7%	0.7%	4.8%		
	I can stage photos of prototypes or lab experiments and incorporate photos into reports with appropriate labels.	Pre	15.0%	42.2%	29.9%	12.2%	0.7%	150.3	<0.0001
		Post	70.1%	23.8%	0.0%	0.7%	5.4%		
	I can create simple schematics, like flowcharts and sketches, and can incorporate them into reports.	Pre	16.3%	29.9%	32.7%	19.0%	2.0%	103.9	<0.0001
		Post	53.1%	38.8%	2.0%	2.0%	4.1%		
D	I can design a spreadsheet such that someone else could understand the experimental set-up and data.	Pre	9.5%	32.7%	32.0%	21.1%	4.8%	128.2	<0.0001
		Post	59.9%	32.0%	2.0%	3.4%	2.7%		
	I can apply basic functions like average, maximum, etc.	Pre	25.9%	28.6%	19.7%	13.6%	12.2%	108.7	<0.0001
		Post	81.0%	12.2%	0.7%	1.4%	4.8%		
	I can generate x-y scatterplots, bar charts, and pie charts from experimental data.	Pre	21.1%	37.4%	17.0%	15.0%	9.5%	107.9	<0.0001
		Post	77.6%	15.0%	1.4%	2.0%	4.1%		
	I can add graph elements, like best-fit lines and "error bars", to my charts.	Pre	19.7%	30.6%	19.7%	20.4%	9.5%	115.2	<0.0001
		Post	76.9%	15.0%	2.7%	1.4%	4.1%		
	I can sort data using sort and filter functions.	Pre	7.5%	23.8%	27.2%	33.3%	8.2%	115.0	<0.0001
		Post	50.3%	34.7%	6.8%	4.1%	4.1%		
E	I can design experiments to measure only the intended outcomes, with as few confounders as possible.	Pre	6.2%	34.2%	39.7%	14.4%	5.5%	125.7	<0.0001
		Post	49.7%	42.2%	3.4%	2.7%	2.0%		
	I can make use of control groups in my experimental designs.	Pre	11.0%	38.4%	35.6%	10.3%	4.8%	107.7	<0.0001
		Post	57.1%	33.3%	4.1%	0.7%	4.8%		
	I can identify sources of measurement variability in my experimental designs.	Pre	11.0%	32.2%	39.0%	16.4%	1.4%	121.4	<0.0001
		Post	53.7%	37.4%	3.4%	1.4%	4.1%		
	I can analyze data sets to determine descriptive statistics, like mean, standard deviation, quartiles, and range.	Pre	19.2%	33.6%	34.9%	8.9%	3.4%	114.5	<0.0001
		Post	68.7%	25.2%	0.7%	2.0%	3.4%		
	I can use analysis of variance (ANOVA) to compare experimental outcomes across groups.	Pre	3.4%	13.0%	27.4%	35.6%	20.5%	154.5	<0.0001
		Post	44.2%	36.1%	14.3%	3.4%	2.0%		
	I can develop standard operating procedures for data collection and storage in experiments.	Pre	5.5%	27.4%	30.8%	28.1%	8.2%	153.1	<0.0001
		Post	53.7%	38.1%	3.4%	1.4%	3.4%		
	I can organize the electronic and physical data in a way that allows someone unfamiliar with the project to follow along.	Pre	6.2%	35.6%	34.2%	17.8%	6.2%	153.5	<0.0001
		Post	59.2%	34.0%	1.4%	1.4%	4.1%		

Growth in self-confidence for specific technical communications skills was correlated with students' pre-course self-confidence. For every skill category (A-E), students with lower pre-course self-confidence generally had greater gains in self-confidence post-course as compared to students with higher pre-course self-confidence in that skill category (pairwise correlation, n=147 $r(2)= -0.73$ to -0.62, $p<0.0001$ all instances).

