Interdisciplinary Collaboration to Address Mechanical Engineering Students' Writing

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Abstract

Producing clear, concise technical writing is often challenging for engineering students, despite the necessity of strong communication skills in the workplace. This paper will discuss a collaborative effort between a mechanical engineering professor and an English professor to improve writing by senior level students in a design course. In previous years, the mechanical engineering professor had noted grammatical errors, substandard document design, and overly complex language in student writing. These errors were attributed to an almost four-year time lag between the freshman technical communication course and the senior design course. To address these issues, a technical writing handbook specific to engineering design reports was developed, as were content and writing-focused rubrics. These documents were intended to reinforce concepts that had been taught in the technical communication course but had been perhaps forgotten by students.
Students were also encouraged to consult with the English professor at the university writing center. Additionally, writing quality was made a significant portion of the students' grades and the writing instructor was given responsibility for assigning that grade. The two instructors met regularly to discuss student work and grading decisions.

A questionnaire gauging student satisfaction with the program indicated that students found all aspects of the program useful. Both faculty members also benefited from the collaboration, seeing not only improvement in student writing but also opportunities to improve writing instruction in their respective courses. These improvements will be discussed as will the exposed need for additional interdisciplinary communication.

Introduction

During the fall of 2012, Dr. James Canino, a mechanical engineering professor at Trine University and Professor Sarah Young, an English instructor at the institution, incorporated a writing component into a required engineering design course. The intent was to address an apparent loss in students' writing skills between their last required English course, taken in their freshman year, and a writing-intensive design course, taken in their senior year.

Writing Instruction for Engineering Majors at Trine University

All engineering majors take a technical communication course during their freshman year. The course is project-based, using case studies to approximate real-world experiences. In the first half of the semester, students work collaboratively to produce a number of documents. They write a set of instructions, a series of definitions and descriptions, and a response to an ethical dilemma using the code of ethics from their field of engineering to support their decisions. They are also

taught to use graphics for communicative purposes and to integrate graphics and text effectively. In the second half of the semester, students research a problem that affects the campus population and propose a creative solution. These written proposals are usually 20-30 pages in length and are presented before university faculty and staff during the final exam period.

Multiple sections of the course are taught each year. Several full-time faculty members share the teaching load and collaborate regularly to ensure the content and structure of each section is similar. These instructors have identified four major foci of the course. Students are urged to write clear, concise sentences, to design documents for maximum readability, to write to a defined audience, and to consider the ethical ramifications of documents they produce.

At first, students struggle mostly with clarity and mechanical problems. Instructors use very low grades on early, low-stakes assignments to make the point that accuracy and attention to detail are paramount. As the semester continues, focus shifts to issues such as effective document design, avoiding fallacious and misleading arguments, and adapting sections of long reports to different audiences. Results of exams and end-of-course reflections indicate that most students become knowledgeable about these foundational writing skills, even if they are not entirely proficient in performing them.

Writing in Thermo-Fluid Component Design

Thermo-Fluid Component Design (TFCD) is a required senior year class at Trine University. The objective of TFCD is to partially satisfy ABET requirements (c), (g), (h), and (k). To this end, TFCD incorporates two major design projects. The students are required to work in groups of 3-4 for each project and to complete a design report after each of the two major projects. Further, students are required to make a presentation of their results from the second project. Dr. Canino had been teaching TFCD since the fall of 2010 and, after reading approximately 50 project reports, concluded that his students desperately needed assistance with their technical writing. Common errors included:

- Overly complex language which obscured the engineering design.
- Figures which were not discussed in the text and were not well designed enough to be self-explanatory.
- Documents that were poorly designed, such that many pages throughout the document needed to be viewed simultaneously in order to understand the design.
- A misunderstanding of audience, such that despite explicit descriptions of the audience to be addressed, students often directed their design reports to Dr. Canino as the professor.
- Poor grammar and conventions, such that the errors interfered with reading the reports.

