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JUNE 22 - 26, 2020 #ASEEVC
Paper ID #30146

A Three-course Laboratory Sequence in Mechanical Engineering as a Framework for Writing in the Discipline

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A Three-course Laboratory Sequence in Mechanical Engineering as a Framework for *Writing in the Discipline*

Abstract

The ability to communicate effectively is very critical to engineering graduates to prepare them for the workplace. It is also an important ABET Learning Outcome. Student technical written and oral communication are embedded in courses spanning the undergraduate experience, traditionally leaving the basic writing skills to be addressed in composition or English courses. A recent restructuring of the *University's* core curriculum heightened not only the practice of *writing across the curriculum* but emphasized the practice of *writing in the discipline.* To accommodate the new core curriculum, it was necessary for each engineering program at the University to redesign one of its courses to be designated *writing intensive*.

The Mechanical Engineering curriculum at the University of New Haven, even prior to the new core, included a sequence of 3 laboratory courses, each targeting different content while emphasizing common skills, including writing lab reports, design reports, progress reports and giving formal oral presentations before an audience. The first laboratory is scheduled for students' sophomore year and targets instrumentation and measurement techniques. The second laboratory is scheduled for students' in their junior year and targets experiments related to mechanics of materials and vibrational analysis. The fourth-year lab includes experiments related to thermo- fluids-and-heat transfer. All three labs heavily emphasize digital data acquisition; each level scaffolding the complexity of the error analysis expected. Underpinning the content of the three laboratory courses has always been a strong writing component. To accommodate the new core, the junior year mechanics lab was transformed from 2-credits to 3-credits.

This paper details the framework of the writing component across the 3-course sequence. The impact of the reformatting of the course on the quality of the students writing is examined through data collected from the students in the fourth-year courses. Observations and lessons learned are being used to inform further changes in the prior-year labs. The initial results show a positive impact based on student feedback and the overall performance of the students.

Background

An ability to communicate effectively is a desired competency for any college graduate. Written and oral communication often form part of a student's core curriculum, with courses in composition and presentation, often being some of the first courses taken. This extends to engineering students, for whom effective communication is an important competency [1] and a required criterion for degree accreditation (ABET - Student Outcome 3: an ability to communicate effectively with a range of audiences). The University of New Haven has identified writing skills as a priority and established Writing Across the Curriculum (WAC) initiative to support writing instruction throughout a student's undergraduate career.

In 2011, the College of Engineering at the University of New Haven carried out a survey of alumni and employers to investigate the skills needed specifically of and by engineering graduates. From this, it became apparent that the need to strengthen skills such as technical communication should be a high priority. The *Project to Integrate Technical Communication Habits (PITCH)* was created and embedded through all programs within the College of Engineering. Details of the program and the resources established are described in prior papers [2, 3, 4].

The engineering faculty involved in *PITCH* developed a series of online resources and handouts many of which are introduced to students early on during their academic time at the university. The resources were designed to be used by all programs, and as such details are broad and examples used are often generic. Integrating writing and communication within the disciplinary courses is not a new model. Adams [5, 6] describes such efforts in the engineering curriculum at the University of Maine. The Council for Programs in Technical and Scientific Communication (CPTSC) [7] indicates that these efforts are widespread.

This paper covers the writing approach threaded through mechanical engineering laboratory courses in the Mechanical Engineering program at the University of New Haven in an effort to support campus-wide initiatives for effective communication competency. The program has a sequence of three required laboratory courses: Instrumentation (MECH2215), Mechanics (MECH 3316), and Thermo-Fluids (MECH4415).

Writing Path for Mechanical Engineering Students

First year

A typical mechanical engineering student at the University of New Haven would start by taking *Academic Inquiry and Writing*, a core curriculum course taught by the English Department. Simultaneously, the student would be introduced to writing *Technical Memos* in *Intro to Engineering*, a course taken first semester along with all the other first year engineering students; this course is taught by the Department of Engineering & Applied Science Education. The following semester, engineering students take *Methods of Engineering Analysis*, a 3-credit course taken concurrently with a 1-credit *Short Engineering Reports* course. The analysis course focuses on basics of programming and computer tools to solve engineering problems. The accompanying course emphasizes students' skills at conveying their process and results to a variety of audiences. The course is taught by a Professor of Education whose home department is Engineering & Applied Science. Future engineering core and major specific courses rely heavily on the writing instruction provided that first year.

