Teaching Case

Hybrid Model for Multidisciplinary Collaborations for Technical Communication Education in Engineering

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***Abstract*—Introduction:** *Engineering programs must take creative approaches to ensure that their students receive needed communication instruction in curricula constantly experiencing pressures of accreditation, state, and industry requirements: expectations for students' knowledge and skills increase although curricula are compressed.* **Situating the case:** *Technical communication and engineering education scholarship describe multiple models for integrating writing instruction into engineering curricula: 1. writing across the curriculum, 2. partnership models, 3. embedded models, and 4. support models.* **About the case:** *Technical and professional writing and engineering faculty collaborated to develop a hybrid model, which borrows from multiple existing models for integrating technical writing education throughout the engineering curriculum, both in and outside of courses, including collaborative workshops, specialized writing center support, and other interventions.* **Methods/approach:** *Survey research was conducted with students on the effectiveness of multiple writing interventions.* **Results/discussion:** *The hybrid model enables students to experience a variety of writing interventions; students perceived them as beneficial. Students found most effective writing interventions occurred in the context of their engineering coursework. Faculty and administrators found the approach beneficial because of its collaborative nature and because it balanced instructional time with external support methods.* **Conclusions:** *Local solutions to universal problems must take many variables into consideration: people and programmatic cultures, disciplinary and institutional contexts, and curricular, regulatory, and funding constraints. The authors' hybrid model for integrating technical writing into the engineering curriculum represents a flexible, sustainable approach adaptable to meet specific needs in specific environments at different institutions.*

Index Terms*—Communication instruction, engineering curriculum design, engineering instruction, interdisciplinary collaboration, technical communication.*

Effective communication with a range of audiences has been recognized as one of the important professional skills in engineering and is one of the seven required student outcomes for ABET accreditation of undergraduate engineering programs [1]. Technical communication, both written and oral presentations, requires necessary skills at different levels of the engineering curriculum, as well as in the workplace when engineering program graduates have to write reports, communicate requirements and results, document processes and procedures, and interpret and convey a variety of technical information. With the shrinking curricula in engineering programs, particularly the legislatively imposed 120 hour maximum that has reduced the number of hours allowable for baccalaureate degrees [9], technical communication has often become one of the required professional skills that students need to acquire without formal coursework. Engineering programs must take creative approaches to ensure that their students receive needed communication instruction in curricula that also constantly experience the combined pressure of accreditation, state, and industry requirements.

In this article, we describe collaborations between engineering and English departments for incorporating technical writing components in the engineering curriculum to address specific writing requirements and skills as they pertain to courses for different levels of students (first year through senior). Technical and professional writing (TPW) and engineering faculty collaborated and adopted a customized hybrid model, combining attributes from four existing models, for incorporating instruction on technical communication skills within the engineering curriculum. (This usage of "hybrid model" is distinct from "hybrid" in the sense of flipped or blended courses that draw on both online and onsite delivery.)

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This article has supplementary downloadable material at https://ieeexplore.ieee.org provided by the authors and translators. The files consist of two appendixes (279 kB and 90 kB in size), a Chinese translation of the abstract by Z. Xi (82 kB in size), and a Spanish translation of the abstract by G. Aguilar (86 kB in size).

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Practitioner Takeaway

- To learn technical writing, engineering students must be exposed to different types of writing instruction over time. The hybrid model facilitates a variety of writing experiences by combining elements from WAC/CXC, partnership, embedded, and service models for integrating writing instruction into engineering curricula.
- Students benefitted most from collaborative workshops in the context of their engineering coursework and assignments, led by both engineering faculty and technical and professional writing faculty.
- By embracing student needs and acknowledging the contributions of each program, engineering and technical and professional writing faculty implemented noninvasive interventions without sacrificing technical course content and without the need for an extra service course.

The selected courses included senior-level project management and capstone projects courses, a junior-level manufacturing processes course, as well as earlier courses in the curriculum, such as first-year learning communities. These efforts were initiated based on the observations of some of the engineering faculty in engineering programs across the nation, and acknowledgment by industry that senior-level engineering students demonstrated room for improvement in communication skills, including the writing component [2], [3]. A curriculum map was used to identify opportunities for writing interventions in courses with specific engineering communication or writing-related deliverables.

After the program was implemented, researchers were interested in the extent to which the model successfully addressed technical writing in a variety of ways throughout the engineering curriculum, as well as how useful students and faculty thought the program was. Researchers therefore explored three questions:

RQ1. Did students participate in multiple parts of the program?

RQ2. What experiences did students have in the program?

RQ3. Did students and faculty perceive the multiple elements of the program as beneficial?

In the remainder of this article, we describe and evaluate a teaching case that outlines how the faculty and departments collaborated to reinforce technical communication instruction throughout the mechanical engineering curriculum under tight curricular constraints. First, the case is situated in technical communication and engineering education scholarship, discussing models for integrating technical writing and engineering instruction. Then, the process for developing and implementing the collaborative hybrid model for integration of technical writing and interventions is described. Next, the methods and results for the teaching case are presented. Finally, conclusions about programmatic collaborations are summarized.

Situating the Case

The conversation about where to deliver writing and communication instruction within engineering curricula has a long history [4]–[6]. The most traditional methods of ensuring that the engineering students receive instruction in technical communication have involved students completing a technical writing service course offered in an English or humanities department or practicing technical communication in technical courses via reports and presentations, though without much explicit instruction [7].

