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Board 100: Enhancement of a Thermo-Fluid Laboratory Course: Focus on Technical Writing

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Abstract— Enhancements to laboratories and the courses which facilitate their use is important to better preparing students for course work, research experiences, and future contributions in the field of engineering. The thermo-fluids lab course offered by the Department of Mechanical Engineering in the College of Engineering Technology and Architecture (CETA) at the University of Hartford is a 3-credit course that has provided a platform for an increasing number of experiments and writing opportunities. This course is also classified by the University as a writing intensive course, meaning students write a minimum of 15 graded pages and specific course objectives related to writing are included on the syllabus, making it a cornerstone of the students' education. This study reports on continued enhancements made to the writing intensive nature of the course, including specific instruction on technical writing and writing as a group. This instruction was provided by the primary professors as well as a member of the University Writing Fellows, a dedicated group of faculty who focus on writing instruction across the curriculum. Writing activities include impromptu writing assignments, peer review, outlining and planning exercises. The overall approach to improving students' skills was: "group-based technical writing development". Assessment tools include instructor-written observations, student surveys, and in-class analysis of short writing samples by peer evaluation. The course itself, which focuses on experimental methods in fluid mechanics and heat transfer, stresses experimental techniques, results presentation, and technical report writing. Experiences in this course have also provided opportunities for honors work, and research opportunities for undergraduate engineering students.

Motivation

As writing in engineering classes can often be pushed to the side, or at least not the focus, a concerted effort in technical writing efforts is important. The primary stage for such an effort can many times be lab courses which require lab reports. In the ongoing development of a thermo-fluid lab course, impacts on student group writing have been observed by instructors and by students themselves. However, these impacts – many times anecdotal – are deserving of further inspection. Further, the potential impact of these group writing enhancements on students' technical writing abilities, and their perceived confidence in such abilities, is important when considering that these experiences might be the primary ones that students receive before completing a degree in an engineering program.

Hence, the present study is motivated by these factors, and the overall interest in maximizing the students' writing capabilities as stimulated by a program in mechanical engineering.

An effort is made as part of this study to capture some of the long-term impacts of the efforts in the thermo-fluids lab course, through a survey of student perceptions of their abilities and experiences. The data included in this study was administered to seniors in a post-requisite thermo-fluids course asking them to reflect back on their technical writing skills and the courses that impacted such skills. This cohort of students had directly been impacted by the technical writing efforts described in this study, and hence could provide such insight as they would have had some time to apply such technical writing skills.

While it would additionally be interesting to see the mapping of the writing and technical learning objectives, and further if the emphasis on writing affected students' technical abilities in understanding thermo-fluids content, such results are only included in this study as part of instructor feedback, and not based on specific empirical evidence which can be observed through the methods in this study. Still, such a topic should be considered in the future.

Instruction on technical writing in the curriculum many times happens through the lab courses. In the Mechanical Engineering Department at University of Hartford, there are currently (at the time of this paper) two lab courses which are deemed writing-intensive courses. In the thermo-fluids lab course, students work within a group on a single technical document, and hence instruction on group based technical writing should be emphasized, with the expectation that better writing and by effect, better overall communication on technical content, will reflect better understanding of the concepts.

Background

Previous literature on the subject of group writing in engineering education has shown a number of interesting results. Shulz and Ludlow [1] focused on group dynamics as a means to successful group technical writing. They looked at leadership within the group and how receptive students were to feedback and criticism from other group members. By focusing on these aspects, they showed improved group technical writing. Nelson [2] chose to focus on smaller group assignments to teach technical group writing. The in-class assignment of writing a generic press release gave students a chance to work in groups with immediate feedback. This helped students in future group-writing assignments. Wheeler and McDonald [3] observed four primary benefits from teaching writing to engineering students. They found that writing enhances group discussions and improves group dynamics. They also found that a synergy develops between writing and collaborative learning when students are asked to critique each other's writing. Shull [4] focused on the design of collaborative techniques to increase both substantive learning and communication skills. They found that the more collaborative assignments were given, the greater the improvement they saw. Using peer editors for written assignments was shown to offer improved group writing skills without the loss of technical learning.