Second year

The students first exposure to writing in the disciplinary courses occurs in our sophomore year, *Instrumentation*; a 2-credit laboratory course. This course has four equal focuses: understanding of physical sensor operation, collection of data using modern instrumentation (including LabVIEW), basic statistical analysis of uncertainty, and communication of results through technical memos. Students complete six experiments in teams of three, with two weeks to complete the analysis and write a group technical memo.

Third year

The next laboratory course taken by Mechanical Engineering majors is the Mechanics Lab. This lab typically taken during the third academic year is 3-credits due to the heighten emphasis on technical report writing. Students are introduced to technical writing, data acquisitions, and uncertainty/error analysis. Like the prior lab, students complete six guided experiments focused on the following areas: mechanical property of materials, vibration, stress analysis and strength of materials. Additionally, the students are expected to design a simple experiment to verify a mechanical response. Labs are performed in teams of three or four students. Each group member is required to complete two reports and four technical memos, in addition to a group report for the design project.

Fourth year

Thermo-fluids Laboratory is the last course in the sequence of labs taken by Mechanical Engineering students at University of New Haven. The students usually complete this lab during their fourth year of study after completing critical courses such as *Fluids* and *Heat Transfer*. In this 2-credit lab, students complete five guided experiments related to an array of thermo/fluids phenomena (double-pipe heat exchanger, flow through straight pipe with fluid, flow through obstructed pipe, cooling of a heated sphere, etc). The last half of the semester is dedicated to a design project and the course serves as the evaluation point for two ABET Student Outcomes.

Coherent & Consistent Messages

The three courses are taught by four full-time tenured/tenure-track faculty members. Currently, one faculty member teaches all sections of the 2^{nd}-year lab, two faculty members teach the 3^{rd}-year lab, and one other faculty member teaches all sections of the 4^{th}-year lab. One of the faculty members was involved in the PITCH resource development. Given that the PITCH resources were developed to be non-major specific, faculty teaching the discipline specific courses developed guidelines specific to their major and specific to their course. In the Mechanical Engineering program, the faculty member teaching the 4^{th}-year lab noted frustration from the students that the guidance and expectations from the lab instructors was different and at times contradictory, especially when it came to formatting. As a result, in 2017 the faculty teaching the laboratory courses met to discuss and address this issue. The faculty generated a sample report and sample technical memo, along with checklists for each. Appendix A includes images of the checklists meant to be used by students to review formatting and content guidelines; the sample report and tech memo are omitted due to length of the documents. These documents are reviewed in class by the faculty and made available to the students via the Learning Management System (Blackboard). In addition, students are reminded of all the campus resources for helping them with writing assignments including the PITCH resources and the campus-wide Writing Center.

Emphasis on Writing within Each Course

One of the central premises of the *Writing Across the Curriculum* and *Writing in the Discipline* initiatives is that writing assignments contribute to the learning of the particular content to which its applied. Balancing the weight given to writing aspects versus the analysis aspects of the laboratory setting requires careful consideration. All three courses have evolved over the past several years to increase the quality of the writing over the quantity of the writing. With the restructure of the University's Core Curriculum, every student enrolled after Fall 2017 would be required to complete at least one certified *Writing Intensive Course (W-course).* The departments across campus were invited to apply for certification of their own courses (i.e., courses within the major); and any faculty teaching a *W-course* must receive training/certification by the English Department overseeing the writing programs.

Second year

The sophomore-level Instrumentation Lab introduces students to physical operations of sensors, methods for acquiring sensor data, statistical analysis of data, and synthesis and communication of results via technical memoranda. These are expected to be approximately 2-3 pages plus attachments. Time is devoted to specific instruction on technical memos structure.

Working in groups of three, students complete six labs during the course of the semester, each over a two-week period. Labs are arranged so that students should be able to complete the data acquisition in the first lab period, work on data analysis and an initial memo draft as homework, then return for the second lab period to re-take data and polish the memo, which is due two days following the second lab period. This structure encourages direct student/faculty interaction on technical writing concepts, as well as data analysis and presentation. Technical writing concepts are reinforced throughout the semester with several 20-minute "mini-lectures" covering topics such as the technical memo structure and creating figures and tables that clearly communicate results.