Outsourcing methods, where disciplinary writing is expected to be taught in nondisciplinary courses, are widespread [6], [8], but ever-more crowded engineering curricula significantly challenge outsourcing methods, as do stringent maximum-hour limitations at public institutions. In Texas, for instance, baccalaureate-level degree programs must provide “compelling academic reason” for degrees requiring more than 120 hours [9]. Engineering programs that primarily rely on first-year writing courses or university core requirements met by humanities and social science coursework may have difficulties preparing engineering students for the writing typified in their majors and professional contexts [10]. Also, some engineering faculty may not feel that all English or other instructors are well equipped to teach technical writing in a manner that is useful for engineering students [11]. Conversely, technical

faculty are often on their own when designing writing instruction, are concerned about removing technical content to make room for writing instruction, or may not see themselves as having sufficient expertise to teach writing [12], [13]. These factors are not limited to engineering faculty and are commonly cited in writing across the curriculum literature as well [14], [15].

Especially since ABET's adoption of the *Engineering Criteria 2000* standards in 1996, which prioritized communication and have been reaffirmed in every revision through 2020, varied approaches to developing engineering students' writing and communication skills have been described in engineering education and technical and professional communication journals as well as conference proceedings [7], [16]–[18]. One of the few program surveys of its kind showed that 50% of US and 80% of Canadian schools required a single course in technical communication, often as a service course. Of the rest, 33% used some form of integrated communication instruction, 33% offered elective communication courses, and 14% had engineering communication centers at the time [8]. However, this type of survey data has not been updated since 2004.

Leydens and Schneider note that communication-across-the-curriculum-style collaborations between engineering programs and writing or communication programs have been on the rise [6]. This section describes four general models for these collaborations described in research on engineering writing curricula, which form the basis of the hybrid model presented in this article:

1. Traditional Writing Across the Curriculum (WAC)/Communication Across the Curriculum (CXC) models
2. Partnership models
3. Embedded models
4. Support models

Traditional WAC/CXC Models Though the other three models could be interpreted as writing across the curriculum (WAC) or communication across the curriculum (CXC) approaches, in its most traditional sense, the WAC/CXC model emphasizes developing and supporting writing instruction in technical content courses, often distributed throughout a program's coursework [7]. Programs using this model may be interdisciplinary in that they involve collaboration and discourse between engineering, writing, and communication faculty through training and workshops [19], but the bulk of writing instruction itself takes place in technical courses and is delivered by technical faculty. Writing or communicating in the disciplines models have been shown to improve engineering students' ability to understand disciplinary content, select important information, solve problems, and justify technical choices [20].

Partnership Models Partnership models involving "authentic integration" are typified by a multidirectional partnership between engineering and writing or communication faculty around design, delivery, and evaluation of instruction in technical communication [8]. Rather than including communication content only in engineering courses, both disciplines have input into course goals, objectives, and opportunities for direct writing instruction. Though the programs remain distinct administratively, partnership models often involve a communication or writing program participating directly in the engineering course or program [6], [8], [21]–[25]. These models typically include the following curricular practices.

- Integrated technical courses with collaborative teaching, where both technical faculty and writing faculty have input into course goals, and direct communication instruction takes place in the technical course
- Explicitly linked writing and technical courses or prescribed series of courses, where connections between two or more courses are purposefully aligned and built into the structure and curriculum of both courses
- Elective engineering communication courses, where the focus is primarily on communication in the specialized context rather than technical content, delivered by technical faculty
- Integrated programs, such as engineering communication minors

Embedded Models The emphasis of the embedded model is creating cross-disciplinarity at the program or institutional level rather than the individual course or curricular intervention. Embedded models often intensify the integration from previously mentioned models by placing writing or communication specialists directly into engineering departments and programs, often circumventing the need to collaborate with another program. In some cases, technical writing faculty have part of their time reassigned to an engineering unit; in others, these faculty are embedded, administered, and funded in the engineering department [26], [27]. Some versions of the embedded model rely on "writing consultants" or "writing fellows";

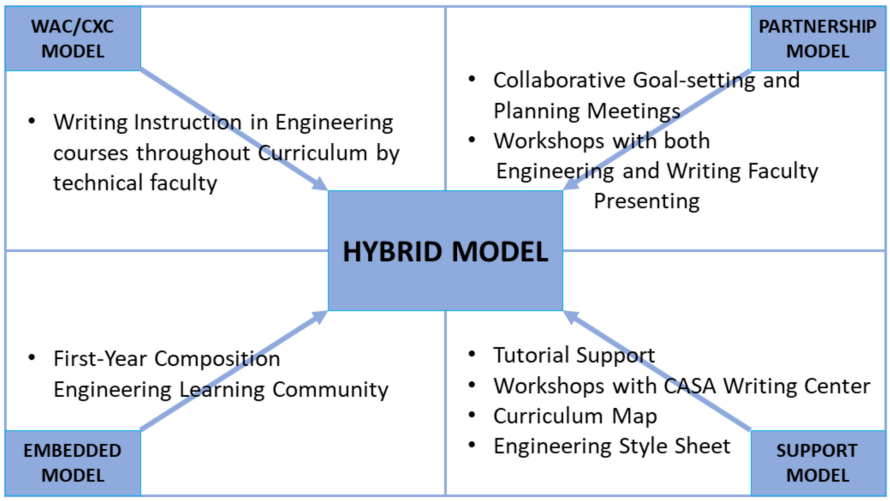

Fig. 1. Hybrid model for multidisciplinary collaborations for technical communication education in engineering.

engineering students work with writing faculty or specially trained graduate students, but in a tutorial role, workshop setting, or writing-intensive course rather than a team-teaching context [28], [29]. The most expansive of these may be complete university programs themselves, involving directors, graduate teaching assistants, and undergraduate senior assistants to teach courses, conduct workshops, tutor students, grade assignments, and conduct assessment [30].