Aditomo et al. [5] observed that writing, when done in groups, was very student centered. They found that students were aware that their portion of the group writing assignment required them to do some independent research to form their own argument. They also found that students still felt the need to meet face to face and not simply complete their group assignments online only.

The present paper focuses on teaching technical group writing in the context of a laboratory setting, rather than in the context of projects or research reports. Technical experimental report writing varies from other types of technical writing as all students participated in the experiment and there is little research involved in the writing.

The thermo-fluids lab course (ME 342W) has a pre-requisite, Heat Transfer, which has its own pre-requisites including Fluid Mechanics. The lab course that typically precedes ME 342W by a year is a Mechanical Engineering Materials and Laboratory course (ME 213W). The typical structure of ME 342W is that there is a lecture each week and a lab each week, with each group performing a lab experiment once every two weeks, and having the remainder of the two weeks to produce a completed lab report. Grading of the lab reports can be guided by use of a rubric, which is also used to give students categorical and clear feedback on their reports in addition to one-on-one written and verbal feedback. The lab facilities utilized includes a wind tunnel, a piping network, a water table, a pump lab, various measuring devices for measuring fluid properties such as pressure and temperature within the lab facilities themselves and as part of individual lab apparatuses, from conduction labs to convection labs to concentric pipe heat exchangers.

Enhancements: How the teaching of technical writing skills is achieved and by whom?

Instruction and recent changes made within the past three years include updating of the lab manuals and consulting the resources of common engineering organizations such as ASME and AIAA, with respect to conference paper requirements. Additional changes include the utilization of MATLAB for processing larger amounts of data, and managing uncertainty analysis throughout the data processing.

Instructors enhanced their teaching of technical writing skills. Students enhanced their technical writing. Some of the class exercises and instruction techniques that were utilized by instructors included activities which put focus on how to work on one document as a group, and other activities which directly highlight certain sections of a lab report. Exercises and techniques include but are not limited to:

- Outlining
- Review of sample lab reports and conference papers
- Exercises which focus specifically on procedure and order of operations in the lab
- Knowing your audience
- The Abstract, before and after

The outlining exercises included having students write a 1-2 page outline for the impending lab report. Such an outline could be based on the general structure of a lab report, the theory required to analyze what was done or would be done in the lab, preparing to answer direct questions asked by the instructor in class or explicitly in the lab handout, and brainstorming of bulleted points, or sub-bullets that could be included which help the lab report to flow and be as informative as possible. Having students work in groups to develop their outlines was a step better than what might typically happen – students many times look at a lab handout or instructions and simply assign parts of the report to each other. Completing an outline together made it so that there was already input from multiple members on each section of the report. They took ownership of the report as a group. They had not only sections that they were considering, but also, sub-sections, which could be assigned according to each student's particular talents or interest. This time, since the outlining procedure preceded these steps, they were better able to manage expectations within their groups. Further, although there were students who were primarily responsible for certain sections, or sub –sections of the report, there was the added benefit that members knew early on who might have interest or capability in providing assistance with certain sections, whether early on in the process or as deadlines loomed. Overall, the instructors' feedback on this procedure is that it sets the standard for group writing, and seems to help result in lab reports that flow better. It should be noted that while this was an exercise utilized in the present study, upon conferring with fellow instructors to reflect on the best technical writing activities, this was planned to be repeated in subsequent semesters, and even required prior to eligibility of acceptance of students' actual lab reports.

Review of sample lab reports (de-identified lab reports) and conference papers helped students to reflect on instructor's expectations for their reports. It is suggested that such a procedure include a good number of samples, or samples that are close to what the instructor expects. This is because if a small number of samples are reviewed, students may make such an attempt to mimic what was done exactly, and miss the nuances of generating writing samples. For example, a review of sample lab reports and/or conference papers can be done which focuses on one aspect of the writing samples, say all things related to the figures. In reviewing multiple figures, captions, and descriptions of various writing samples, students could start to think, "does that figure convey a clear message?" or "does that figure follow general standards expected of a graph, or schematic, etc.?" or "does that figure do a good job of conveying what the author has described?" Review of sample lab reports and conference papers was important to helping illustrate expectations which were described in the lab manual. It is anticipated that while versions of a lab manual are updated to include some clear examples of select portions, viewing final samples in their entirety, as was done in this procedure is also suggested.