Dr. Canino found these and other issues so significant that when Professor Young sent an e-mail to the engineering faculty asking if anyone was interested in collaboration, he quickly replied. Dr. Canino and Professor Young then began working on a means to incorporate technical writing into TFCD for the fall semester of 2012.

Description of the Collaboration

The first task was to determine how to assess student writing. A rubric with four categories – adaption to audience, document design, organization, and mechanics – was designed. In each category, students were given a score of 95%, 85%, 75%, 65%, or 25%. These scores were averaged to determine the overall grade on the writing portion of the reports. A separate rubric, designed by Dr. Canino alone, was used to evaluate the reports' technical content.

Once the writing rubric was completed, it was necessary to determine what percentage of the students' grades would be based on it. Initially, Dr. Canino decided on 10%. However, discussions with other professors at Trine indicated that 10% was not significant enough to motivate the students to improve their writing. Therefore, it was determined that 30% of the students' project grades would be based on the technical writing rubric. At first Dr. Canino was uncomfortable making the technical writing portion of the design report worth such a high percentage. A student could earn a failing grade on the technical portion of the design, yet still receive a passing grade based on the writing portion. In order to address this concern, Dr. Canino indicated on the technical rubric that an "F" grade in certain sections would require the group to redo the design project for a maximum possible grade of "C". For example, if students made a major error in their pipe flow calculations, which resulted in a design that violated conservation of mass or linear momentum, they would be required to redo the project. Examples of both rubrics are appended to the end of this paper.

In retrospect, Dr. Canino's concerns regarding the 30% weighting of the writing rubric were overstated. It was found that the best engineering designs also had the best reports. In truth, students must understand their engineering analysis if they are to explain it in a clear and concise manner.

After writing the rubric, Dr. Canino and Professor Young collaborated to draft a guide to writing engineering reports. The guide was distributed to students at the beginning of the class and was intended to be used as a resource as the students were writing. The guide was partially based on similar documents created by the Department of Mechanical Engineering at the University of Minnesota.[1] An additional change to the course was that students were asked to submit multiple drafts of certain sections of their report. Both Dr. Canino and Professor Young provided feedback individually and then met to discuss their assessments. Students were encouraged to seek Professor Young outside of class for assistance with the writing and design of their reports. These meetings often occurred in the Trine University Writing Center.

Students' Reactions to the Collaboration

To determine if the students found the addition of technical writing to the course useful, students were asked to fill out a simple anonymous survey. Twenty-one of the 24 students in the class took the survey. Some of the results are summarized in Figure 1. As can be seen, the vast majority of students found the writing guide, in-class review of technical communications, Writing Center, and grading rubric useful.

Dr. Canino and Professor Young were surprised to learn that students found the in-class review helpful. After the review both instructors had decided to eliminate it from future classes since it seemed to have gone "poorly." Based on the student feedback, the in-class review will be retained and improved for future classes.