Support Models Support models rely on writing or communication instruction support for students and faculty that takes place outside or supplemental to classrooms, but in ways that are purposefully and explicitly aligned with the needs of engineering students. Rather than just taking part in general tutorial and other student support services, models for integrating writing instruction into engineering curricula might rely on any number of targeted practices. A common part of consultant or fellows programs consists of workshops and clinics that are designed as specific interventions for students in selected classes or points in the curriculum [22], [30]. Communication centers and tutorial support feature undergraduate, graduate, or professional tutors with training and experience in engineering communication [31], [32]. Support models might also offer instructional development for technical faculty, especially resources to help them work through pedagogical issues (balancing feedback and number of students; effective writing pedagogy) or materials to supplement instruction [13].

The rest of this article describes the hybrid approach taken by engineering and technical and professional writing faculty to collaboratively design interventions for integrating writing instruction into engineering curricula at a mid-sized public university in Texas, USA. This hybrid model draws on elements from the WAC/CXC, Partnership, Support, and Embedded models to create flexible, sustainable, and meaningful collaborations. Fig. 1 represents the hybrid model for collaborations developed in this study, borrowing from a spectrum of existing models for technical communication education in engineering.

About the Case: Writing Needs in the Mechanical Engineering Curriculum

Engineering faculty and TPW faculty met numerous times early in the process to identify student problems in technical communication and establish goals for addressing them. Working collaboratively, engineering and TPW faculty identified several issues facing engineering student writers.

- After writing in first-year engineering and university-required first-year composition courses organized as part of learning communities that bring engineering students together in intentionally clustered co-requisite courses in engineering, composition, mathematics, and first-year seminar, many engineering students experience a “gap.” A limited amount of writing (and practice) is required in classes in their degree plan that immediately follows their first-year writing experience. By the time these students encounter courses that, once again, require them to write more actively (see Table I), skills

TABLE I
CURRICULUM MAP FOR TECHNICAL WRITING IN THE MECHANICAL ENGINEERING PROGRAM

Required Courses in Engineering and Mechanical Engineering BS		Technical Writing Outcomes								
		1	2	3	4	5	6	7	8	9
Year 1	ENGR 1211: Introduction to Engineering	I	I		I	I	I	I	I	I
	ENGR 1312: Engineering Graphics I							I		
Year 2	ENGR 2325: Statics									
	ENGR 2316: Thermodynamics									
	ENGR 2322: Materials Science		I		I	I	I	I	I	I
	ENGR 2326: Dynamics									
Year 3	ENGR 2460: Circuit Analysis		R		R	R	R	R	R	R
	ENGR 3315: Fluid Mechanics									
	ENGR 3320: Strengths of Materials									
	ENGR 3350: Manufacturing Processes		R		R	R	R	R	R	R
	MEEN 3310: Engineering Analysis for Mechanical Engineering									
	MEEN 3330: Solid Mechanics for Mechanical Engineering									
	MEEN 3230. Solid Mechanics Lab									
	MEEN 3345: Heat Transfer									
Year 4	MEEN 4240: Project Management	I	R	I	R	R	R	R	R	R
	MEEN 4351: Dynamic Systems Analysis & Modeling									
	MEEN 4420: Engineering Lab Measurements		R		R	R	R	R	R	R
	MEEN 4360: Thermal Systems Design									
	MEEN 4365: Mechanical Systems Design		R		R	R	R	M	R	R
	MEEN 4370: Capstone Projects	R	M	R	M	M	M	M	M	M

Note: **I**: Indicates that students are introduced to the outcome. **R:** Indicates that the outcome is reinforced; students are afforded the opportunity to practice. **M:** Indicates that students have sufficient practice to gain mastery.

developed in first-year courses may have atrophied.

- Engineering students often write narratively and seem to have limited experience in what style, organization, and language should be used in a document intended for an engineering audience.
- Because of curricular compression, engineering students do not have room in their degree plans for a separate technical writing course.
- Single-occurrence workshops held outside a specific classroom context, offered as a solution in compressed engineering curricula, have a limited impact on the development of student writing and present challenges for encouraging student attendance.
- Students need guidance in developing skills for and experience with writing in the specific genres that are required.

Engineering and technical writing faculty collaborated to develop a hybrid model that integrated parts of traditional WAC models, partnership models, and support models. The approach involved developing several interventions designed to support technical writing throughout students' undergraduate curriculum. Together, faculty from both departments determined that this hybrid model—adapting elements of several proven approaches—addressed the engineering students' needs while working within curricular,

institutional, and regulatory constraints on the program.

The hybrid model was introduced over a two-year period to address the curricular writing "gap" and included the following interventions.