Exercises which focus specifically on procedure and order of operations in the lab, are key to helping students understand what is required of technical writing. Leveraging peer feedback for such an exercise is useful, as students work to explain to each other what was done, and are not only able to identify and demonstrate the literalism required in instructions, but how our own explanation of instructions can be remiss of full effectiveness. While other forms of writing and communication might expect interpreters to read between the lines to determine meaning, or even interpret multiple meanings or varied creative meanings, students are prompted to make sure that anyone (or anyone expected to be part of the their audience) reviewing their writing sample would be able to go into the lab and repeat their procedure if required. One example of a procedure-related exercise that was conducted was an instructions challenge, which required each group of students to write up their most effective set of instructions for making a peanut butter sandwich. Each group had a set time of ten minutes to write up these instructions. Then, each group had a group member come up to the front of the class to read their instructions. It was competitive in nature, but performance or ranking did not affect students' course grades. After all groups read, and the class provided feedback on each, the students all got a chance to vote for the best instructions, and almost unanimously picked the best instructions. This exercise helped students' set their goals of being very thorough in the procedure sections of their technical lab reports.

Knowing your audience, is a good consideration for writing. For example, for the procedure-related activity, students were tasked with writing "clear" instructions. While this should be "clear" for people with even limited technical background, knowing who exactly might be interested in reading such a report, can help in determining what aspects need to be explained in even more depth than others. Further, this helps inform the writing of the abstract as engineers and researchers who might read such a report need to be quickly informed whether it is a report that they indeed want to consider in more detail as they sift through a wide selection of options. An example of this is in describing non-dimensional parameters such as Reynolds number, or characterizing flows in such a way that potential readers can know if this is the type of report they are looking for.

"The Abstract, before and after," is a group-writing technique which was used to enhance writing samples. A sample abstract was projected onto the board and a discussion was generated over what were the good parts, which parts were not as good, and what might be improved. Conversely, there were similar abstracts of better and best quality that were discussed to gage quality and develop improvements that might be considered.

Assessment of students' technical writing abilities, skills and performance

Instructor observation and grading were key to analyzing students' writing skills. Writing samples could be included here, but may not be as clear in illustrating improvements in writing. Hence, future studies will aim to show different versions of the same sections of a lab report, and on the same or similar topics. That way improvements in technical writing (or lack thereof) can be better observed, and more compelling.

The rubric for assessing lab reports is consistently revisited, but typically captures the same type of important elements. Still the upgrading of grading rubrics across sections of ME 342W is a way to better categorize and capture tangible elements of why a piece of writing is better or worse.

In general, the improvement of writing skills, laboratory skills, experimentation, use of instrumentation, and connection to theory, were paramount. The final technical writing products were a way to illustrate student groups' capabilities in all of the aforementioned. In future studies, it could be additionally interesting to include not only surveys, but group and self-assessment of writing assessments, in the same way as peer review.

Evaluation and assessment of overall effort: Likert-scale statements and open-ended questions

Surveys were administered to students in the Thermal and Mechanical System Design (ME 440) course, during the next academic year following the ME 342W course. These surveys included open-ended questions and Likert-scale questions. Since ME 342W is effectively a prerequisite course for ME 440, and builds on similar subject matter, and requires some writing toward the end of the semester, it was decided that this would be a good opportunity to gather student feedback on their writing abilities as seniors in the ME 440 course, and see if previous courses and experiences could be identified by students as helping them with their technical writing abilities. As part of this process open-ended and 5-point Likert-scale type questions were asked, with "1" representing strongly disagree, and "5" representing "strongly agree. Students had the opportunity to provide feedback on their writing skills and experiences in engineering in general, and questions were also asked about the specific course, ME 342W as well.