The post-course survey also asked students about the utility of different course elements. Nearly all students reported the video tutorials for specific skills like graphing in MS Excel to positively (16.3%) or very positively (81.6%) for enhancing their learning. Similarly, approximately 95% students recognized the value of the two summative assignments, despite in-class and survey comments about workload. In-class breakout group activities were rated as least beneficial, with 45.8% of students feeling that they had minimal to negative impact on their learning.

Students provided valuable feedback about *Technical Communications* in the open response survey items (Table 3). When asked about the most valuable skill they acquired in the course, students highlighted the ability to write and compose a technical report as well as specific MS Excel skills including formatting and incorporating charts and figures (27%). The online video content and tutorials were highlighted as being the most useful aspect of the course (49%) and students in general thought that the class assignments were well designed to support their learning (27%).

Nearly a quarter of students indicated in their written comments that workload for *Technical Communications* was particularly heavy for a 2-credit course (22%) and indicated some assignments could have been shorter in length or somewhat redundant in the skills they were expected to learn (11%). When asked to provide advice for future students in the course, students stressed the need to start assignments early and manage time properly (61%) and to attend class and fully utilize office hours and other class supports such as the teaching assistants (18%).

Figure 3. Select student responses to open response survey questions: (a) “What aspects of this course were helpful for your learning?” (b) “Which aspects of this course could be improved for next time?” (c) “What advice would you pass along to other students taking this class to help them succeed?” and (d)” What was the single most useful thing that you took away from this class?”

(a) The individual assignments / feedback were extremely helpful for my learning. The assignments were relevant to what is needed in the summatives and the feedback was helpful in determining what needs to be fixed.

(b) The number of credits that this course is worth should be worth much more, I feel that I spent maybe the most time out of any classes working on assignments for this class, and this class is worth fewer credits. [truncated]

(c) Just keep up with the assignments. College is a time management game, and these assignments pile up.

(d) I've learned how to convey technical information in a way that is concise and clear to other technical individuals.

Discussion

This paper presents a preliminary evaluation of a technical communications course that addresses a need in the engineering education community for situated, within-discipline learning experiences particularly for early-years students. Course learning objectives covered a range of industry-relevant communications skills. Course assignments were intended to simulate workplace communications for practicing mechanical engineers. Despite the large enrollment class size (ca. 200 students), the instructional team was able to implement research-based instructional strategies for effective technical communications courses, specifically, timely feedback, use of rubrics, and exemplars.

Findings from the preliminary evaluation suggest the course is associated with improvements in students' self-confidence across a wide range of technical communications skills. Students entered the course with relatively high self-confidence in "the rules" of writing composition such as proper grammar and spelling and identifying plagiarism. They were less confident in organizing their writing to make a technical argument. Encouragingly, students with lower self-confidence at the beginning of the course showed the greatest gains, while those with high self-confidence also benefitted from the course. Collectively, the findings indicate that course activities, including summative assignments, weekly assignments, lectures, and skills videos, were a positive influence on student self-confidence regardless of prior knowledge. Tentatively, we hypothesize gains in student self-confidence might be attributed to discipline-specific assignments that align with communication norms among practicing engineers.

Prior studies have advocated for contextualized learning experiences in technical communications [6, 29] and have highlighted industry-sponsored capstone design as an opportunity for these experiences. While it may provide industry relevant experiences, capstone design is taken in the senior year, which is far too late in students' programs of study to build and refine essential communications skills. *Technical Communications* was designed to provide contextualized communications exercises early in undergraduate program of study. Rather than focusing narrowly on composition of laboratory or design reports [10-14], our course fostered the development of a broad range of industry-relevant communications skills [4, 6, 8], including technical briefs and memos, emails, managing large data sets, and graphical representation of data.