- **Curriculum Map (Throughout Curriculum):** A TPW faculty member developed a curriculum map by working with engineering faculty (see Table I). The map identified when particular engineering writing skills were emphasized in the curriculum prior to the implementation of the hybrid model, as well as locations for possible future interventions. Sample student writing in engineering assignments was also analyzed as part of the curriculum map development process. Not simply a planning document for other parts of the model, the map is a support resource [13] intended to help the engineering program identify other needs and opportunities for instruction in technical communication.
- **First-year Composition (FYC) Engineering Learning Community:** FYC at the university is taught through a learning communities (LC) model, in which students in pre-engineering courses are enrolled in the same sections of first-year composition taught by instructors familiar with engineering writing. Students in LCs enroll in explicitly linked co-requisites in common cohorts. LCs are organized at the level of the institution rather than solely within the engineering or English programs and are thus largely free of turf disputes that might result from more traditional outsourcing arrangements. Though they pre-existed the interventions described in this article, LCs are important to include as part of the hybrid approach. These clusters provide a foundation for students to understand relationships between writing, communication, and engineers' work, and they introduce technical writing practices early in students' education. They are also a space for other hybrid model interventions, such as introducing the Engineering Style Sheet (see Appendix A in the supplementary material).
- **Engineering Style Sheet**: As part of the hybrid model, writing faculty developed a style sheet for courses in pre-engineering learning communities that emphasized some of the major elements in engineering writing. The style sheet was accompanied by an infographic intended to provide a visualization of information included on the style sheet. This one-page infographic was most welcomed by students, as it represented a concise reference guide for technical writing (see Appendix A in the supplementary material).
- **Writing Center (Throughout Curriculum):** As part of the hybrid model, an English graduate student with a BS in a science discipline was trained as a Writing Center associate to provide Writing Center support for engineering students. The Writing Center coordinator received the same training that the Associate received and audited the writing workshops given to upper division engineering students. In addition, technical and professional writing faculty offered additional training and support about tutoring technical writing for all Writing Center tutors.
- **Workshops During Labs (Third Year):** Writing workshops were conducted during lab sessions of the 3000-level Manufacturing Processes course, which was chosen because it is required of all mechanical engineering students and ideally taken during a student's third year. Students participated in workshops while in the process of writing reports describing a materials experiment that they had conducted. Providing writing instruction at a point in the curriculum when writing was relevant to the engineering students' tasks at hand offered a teachable moment in which writing instructors were able to discuss directly applicable writing techniques, and engineering faculty were able to support the writing concepts with anecdotes from their own engineering careers.
- **Workshops for Capstone Courses (Fourth/ Final Year):** Workshops focusing on how engineers use writing in a variety of contexts for a variety of audiences were conducted during the 4000-level project management course, which is taken the semester before a student graduates during the fourth or final year of the degree program. Students, who were working in teams, had to orally abstract their still-developing capstone projects for the nontechnical workshop facilitators. These highly conversational workshops emphasized the need to front-load to encourage readers to continue reading, to consider audience in different ways than students had previously, and to distinguish between academic and technical writing.

A key intervention in the hybrid model is the curriculum map. To better understand when, where, and what type of writing instruction occurs in the engineering curriculum, a technical and professional writing faculty member was given released time from the university to construct a curriculum map (see Table I). This map is a resource for the engineering program to use as they

continue to "scale up" writing in engineering [13] and determine the timing and curricular placement of future interventions for developing targeted writing skills. Derived from syllabi, project descriptions, and supporting instructional materials, the map identifies when technical writing skills are introduced, reinforced, and practiced, ideally leading to mastery over the course of four years, based on the coursework identified in the program's degree plan. The following outcomes describe technical writing skills emphasized by engineering program faculty as abstracted from assignments and supplemental materials that were collected. As writers in the engineering program, students should be able to

1. Identify audience knowledge and needs
2. Select and organize appropriate content for an audience
3. Read a new or unfamiliar genre to understand how it works
4. Document and present procedural information
5. Document and present results, critical analysis, and conclusions
6. Document and present secondary research and theory
7. Incorporate visuals and numerical data
8. Create a usable document
9. Use a writing style appropriate for the audience

Methods

We used a mixed-methods approach to determine which elements of the program students participated in, gather details about their experiences, and determine which interventions students and faculty found to be the most successful. Information was collected from two populations: graduating seniors taking the capstone course for the BS in engineering and engineering faculty who teach in the mechanical engineering program.

Engineering students in the final capstone semester of their BS program ($N_1 = 46$) as well as those who graduated one or two semesters before or who had previously taken manufacturing processes courses ($N_2 = 91$) were invited to participate in an Institutional Review Board (IRB)-approved survey in which they were asked a series of questions concerning which writing interventions they had experienced, their impressions of those interventions, and to what extent their understanding of and attitudes about writing in engineering had changed. The survey used a combination of five-point Likert scale questions, multiple-choice questions, and open-ended questions. (See Appendix B in the supplementary material for survey questions.) Responses from participants ($n = 38$, $N = 137$, response rate 27.7%) were collected and analyzed using Qualtrics. Because of the nongeneralizable nature of the teaching case and because this was not a quasi-experimental classroom research study, statistical analysis was not used.