While Likert scale responses are not reported on a pre- and post- basis, the results do indeed provide a set of data points, which can be built upon in considering insight and continued future improvements of the mechanical engineering program and associated achievement of programmatic goals. Overall students responded positively and in retrospect about their writing abilities and previous experiences in ME 342W.

Survey questions # 1 and #2 were open-ended questions. For survey question # 1, senior-level ME 440 students were asked: "Of all the engineering classes that you have taken at this university, which do you feel was best at helping you with your technical writing skills? Briefly describe why you selected this course." Survey question # 2 followed up by asking students to then specify their choice of second best course which fit this criteria. Table 1 summarizes the answers to Question # 1 (Q#1) and Question # 2 (Q#2), by tallying all of the courses mentioned, whether by course code, explicit course title or some combination of each.

Table 1: Student responses to 5 point Likert-scale statements

Survey Statement	Average	Standard Deviation
During this course (ME440), I utilized writing skills and techniques that were developed and/or honed in my previous ME 342 (Fluid Mechanics & Heat Transfer Lab course).	3.83	1.08
During **any of my courses this semester**, I utilized writing skills and techniques that were developed and/or honed in my previous ME 342 (Fluid Mechanics & Heat Transfer Lab course).	3.86	1.15
During **a previous course, Fluid Mechanics & Heat Transfer Lab (ME342W)**, my technical writing improved.	4.22	1.07
During **a previous course, Fluid Mechanics & Heat Transfer Lab (ME342W)**, my ability to do group-based technical writing improved.	4.33	0.96
I am confident in my technical writing skills.	4.06	0.79
I am confident in my ability to work collaboratively within teams of engineers.	4.31	0.92
During **a previous course, Fluid Mechanics & Heat Transfer Lab (ME342W)**, I became more confident in my technical writing skills.	4.06	1.04
During **a previous course, Fluid Mechanics & Heat Transfer Lab (ME342W)**, I became more confident in my ability to work collaboratively within teams of engineers.	4.08	1.05
Technical writing skills are important.	4.86	0.35
Being able to write as part of a group is important.	4.78	0.54

In regard to Q#1, although the total number of respondents to the survey was n = 36, only 34 students provided answers to Q#1. Of those 34, two students indicated the answer "none." Each of those two students went on to expound on their answer. One stated that "I best learned technical writing at work. Closest would be Fluid Mechanic Heat Transfer Lab." The other stated that "I learned mostly about formatting in mechanics and materials lab." While these two "none" answers can be considered as actually specifying ME 342W and ME 213 as the "best", in Table 1, these are still counted here as "none" to help provide insight which is most useful to the assessment of the effectiveness of the writing efforts in the mechanical engineering program, and specifically in the course of interest (ME 342W). It should be noted that although there were 36 respondents to the survey, there are a total of 37 answers specified in Table 1 for Question #1, since one student wrote two answers: both, "ES212 and ME 350." In regards to Question #2, 32 students provided answers, while four left their answer blank, without any response. Of the 32 respondents, two students specified non-engineering courses such as physics or the freshman writing course. Two students gave indistinguishable answers that were vague or nonexistent course numbers, which did not allow for easy identification of which course they were referencing.

Table 2: Numbers of ME 440 students who recall best courses for improving technical writing skills.

	Course	1st best for technical writing	2nd best for technical writing
a.	Fluid Mechanics—Heat Transfer Laboratory (ME 342W)	23	4
b.	Mechanical Engineering Materials and Laboratory	4	15
c.	Thermal and Mechanical System Design	2	0
d.	"None"	2	0
e.	Blank (no response provided)	2	4
f.	Heating, Air-Conditioning, and Refrigeration	1	0
g.	Heat Transfer	1	1
h.	Vibrations I with Applications	1	0
i.	Mechanics of Materials	1	1
j.	Engineering and Environmental Acoustics	0	1
k.	Graphic Communication	0	1
l.	Capstone Design Project	0	3
m.	Thermodynamics	0	2
n.	Non-engineering course such as " writing," or "physics"	0	2
o.	Indistinguishable (vague description or nonexistent course code)	0	2
	Total number of responses:	**37**	**36**