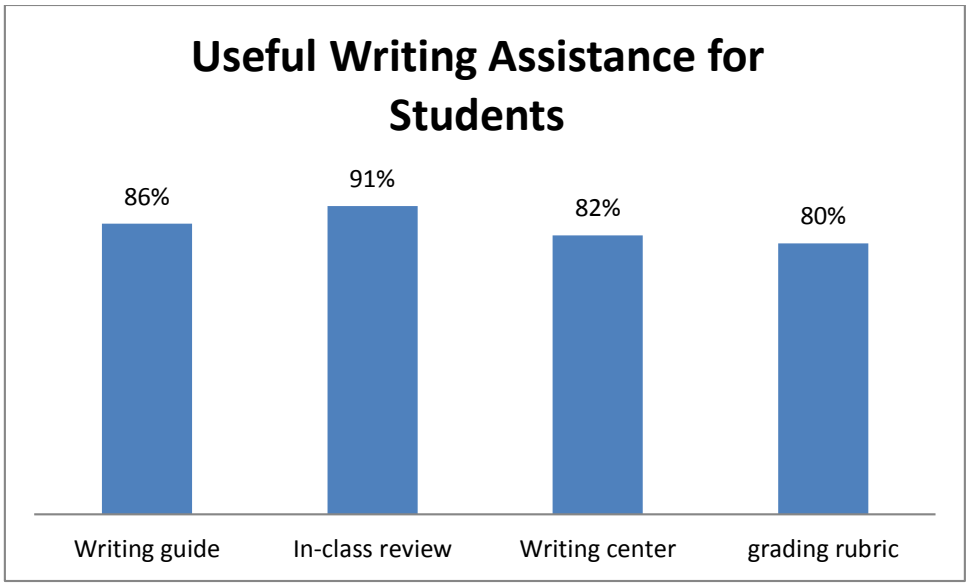

Figure 1. The percentage of students who answered "strongly agree" or "agree" to the statement "I found the following tools useful."

Before reading the free response section of the survey, the instructors expected students would respond negatively to the additional focus on technical writing. Dr. Canino believed that engineering students would do anything to avoid an additional English course. On the contrary, many student comments indicated a positive experience. A few such comments are shown below.

- "The technical writing in the course was very useful. I wish that more of my classes during my sophomore and junior year would include writing more technical documents and presentations. It was difficult to bring myself back in the mindset of technical communication with the gap between first semester sophomore year to now."
- "I think we found ourselves challenged to express these technical ideas in a manner different from how we have always experienced it; purely technical and riddled with engineering jargon…Seniors nearing entry to the workforce should be exposed to the feedback from someone like Professor Young, a non-technical reader, to practice their writing skills for the wide array of audiences an engineer's work will have."
- "This [Technical Writing] is a skill that I am aware will be required in the mechanical engineering field, and though it provided a challenge greater than the technical project alone, I am grateful for the experience."

Surprisingly, not one of the free responses was negative towards the integration of technical communications into the class. There were a few suggestions on how to improve the course, but these were more concerned with the details of the integration of technical communication into the course, rather than calls for its complete removal.

As typified by the first student response quoted above, many students commented on the significant delay between their technical communication class and writing assignments in their engineering classes which occur in their senior year. Several students suggested that the faculty examine ways to incorporate writing into the sophomore and junior years.

Engineering Instructor's Reaction to the Collaboration

The collaboration was very valuable to Dr. Canino for several reasons. The collaboration allowed him to focus on the engineering content of the reports without having to be concerned with the reports' format and conventions. This allowed Dr. Canino to spend more time evaluating the engineering design, while still knowing that the students would be given valuable feedback regarding their technical communication. Moreover, it was nice to know that the elements of technical communication that Dr. Canino found important were being taught in the freshman technical communications class. In previous semesters, when Dr. Canino pointed out issues with documents, some students argued that they had never been taught that concept. Through this collaboration Dr. Canino is now confident that the concepts he perceives as important are being taught to the students, and they can be held accountable for that knowledge in upper division classes.

An unexpected benefit of the collaboration was that the engineering content of the reports was easier to grade. Since there was a focus on clear and concise writing, the reports were shorter but contained all of the technical information necessary to perform an evaluation. Additionally, much less time was spent trying to decipher what the students were attempting to describe, since their grammar, conventions, and document design had improved so significantly.

Moreover this collaboration and the response from the students served to reinforce the idea that good communication skills need to be incorporated into the sophomore and junior year in Trine's mechanical engineering program. Not only did the students note that the time lag between technical communications and this class was problematic, but Dr. Canino also noted significant improvement in the writing of this semester's students over previous semesters' students. He hopes that additional opportunities to practice good technical writing earlier in the curriculum will lead to better capstone design reports.