Engineering faculty who were teaching students who participated in technical writing interventions ($n = 4$) were asked a series of questions about their perceptions of what, if any, positive effects the writing interventions had on student writing. The targeted faculty included those whose courses involved a technical communication component (lab reports, project proposals, progress reports, final reports, memos, etc.), and who had observed students after the introduced writing interventions. These questions included the following.

1. Did you see observable benefits in student technical writing, or in instruction (to students) around student writing?
2. If so, which course, and what are some examples of benefits you might have observed?
3. How effective were the seminars that [Technical Writing faculty] may have done?
4. Were there other things that you thought were helpful?

Although anecdotal in nature, faculty response was significant in assessing the value and effectiveness of the writing interventions.

Results and Discussion

Students Experienced a Variety of Interventions and Believed That Interventions Had Been Beneficial Although the program was begun during most of the students' sophomore years, nearly all participants surveyed had participated in one or more of the interventions. Fig. 2 shows the interventions that the participants experienced.

Project management and capstone projects represent a sequence of courses that mechanical engineering students take in the final year of their curriculum. All but three survey respondents participated in the technical writing workshop in project management courses in either Spring or Fall 2019. The majority of the survey respondents (33 of 38) were students from the Spring 2020 capstone projects course, graduating senior students who had taken the project management

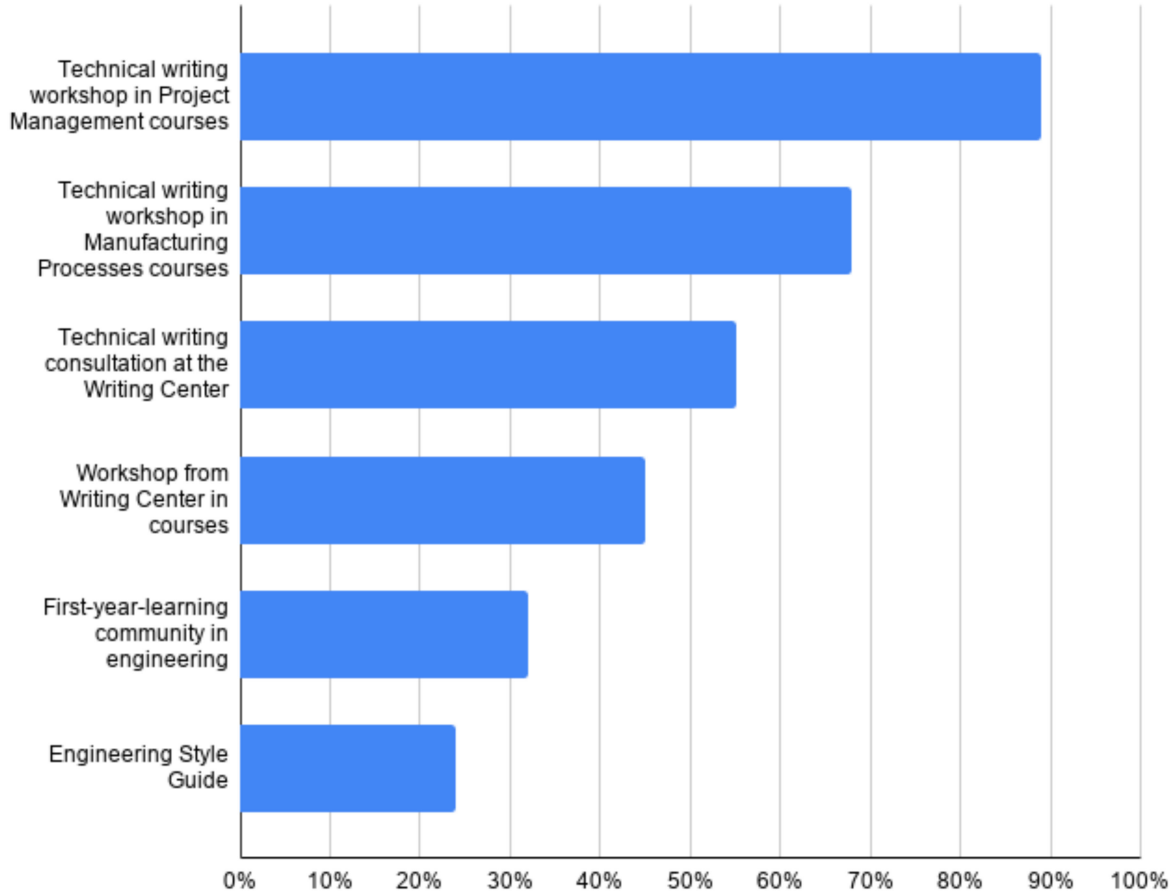

Fig. 2. Technical writing/communication interventions that engineering students experienced.

course the semester before. Others (5 of 38) were alumni who had graduated previously or took project management in Spring 2019. The majority of the students (about 70%) indicated participation in other interventions including the technical writing workshop in the manufacturing processes course that they had completed previously.

Over 50% of the students took advantage of technical writing consultation services through the university's Writing Center. One of the project management faculty (Fall offerings) mandates technical writing consultation for large team reports in her course. In all other courses, seeking such consultation is voluntary. As the data summarized in Fig. 2 indicate, about 45% of the students took advantage of communication workshops by Writing Center tutors. About 25% of the students used the style guide. We think that this was a matter of awareness rather than the usefulness of the document. As expected, the number of participants in the first-year learning community in engineering was slightly over 30%, since the first-year learning communities were implemented after most of the respondents had completed their first year.