Evaluation and assessment of overall effort: Open-ended questions #1, #2, and #3

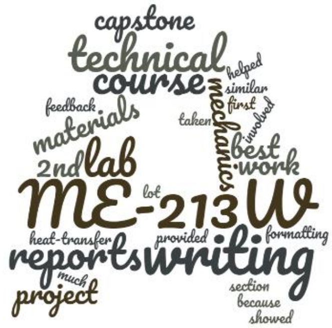
Figure 1 shows three word-clouds which were developed to illustrate student responses to each of the three open-ended questions: Q#1, Q#2, and Q#3. These word-clouds were illustrated to spell out the word, "LAB," since it is the lab courses in mechanical engineering which students selected as best and second best at helping them improving their technical writing skills. From an instructor's perspective, this is not a surprise, and is actually reassuring, as these courses are specifically designated as "Writing Intensive Courses" by the university. Still, in addition to students explicitly specifying the lab courses as the classes which contributed most to their technical writing skills, deeper insight could be revealed as students expounded on their responses to Q#1 and Q#2. Their reasoning for their answers and the type of emphasis that certain aspects of the course may have had on the students were described. For example, one of the most frequently used words in response to Q#1 was "feedback," indicating that the existence, and or level and quality of "feedback," was a determinant in their opinion of the best writing courses in engineering (again, from the perspective of a senior ME 440 student in mechanical engineering).

For cases such as this in which a word was used frequently, the context of the use of the word was then checked to see if it was utilized in a positive or negative way to assess and describe a course. In any case, the uses of the word, whether in a positive or negative statement, indicates its importance in assessing a class, and provides insight for improving future courses and the program in general. Every use of the term "feedback" (a total of 7 times in Q#1) is included here as one example of this check:

- [professor] was really good and detailed at giving feedback on our writing
- Closest would be Fluid [M]echanic[s] Heat Transfer Lab. Lots of feedback from the professor and [m]ultiple opportunities.
- ME 213W the materials lab course would be my second choice. There was a lot of reports, but the feedback on them was not the best.
- ME 342W Consistently provided feedback on content and formatting
- ME 342W, ME 213W did not offer any feedback on any papers and 342 offered plenty of feedback and help
- ME-342W, consistently used ASME format and received feedback on reports
- I feel the best course was ME 342W was the best, because it involved more partner and instructor feedback

In response to Q3, students got to specifically highlight certain activities (or lack thereof) in the ME 342W course. This was also represented in the word-cloud developed in response to Q3, and shown in Figure 1.

(Q1)



(Q2)

(Q3)

Figure 1: Word-clouds summarizing student responses to each of the three open-ended survey questions

It should be noted that, to prepare the word-cloud, certain edits were made to the responses such as the following:

- Capital and lowercase versions of words were combined for example in response to Q1, the word "lab" appeared nine times and the word "Lab" appeared six times; these were combined into "lab" and represented 15 times.
- Plural and singular versions of words were combined for example, in response to Q1 the word "Fluid" appeared four times; "Fluids" appeared two times; and the word "fluid" appeared once. These were combined into "fluid," and counted a total of seven times.
- Words that appeared only once within the response to each question, were deleted for the purposes of generation of the word-clouds.

Student responses to the request in Q#3 to describe the most useful writing skills learned during the Fluid Mechanics & Heat Transfer Lab (ME 342W), are grouped by recurring themes and indicated below. It should be noted that for cases where students mentioned more than one tip/trick/skill in their response, these were split up and listed as separate tips/tricks/skills here:

Tips about Figures:

- Make sure figures are extremely clear and well formatted (and can work if in B &W).
- [Explain] in words then reference images
- Technical formatting and creating effective visuals and figures in a paper
- Combination of clear pictures and diagrams in procedure

Tips and skills about technique and finding the group's "voice":

- To keep everything as straightforward as possible. Less is more.
- Writing a group paper and making sure it sounds like one person throughout.
- I learned how to write a report in a group w/ a good flow. (not choppy)
- How to put data into [the] report,