Interestingly, we found that not all students entered the course with communications skills that would be considered pre-requisites in engineering lab courses, whether writing intensive or not. For example, a substantial percentage of students (40-60%) were not confident in basic MS Excel skills like graphing or spreadsheet organization. Students reported low self-confidence for using MS Excel reinforce the need for early-years, within-discipline technical communications instruction. Lastly, this study illustrates that it is possible to design and deliver a technical communications course in a large-enrollment format grounded in research-based instructional practices [6, 15-19]. Similar to other instructors [30, 31], we found the key to managing the large enrollment of a technical communications course is using of well-trained teaching assistants to provide students with timely feedback on weekly assignments. Our strategy was to provide the teaching assistants with continuous instructional support in the form of weekly meetings with the instructor.

Technical Communications is unique in that it featured a contextualized learning experience for course assignments, namely, asking students to communicate as if they were product engineers at Melissa and Doug®. In reality, Melissa and Doug® is a partner of the program and periodically sponsors introductory design and capstone projects. These connections provide a realistic context for students when they are asked through course assignments to position themselves practicing engineers. While others have relied strictly on post-course evaluations [11, 12] or used aggregate measures of technical communications skills (e.g., "conventions" and "writing mechanics") [12, 13], we considered student growth for specific skills (e.g., graphs in MS Excel) that were aligned with our course learning objectives. Administration of a pre-course skills survey allowed us to pinpoint gaps in students' background knowledge and address these with supplemental instruction.

One limitation of our evaluation was our reliance on self-reported data by students rather than more objective measures of student achievement or growth in skill proficiency over time. Moreover, this study did not measure the extent to which students were able to transfer skills learned in this course to subsequent courses. Given that *Technical Communications* is a foundational course in our undergraduate program, which embeds writing across the curriculum [6, 9, 22, 23], we plan to employ common templates, exemplars, and rubrics in other undergraduate courses where technical communication skills are required. Future research will investigate longitudinal transfer of technical communications skills by students from this course to subsequent courses in their undergraduate programs of study.

In future iterations of the course, we plan to embed workplace-relevant ethical considerations into assignments and meaningfully integrate AI tools to promote student skill development [32]. Future research will focus on whether students successfully carry forward the technical communications skills that they learned in this course into future communications assignments in the undergraduate program.

References

[1] B.M. Aller, Writing practices in the engineering workplace: Findings and implications for teachers of engineering communication, Michigan Technological University, 2001, .

[2] L.M.d.S. Almeida, K.H. Becker and I. Villanueva, "Engineering communication in industry and cross-generational challenges: An exploratory study," European Journal of Engineering Education, vol. 46, pp. 389-401, 2021.

[3] P. Sageev and C.J. Romanowski, "A message from recent engineering graduates in the workplace: Results of a survey on technical communication skills," J Eng Educ, vol. 90, pp. 685-693, 2001.

[4] H.J. Passow and C.H. Passow, "What competencies should undergraduate engineering programs emphasize? A systematic review," J Eng Educ, vol. 106, pp. 475-526, 2017.

[5] ABET, "Accreditation Policy and Procedure Manual (APPM), 2021-2022 " .

[6] J.A. Donnell, B.M. Aller, M. Alley and A.A. Kedrowicz, "Why industry says that engineering graduates have poor communication skills: What the literature says," pp. 22-1687, 2011.

[7] S. Danielson, A. Kirkpatrick and E. Ervin, "ASME vision 2030: Helping to inform mechanical engineering education," pp. T1J-1, 2011.

[8] D.E. Kirkland, "Standpoints: Researching and teaching English in the digital dimension," Research in the Teaching of English, vol. 44, pp. 8-22, 2009.

[9] J.D. Ford, "Knowledge transfer across disciplines: Tracking rhetorical strategies from a technical communication classroom to an engineering classroom," IEEE Transactions on Professional Communication, vol. 47, pp. 301-315, 2004.

[10] B. Yalvac, H.D. Smith, J.B. Troy and P. Hirsch, "Promoting advanced writing skills in an upper-level engineering class," J Eng Educ, vol. 96, pp. 117-128, 2007.

[11] D.E. Gragson and J.P. Hagen, "Developing technical writing skills in the physical chemistry laboratory: A progressive approach employing peer review," J.Chem.Educ., vol. 87, pp. 62-65, 2010.