Many Students Expressed That the Most Effective Interventions Came When Writing Was Actually Taught in the Context of an Engineering Course Based on comments from the student surveys, the most effective intervention occurred when writing faculty came into engineering courses and addressed writing projects in the context of the engineering and projects that they were being taught, particularly in the workshops given during ENGR 3350 Manufacturing Processes and during ENGR 4370 Capstone Projects. One participant noted that "Having a hands-on explanation of what exactly is expected on a document truly helps." Another noted that

> This helped place every team's mindset into the type that's needed to write technical papers; it wasn't just another "composition" lecture but rather a set of guidelines to ensure objectives are met.

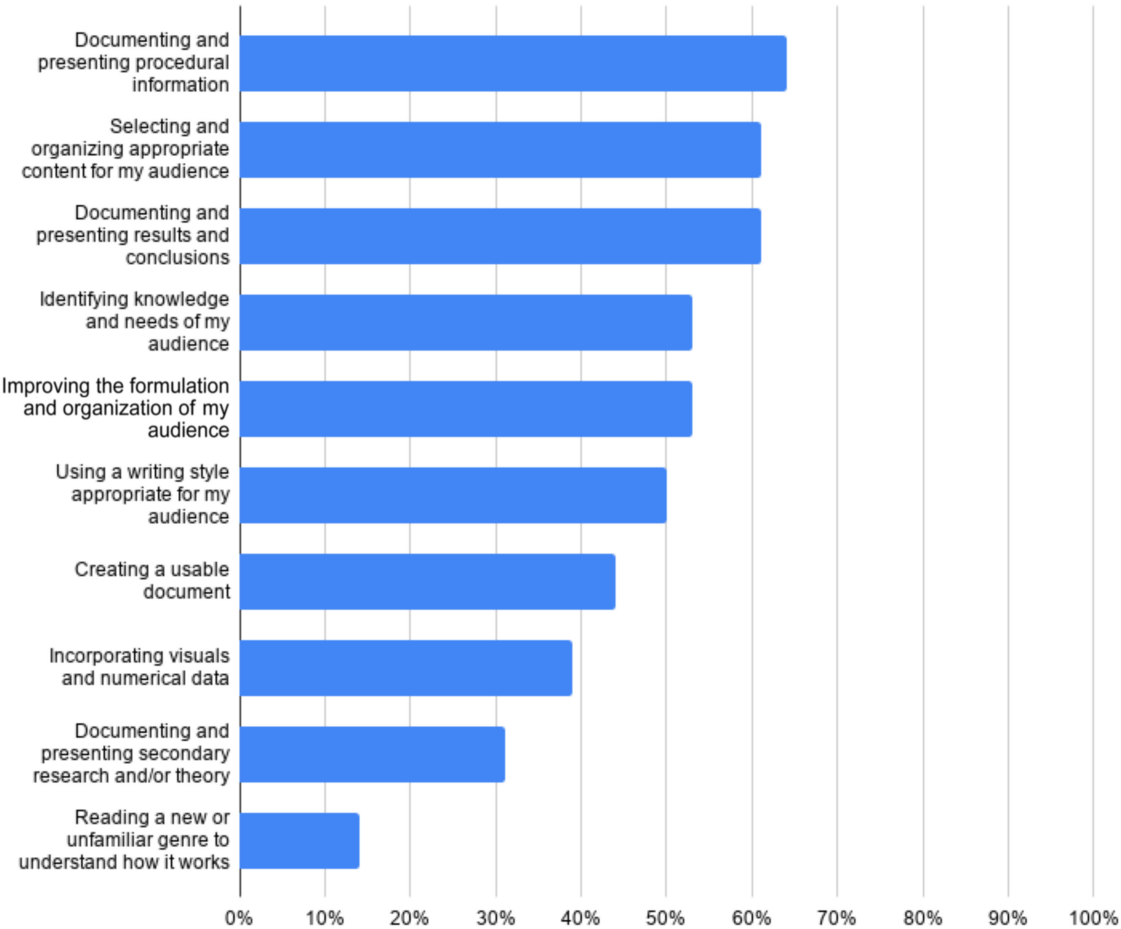

Fig. 3. Areas in which students reported improvement as a result of the program.

Similarly, students found that writing tutors trained specifically in engineering writing were helpful for two reasons: because of their writing knowledge and because they were able to address specific writing needs in the students' actual technical project reports. One respondent wrote,

> … tutors and consultants provided much information due to their knowledge and expertise in the subject.

Another noted that

> The personal consultation … was the most helpful because it focused more on the issues I was having rather than keeping it broad.

The success of these interventions illustrated that introducing writing interventions *when students are working on specific, professionally relevant writing tasks* is far more effective than general "how to" sessions or "one shot" workshops. Each intervention provided students with some benefit, but writing instruction *in the context of their own writing* was found to be the most beneficial intervention when compared to providing general rules or abstract instruction. In addition, the cumulative effect of the interventions was likely another factor in student writing growth; the fact that a number of writing supports were given over time, in different ways, at different points in the curriculum was significant. Writing growth is idiosyncratic—what works for one person might not work for the next. Therefore, a range of writing supports is expected to have been as important as any one specific writing intervention, further justifying the benefits of the hybrid model.