- Inserting details about every figure
- Be concise when writing reports, cut out filler words and use numbers when possible

Tips and skills about Formatting and sections of report:

- Learning about ASME format
- Basic formatting and sections required
- A skill I learned was how to write in a passive voice
- How to accurately include figures and equations.
- Familiarity with ASME format
- The standard[s] and requirements of writing [an] ASME paper and engineering report paper
- How to convey information technically and
- How to correctly format information correctly
- ASME format in general. I had no prior experience before.
- Learning how to write the proper format for engineering papers

Tips about the role of lab notes in producing a technical report:

- Write things down in detail [during the experiments] as you go, because it's hard to remember details later.

Tips about the flow of the report and group writing:

- How to set up the theory section to flow with the analysis of the lab.
- Outlining a paper with each item we needed to include (bulleted list with subsections)
- How to write a cohesive paper with [multiple] writers, however this could have been discussed some more

Tips about feedback:

- The feedback from [the] professor and clearly understanding the material

Tips and skills about software use, and data processing:

- How to use the shortcuts in word for editing certain sections and pictures.
- How to [properly] format in a two column style
- I learned tricks using word doc and also how to write a [proper] lab paper
- Using MATLAB more in depth

Tips about outlining and organization:

- Organizing thoughts to put in a report
- Planning and revising reports to make writing quicker and easier
- Writing about results and discussion together

Other comments:

- I believe the course can be improved by teaching [students] to use LaTex, using statistical methods (T-test/ANOVA) to verify measured data, review more official publications as examples of strong technical writing
- Everything [the instructor] talked about in class was helpful
- We know how to use that machine and find out the data
- ME 342W was more [professional] writing as an eng[ineer]
- The whole was useful
- I didn't take the heat transfer lab, I just take ME 342

In summary, there were not many specifically worded activities that were listed by students, but there were recurring themes noticeable within their responses. Hence, it is concluded that the course could benefit from more writing activities with even more structure, but the overall writing experiences in ME 342W can be considered to be positive. One example which illustrates the need for a more concerted effort with structured activities is the lack of mention of the "outlining" activities. The concept of writing an outline to a paper, especially as applied to group writing should be emphasized, in such a way that its use is vastly employed in useful ways by students, and would be subsequently evidenced in a resounding manner in any assessment of such technical writing instruction. Conversely, more structured activity and lack of mention in assessment could help show lack of effectiveness of this method, which would still be of interest, as the overarching goal of these efforts is to identify improvements which enhance technical writing, while minimizing those efforts which are less effective. Going back to the example, the concept of "outlining" a paper was only specified once in student responses to Q#3. It is concluded that writing an outline, is among the important activities that can be better structured and/or enhanced, across all sections of the ME 342W lab course, and other engineering labs.

Conclusions

As writing in engineering classes is not the main focus, efforts at still ensuring that students are well prepared for effective technical writing, should be continuously enhanced and revisited. The present study described select activities and assessment of students' perceptions of their technical writing abilities and experiences in the mechanical engineering curriculum. In most cases, students identified the thermo-fluids lab course as the course which helped their technical writing abilities. Hence, while technical writing skills should be infused throughout the curriculum, a concerted effort to establish good technical writing skills in this writing-intensive engineering course, is important. The present study demonstrated assessment of such activities, by administering related surveys in a post-requisite course well after (months after) students had completed the thermo-fluids course and had a chance to demonstrate their writing experiences in other environments including classes, internships, publications, and more. Survey results representing students' feedback are one set of data points toward demonstrating impact of the approaches utilized, but more sufficient evidence, specific to elements of the approach should be collected and demonstrated to "prove" enhancement in students' writing skills, based directly on the instructor's approaches. In conclusion students' technical wring abilities did improve, from the perspectives of the instructors, and by students' own admission, and they were able to demonstrate better understanding of engineering concepts through writing. Future studies should additionally illustrate the mapping of the writing and technical learning objectives, and utilize methods which also demonstrate exactly how emphasis on writing, affected students' technical abilities in understanding thermo-fluids content.

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