English Instructor's Reaction to the Collaboration

The collaboration was also valuable to Professor Young. Technical communication instructors have often expressed frustration at not knowing whether the skills emphasized in the course actually benefit students later in their academic careers. Occasionally, faculty members have even proposed eliminating technical communication courses entirely to "let the engineers handle their students' writing." The perception was that the sort of technical writing required in engineering fields was too far removed from the expertise of the English faculty. Through this collaboration, Professor Young learned that most of what is being taught in technical communication is directly applicable to writing done in upper division courses. She was also able to make judgments about which skills to emphasize in future technical communication courses.

In order to address the time lapse between the freshman writing course and the senior design course, she intends to alter the written final exam. Students currently write a self-performance review, enumerating the skills they have acquired in the course. In the future, they will be presented with pages of a flawed technical report, modeled on ones written for thermo-fluid component design. They will be asked to evaluate the report's overall effectiveness and to correct a number of key errors. They will then write a brief report explaining the skills from technical communication that they will need to apply in their senior design course. Potentially, these documents can be saved and returned to students in their senior year as a reminder.

Changes to Future Collaborations

After reflecting on the experience and examining student feedback, the following changes have been considered.

- Administer an initial assessment, in the form of a 1-2 page writing assignment, to determine what skills and knowledge students have retained from Technical Communication. This should help instructors tailor the review sessions to the needs of the class.
- Structure the assignment schedule so that students are able to get feedback on significant portions of their report before turning it in for a final grade. Often, students finished their final draft only hours before turning it in and thus had no time to consider revisions.
- Spend additional time discussing and defining the reports' various audiences and their needs. Students, understandably, had difficulty anticipating the needs of hypothetical audiences. More emphasis needs to be placed on this concept at the beginning of the course.
- Alter the assessment of "adaption to audience" so that the English instructor is assessing this concept only in the executive summary and conclusion and recommendation sections. It was difficult for Professor Young to determine whether the technical sections of the report met audience expectations. An engineering professor is better equipped to make these sorts of judgments.
- Train Writing Center tutors to work with engineering reports. Part of the goal of the program was to encourage engineering students to seek outside assistance with their writing. It was difficult for Professor Young to provide all of that assistance herself. Additional tutor training would benefit not only thermo-fluid component design students, but also students in other engineering design courses.

Conclusions

In conclusion, the collaboration between an engineering professor and an English professor in a senior level design class yielded benefits to the students and the faculty involved. This collaboration will be continued and hopefully similar collaborations can be integrated into the senior capstone design class. Additionally the collaboration exposed the need for greater communication between engineering and English faculty. Prior to the collaboration, both groups had misconceptions about the other's curricula, classroom expectations, and student needs. Increased communication between the disciplines should enable instructors to make more informed decisions about classroom practice.

References

1. The University of Minnesota Department of Engineering. "U of M Department of Mechanical Engineering: Undergraduate Education: Writing Standards." University of Minnesota . 2012 . http://www.me.umn.edu/education/undergraduate/writing.shtml (accessed January 12, 2013).

Biographical Information

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Rubric for Evaluating Technical Content of Project 1

Final Grade _____% / 70%

PIPE FLOW COMPUTATIONS: Are all of the pipe flow computations done correctly? _____% / 35%

A (95%)	The major losses, minor losses, and flow rates are all computed correctly
B (85%)	The major losses, minor losses, and flow rates are computed correctly, but there are a few losses that were unaccounted for. The losses could have easily been overlooked.
C (75%)	A significant error is present in the computation of the major losses, minor losses, or flow rates. However, the error does not mean your design violates conservation of mass or energy and your design requirements are still satisfied.
D (65%)	A significant error is present in the computation of the major losses, minor losses, or flow rates. The error is blatantly obvious and provides significant evidence of a lack of understanding of the basics of pipe flow. The error means your design does not satisfy the design requirements, however, the error does not mean your design violates conservation of mass or energy.
F (25%)	You have failed to meet the minimum requirements for a "D," outlined above. There are serious and pervasive errors. The pressure drops and/or flow rates you have computed are obviously wrong. Receiving an "F" in this section will require you to re-due your project with a maximum project 1 grade of 74%.