Students Demonstrated the Ability to Connect Writing With Specific Professional Tasks That They Might Perform as Engineers Engineering students expressed that their thinking about writing became more complex as a result of the workshops. Fig. 3 demonstrates the areas in which students self-reported technical writing skills in which they improved as a result of the workshops.

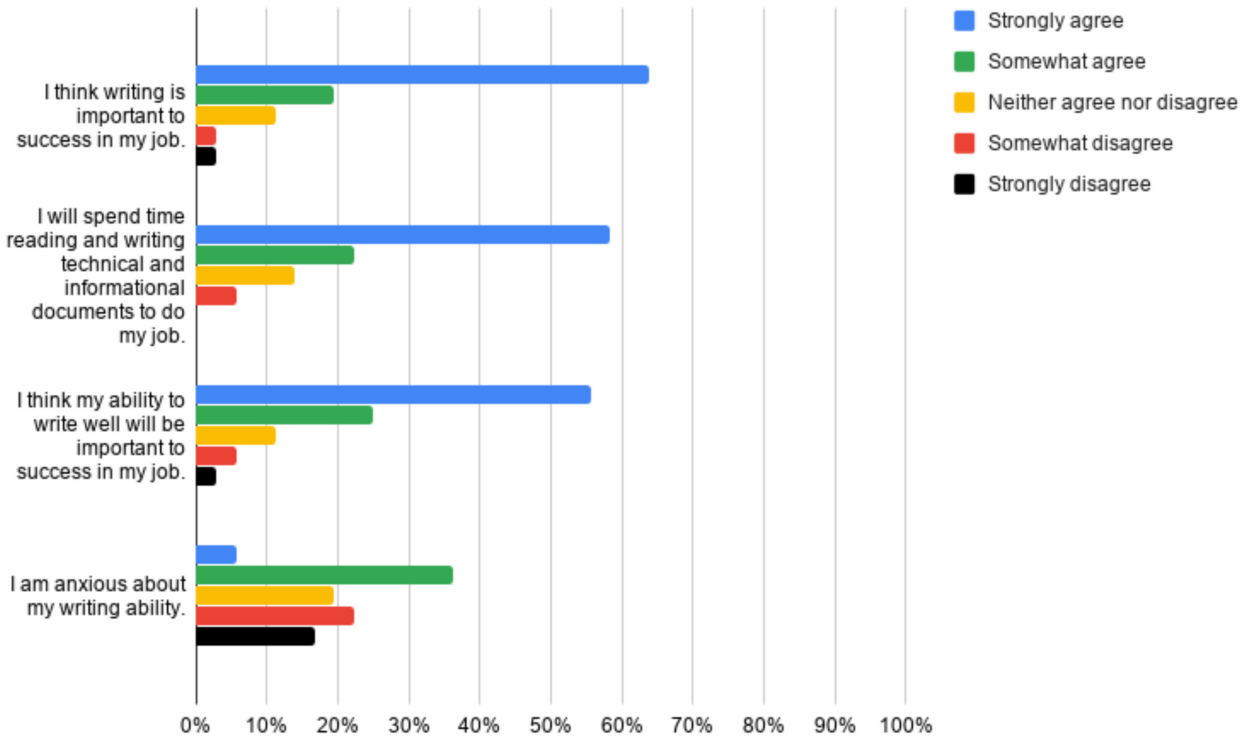

Fig. 4. Participants' reported level of awareness of writing in professional success.

As shown in Fig. 3, over 60% of the survey participants indicated that the technical communication interventions helped them with their skills in documenting and presenting procedural information, selecting and organizing appropriate content for their audience, and documenting and presenting the results and conclusions of their work. Over 50% of the students responded that the technical communication interventions helped them with identifying knowledge and needs of their audience, improving the formulation and organization of their writing, and using a writing style appropriate for their audience. About 40% of the students saw benefits in the interventions in creating a usable document and incorporating visuals and numerical data. About 30% of the students indicated that the interventions helped them with documenting and presenting secondary research and theory, while only about 15% found the interventions helpful in reading a new or unfamiliar genre to understand how it works. We believe that the last two findings result from the fact that these topics were not particularly emphasized during the interventions, or the students did not get to practice with these two factors after the workshop to observe the improvements in their skills.

The hybrid model helped students make the connection that writing is not an afterthought or an inconvenience, but is at the heart of what an engineer does: engineers solve problems and, just as important, communicate those solutions to others including decision makers in a way that enables the best use of the information provided. This is one of the reasons why the "ability to communicate with a variety of audiences" is a high priority for ABET [1].

Each category documented in Fig. 3 illustrates a growing awareness of audience, including who will read engineers' writing, how to present information in ways most useful to the audience, and how to meet readers' needs. This sophisticated audience awareness shows a realization that effective professional writing is far more than avoiding grammatical mistakes or writing the same way in every situation.

Fig. 4 illustrates students' increasing awareness of the role that writing plays in achieving professional success in engineering fields, as a result of the presented hybrid model, which prepares the students for the importance of "effective communication" in the engineering professions, and "communicating effectively" as engineers.