[12] C. Hubka, E. Chi, Y. Chen, V. Svihla, J. Gomez, A. Datye and T. Mallette, "A writing in the disciplines approach to technical report writing in chemical engineering laboratory courses," in Proceedings of the ASEE 126th Annual Conference and Exhibition, 2019.

[13] K. Wright, P.E. Slaboch and R. Jamshidi, "Technical writing improvements through engineering lab courses," International Journal of Mechanical Engineering Education, vol. 50, pp. 120-134, 2022.

[14] A. Pfluger, M. Armstrong, T. Corrigan, E. Nagelli, C. James, A. Miller and A. Biaglow, "Framework for analyzing placement of and identifying opportunities for improving technical communication in a chemical engineering curriculum," Education for Chemical Engineers, vol. 31, pp. 11-20, 2020.

[15] S.S. Taylor, "Comments on lab reports by mechanical engineering teaching assistants: Typical practices and effects of using a grading rubric," Journal of Business and Technical Communication, vol. 21, pp. 402-424, 2007.

[16] E.A. Price and M.J. Harkins, "Scaffolding student writing," Language and Literacy, vol. 13, pp. 14-38, 2011.

[17] L.J. Deiner, D. Newsome and D. Samaroo, "Directed self-inquiry: A scaffold for teaching laboratory report writing," J.Chem.Educ., vol. 89, pp. 1511-1514, 2012.

[18] C. Wallwey, T. Milburn and B. Morin, "Scaffolding Technical Writing Within a First-Year Engineering Lab Experience," in 2021 ASEE Virtual Annual Conference Content Access, 2021.

[19] M.A. Cantera, M. Arevalo, V. García-Marina and M. Alves-Castro, "A rubric to assess and improve technical writing in undergraduate engineering courses," Education Sciences, vol. 11, pp. 146, 2021.

[20] S.I. Ringleb, O.M. Ayala and J. Kidd, "Implementing Peer-Review Activities for Engineering Writing Assignments," 2017.

[21] N. Smith, "Guided peer review of technical writing for large laboratory course," in 2019 ASEE Annual Conference & Exposition, 2019.

[22] D. Kim and W.M. Olson, "Using a transfer-focused writing pedagogy to improve undergraduates' lab report writing in gateway engineering laboratory courses," IEEE Transactions on Professional Communication, vol. 63, pp. 64-84, 2020.

[23] S. Manuel-Dupont, "Writing-across-the-curriculum in an engineering program," J Eng Educ, vol. 85, pp. 35-40, 1996.

[24] E. Wheeler and R.L. McDonald, "Writing in engineering courses," J Eng Educ, vol. 89, pp. 481-486, 2000.

[25] D.R. Russell, "Rethinking genre in school and society: An activity theory analysis," Written Communication, vol. 14, pp. 504-554, 1997.

[26] S.M. Jeter, J.A. Donnell, C. MacDougall and J. Snedeker, Writing style and standards in undergraduate reports, College Publishing, 2016, .

[27] E.R. Tufte, The visual display of quantitative information, Graphics press Cheshire, CT, 2001, .

[28] V. Braun and V. Clarke, Thematic analysis, American Psychological Association, 2012, .

[29] D.R. Russell, Writing in the academic disciplines: A curricular history, SIU Press, 2002, .

[30] J. Petrović and P. Pale, "Achieving scalability and interactivity in a communication skills course for undergraduate engineering students," IEEE Transactions on Education, vol. 64, pp. 413-422, 2021.

[31] N.T. Buswell, B.K. Jesiek, C.D. Troy, R.R. Essig and J. Boyd, "Engineering instructors on writing: Perceptions, practices, and needs," IEEE Transactions on Professional Communication, vol. 62, pp. 55-74, 2019.

[32] P. Fyfe, "How to cheat on your final paper: Assigning AI for student writing," Ai & Society, vol. 38, pp. 1395-1405, 2023.