HYDRODYNAMICALLY REMOTE AREA: Has sufficient analysis been done to justify the most hydrodynamically remote area? _____% / 7.5 %

A (95%)	All reasonable areas were checked with corresponding calculations to verify the selection of the most hydrodynamically remote area
B (85%)	More than one area, but not all reasonable areas, was checked with corresponding calculations to verify that the selection of the most hydrodynamically remote area. The missed area could have been overlooked due to a small misunderstanding of pipeflow.
C (75%)	More than one area, but not all reasonable areas, was checked with corresponding calculations to verify that the selection of the most hydrodynamically remote area. The missed area should have been checked.
D (65%)	Only one area was checked with corresponding calculations to verify that the selection of the most hydrodynamically remote area. It is obvious based on a simple inspection that the missed areas should have been checked
F (25%)	You have failed to meet the minimum requirements for a "D," outlined above. There are serious and pervasive errors. Receiving an "F" in this section will require you to re-due your project with maximum project 1 grade of 74%.

JUSTIFICATION OF DESIGN DECISIONS: Have all of the design decisions been justified? _____% / 7.5 %

A (95%)	All design decisions have been justified along with logical explanations that will convince your audience your design is the "optimal" choice
B (85%)	All design decisions have been justified along with logical explanations, but your explanations fail in some ways to convince your audience your design is the "optimal" choice
C (75%)	All design decisions have been justified, but some of the justifications are wrong or misleading. Your explanations fail in to convince your technical manager, but might convince someone with less technical knowledge.
D (65%)	Some design decisions have been justified, but some of the justifications are wrong or misleading. Your explanations fail in to convince your technical manager, but might convince someone with less technical knowledge.
F (25%)	You have failed to meet the minimum requirements for a "D," outlined above. There are serious and pervasive errors.

DESIGN REQUIREMENTS: Have all of the design requirements been satisfied? _____% / 10 %

A (95%)	All design requirements have been satisfied along with a complete set of calculations
B (85%)	All design requirements are satisfied, but a few minor calculations are missing
C (75%)	All design requirements are satisfied, but no effort was placed in minimizing costs. There are obvious cost improvements that can be made to the design without impacting other requirements.
D (65%)	Most of the design requirements are satisfied. You must at least be under the hydraulic graph to earn any grade other than F.
F (25%)	You have failed to meet the minimum requirements for a "D," outlined above. There are serious and pervasive errors. Receiving an "F" in this section will require you to completely re-due your project with maximum project 1 grade of 74%.

CONTENT: Does the document include the information the audience needs to understand and/or act? _____% / 10 %

A (95%)	Document includes all of the information that the audience needs to fully understand and/or act
B (85%)	Document includes most of the information that the audience needs to fully understand and/or act
C (75%)	Document includes some of the information that the audience needs to fully understand and/or act
D (65%)	Document includes a minimal amount of the information that the audience needs to fully understand and/or act
F (25%)	You have failed to meet the minimum requirements for a "D," outlined above. There are serious and pervasive errors.

Rubric for Evaluating Writing and Document Design in Engineering Reports

Final Grade (average of the four categories below) _____% / 30%

AUDIENCE: Is the report written with the audience in mind? _____**%**

A (95%)	Each section is perfectly tailored to its primary audience, obviously taking into account their needs and level of expertise.
B (85%)	Each section addresses the needs of its primary audience well with a few lapses
C (75%)	The primary audience for each section could probably read and follow this report but some or all sections have not been written with them in mind.
D (65%)	The primary audience for some or all of the sections would have trouble understanding this report. Report was written with the instructor in mind, not the audience indicated on your assignment sheet.
F (25%)	You have failed to meet the minimum requirements for a "D," outlined above. There are serious and pervasive errors.