As shown in Fig. 4, more than 80% of the respondents indicated that they strongly agreed or somewhat agreed with the statement "I think

writing is important to success in my job" (64% strongly agreed, 19% agreed) and "I think my ability to write well will be important to success in my job" (56% strongly agreed, 25% agreed). And 80% of respondents strongly agreed (58%) or somewhat agreed (22%) that "I will spend time reading and writing technical and informational documents to do my job." Only about 40% of the surveyed students agreed that "I am anxious about my writing ability," a result that is promising after the introduced interventions, increasing students' awareness of the importance of writing to success and their technical writing skills.

Faculty and Administrators Believed That Multiple Parts of the Approach Were Beneficial

Paretti et al. showed that engineering instructors are largely supportive of discipline-specific communication instruction in their courses and do not necessarily want professional development or training from writing faculty; supporting materials can help them give communication the necessary instructional time and attention [20]. The curriculum map prepared as part of this program is one example of a tool that can utilize the expertise of writing faculty to support ongoing instruction in writing from engineering faculty without having to choose between technical instruction and writing instruction as a solution to the problems identified in the literature [13], [20].

Three participating faculty in engineering provided feedback on the interventions. One noted that

> The technical writing workshop continues to show a benefit to the students' ability to write a professional report. The students learn how important proper formatting is, along with placing titles below figures and above tables. Technical correctness and spelling are critical to clear communication.

A faculty member/administrator said the "in-context writing instruction" was particularly valuable. Furthermore, an external team of on-campus evaluators congratulated both the engineering and English/TPW faculty on the jointly developed creative solution presented here as the hybrid model, which allowed "in-context" workshops provided by the faculty collaborators in English/TPW that both faculty and students in engineering found valuable.

Conclusion

In this study, we present a hybrid model that captures collaborative efforts between the departments of engineering and English for technical communication education in engineering contexts. Planning for when, where, and how to support engineering students in this case required resolving complex and sometimes competing needs at student, faculty, program, and institutional levels. The developed hybrid model allowed the authors to meet multiple needs by mixing approaches to integrating technical writing instruction with engineering instruction and doing so in a collaborative, sustainable, and flexible way that students perceive as beneficial—and are thus more likely to learn from and value.

This teaching case set out to investigate three questions: Did students participate in a mixture of different interventions? What experiences did students have? Did students and faculty find the interventions beneficial? The interventions in this program were designed and implemented to fit the engineering students' degree plan over time, and students reported experiencing a combination of workshops and Writing Center tutorial sessions, as well as using the Engineering Style Sheet. Students responded most positively to workshops that were embedded into courses and connected to specific projects that they were actively working on (such as a workshop and conversation about audience and translating technical information and rationales to nonspecialists as students were working on capstone project proposals). These workshops relied on participation from both technical writing and engineering faculty. The majority of the surveyed students who participated in the technical communication interventions reported improvements in their technical communication skills in six out of 10 presented contexts as a result of the interventions. Participants reported their understanding of the importance of technical writing in the engineering profession had improved; a significant majority of the students (over 80%) agreed with the importance of writing and writing well to the engineering profession and their own success.

One drawback of the case study approach is a hallmark of case study research: generalizability is not possible because of the small sample size. Because the research portion of this teaching case relies on self-reported data about improvement and learning, the study does not measure effectiveness of the hybrid model in the same way a quasi-empirical classroom study might. At the same time,

our goal was not to measure effectiveness in terms of whether workshops or Writing Center visits determined improvement on particular technical writing skill outcomes. Instead, our goal was to evaluate the effectiveness of the hybrid model in terms of its reach and perceived benefit from key stakeholders such as engineering students and faculty. The positive outcomes reflected in the survey results thus indirectly support the improvement of general technical writing skills based on the introduced interventions.

The results of the case study do not show that there is one correct way to collaborate among the engineering and technical and professional writing programs. Rather, by combining and drawing from multiple approaches, the hybrid model is adaptable to different institutions with appropriate interdepartmental collaborations and institutional support to match the institution's own set of parameters. Local solutions must take a multitude of variables into consideration. Such variables include not only the people and programmatic cultures, but also disciplinary and institutional contexts, in addition to curricular, regulatory, and funding constraints.

This article presents a highly feasible and implementable hybrid model that combines support from both engineering and writing faculty, as well as the institution, tested through a case study. The hybrid model resulted in a number of successful communication and writing interventions over time in the engineering curriculum where the engineering students participated within the context of their engineering coursework. The success of these collaborations and interventions lies in the mutual respect and understanding of all of the constituents; the engineering and writing faculty embraced the needs of the students and contributions of each of the programs to the education of the engineering students. Working together with the trust necessary for the hybrid model to work, interventions were implemented noninvasively without sacrificing technical course content or the need for an extra technical communication service course.

Seeing "teaching technical communication" as part of "teaching engineering," engineering faculty alloted class or laboratory time in courses that were already part of a tightly packed engineering curriculum. Writing faculty worked together with engineering faculty in that engineering context. The institution also showed that it valued technical and professional writing faculty time by providing financial support for the faculty members who conducted the workshops and for the personnel who developed writing guides or contributed to the development of the hybrid model in other ways. Institutional support is therefore particularly important in the successful implementation of the hybrid model for engineering technical communication interventions.

The introduced and implemented hybrid model for technical communication education of engineering students represents a flexible, sustainable model that is adaptable and adoptable to meet specific needs in specific environments at different institutions.

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