ORGANIZATION: Is the report organized to help readers find information? _____%

A (95%)	Well-designed front matter, headings, and subheadings help the reader understand the report's organization. Organization, both between and within paragraphs, is clear. There is strong use of transitions. Report avoids all unrelated tangents and unnecessary repetition
B (85%)	Front matter, headings, and subheadings help the reader understand the report's organization with a few lapses. Paragraphs are almost always presented in a logical sequence and connected with good transitions. Organization within paragraphs is almost always clear. Report avoids almost all unrelated tangents and unnecessary repetition.
C (75%)	Front matter, headings, and subheadings are present but have multiple, noticeable errors. Paragraphs are sometimes presented in a logical sequence and sometimes not. There is only sporadic use of transitions. Report contains several unrelated tangents and/or instances of unnecessary repetition.
D (65%)	Front matter, headings, and subheadings are either not present or have frequent, distracting errors. Paragraphs are usually not presented in logical sequence. There is very limited or no use of transitions. Organization within paragraphs is almost never clear. Document contains frequent distracting unrelated tangents and/or instances of unnecessary repetition.
F (25%)	You have failed to meet the minimum requirements for a "D," outlined above. There are serious and pervasive errors.

DOCUMENT DESIGN: Is the report designed for maximum readability? _____%

A (95%)	Document is professionally designed. Short paragraphs create maximal white space on the page. Fonts, font sizes, and styles are used appropriately to signal levels of importance. Related information is placed as close together as possible. All figures and graphics clearly communicate an idea or argument. They are all labeled and (if necessary) cited appropriately. All figures and graphics are explained thoroughly in the text and referenced by title.
B (85%)	Document makes a strong attempt at professional design. Short paragraphs create good white space on the page. Fonts, font sizes, and styles are used appropriately to signal levels of importance, with a few lapses. Related information is placed close together, with a few lapses. Figures and graphics clearly communicate an idea or argument, with a few lapses. Figures and graphics are almost always labeled and (if necessary) cited appropriately. Figures and graphics are almost always explained in the text and referenced by title.
C (75%)	Document attempts professional design. Short paragraphs are sometimes used to create white space on the page. There is an attempt to use fonts, font sizes, and styles to signal levels of importance, though there is much room for improvement. Related information is sometimes placed close together, though there are a number of mistakes (i.e. headings appear alone at the bottom of a page or a graph is explained on a different page than the one on which it appears). Figures and graphics sometimes communicate an idea or argument. Figures and graphics are sometimes labeled and (if necessary) cited appropriately. Some graphics and figures are explained in the text and/or referenced by title.
D (65%)	Document fails to meet professional design standards. Paragraphs are usually too long and white space is minimal. There is little or no apparent attempt to use fonts, font sizes, and styles to signal levels of importance. Related information is hardly ever placed close together on the page. Figures and graphics rarely communicate an idea or argument. Figures and graphics are rarely labeled or (if necessary) cited appropriately. Very few graphics and figures are explained in the text and/or referenced by title.
F (25%)	You have failed to meet the minimum requirements for a "D," outlined above. There are serious and pervasive errors.

CONVENTIONS: Is the report edited and proofread to a professional standard? _____%

A (95%)	There are virtually no errors in spelling, grammar, punctuation, and/or word choice. Sentences are simple, direct, clear, and concise.
B (85%)	There are few errors in spelling, grammar, punctuation, and/or word choice. Sentences are simple, clear, and concise with only a few lapses.
C (75%)	There are a number of noticeable errors in spelling, grammar, punctuation, and/or word choice which do not interfere with understanding. Sentences are usually simple and clear, but there are some awkward constructions, wordy sentences, and/or repetitious phrasings.
D (65%)	There are many distracting errors in spelling, grammar, punctuation, and/or word choice which interfere with a reader's ability to understand the report. There are frequent awkward constructions, overly wordy sentences, and/or repetitious phrasings.
F (25%)	You have failed to meet the minimum requirements for a "D," outlined above. There are serious and pervasive errors.