All memos are written in groups, with a single submission via an online platform. For each memo, brief feedback and a numerical grade is given to the students via an online rubric. This is kept simple to enable rapid turnaround of grades to students; the goal is by the next lab period (3 business days). For the first memo students are required to schedule a one-on-one meeting between the group and the faculty to discuss the memo, during which time a paper or digital copy is marked with more in-depth comments. Students are encouraged to schedule similar meetings for future memos before the due date to discuss in-progress memos or after the due date to receive feedback on graded memos. One or two groups each semester will do so, with noticeable improvement in memo grades. To encourage student accountability no late work is accepted, with the lowest memo grade dropped from the final grade computation.

This course has evolved over the past several years to increase the focus on technical writing quality over quantity. Previous iterations consisted of nine one-week labs, with students writing individual memos on only three of the nine experiments. This did not give students the full pedagogical "experiment, analysis, synthesis" experience, with students only focusing on the labs for which they needed to write memos. In addition, the grading workload led to a delay in returning useful feedback to the students in a timely manner.

Third year

Building on the established foundation from the prior year, the junior-level Mechanics Lab was selected as the *W-course* in Mechanical Engineering; resulting in the addition of 1-credit to allow for the additional written components and expectations. This third-year course has a particular emphasis on "multiple drafts", where students are forced to do rewrites, incorporating editorial feedback from the instructor. This has resulted in increasing quality of student writing throughout the semester. The focus of the Mechanics Lab is writing full technical reports; these are typically 8-12 pages in length plus appendices. The students work in teams to collect data and are expected to write two individual technical reports, each worth 30% of the student's overall grade, and one team final design report worth 30% of student's overall grade. The students submit each report as a draft and instructors return the reports with feedback within one week. The instructor then holds *conferencing feedback sessions* to discuss with each student the comments provided on the drafts. In these sessions, the instructor reviews the paper while meeting with the student(s) and provides vocal comments in real time; the papers are not separately marked up and returned. Students have one additional week to make revisions and submit the final versions. For the design project report, peer review/feedback is conducted. In addition to the checklists and sample materials provided, the instructor shares with the students the rubric he employs in grading their reports. On average, the students' performance in written communication has increased by over 25% based on end of term grades. Once successfully completed, the students satisfy the *W-course* Curriculum requirement.

Fourth year

In the senior year lab, emphasis is on conveying results via the writing of reports and memos. At this point, students are expected to be proficient in the mechanics of writing technical memos and full laboratory reports. This enables the instructor to focus on students grasping the concepts of the techniques presented for collecting data as well as the thermal-fluids concepts central to the course. Following the format described in the prior two laboratories, students work in teams of 3 to collect data; in general, they then have 2 weeks to submit their reports or memos. For the first lab, students are encouraged to work collectively and submit a team lab report. Drafts are due one week later. Time is allocated during the lab period for the instructor to hold *conferencing feedback sessions* with each group. At this review the instructor checks and discusses formatting (*i.e.*, figures captioned, equations numbered, significant figures, error bars, etc) and key compositional elements (*e.g.*, the abstract, data in the appendices, detailed uncertainty calculations referenced, etc.). It is in doing this *conferencing draft review* that the instructor has noted the inconsistencies between what the students are expected to be proficient in (i.e. technical communication) and what they state they are familiar with.

After the first lab, for the following labs, team members rotate who submits a full report and who submits a technical memo. The memos here serve to inform on conceptual understanding of the basics behind the experiment performed. The technical report written by the individual and the design laboratory project serve to assess ABET Student Outcomes 3 (communicate effectively with a range of audiences) & 6 (develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions). Students are reminded they may submit drafts and receive feedback but must do so before the due date for each report. In instances where the reports are judged to be incoherent, incomplete, or unacceptable, the report or memo is returned to the student with a grade of 0 and encouraged to correct and resubmit. Reports that receive less than 80% are retuned to the students and encouraged to revise and resubmit; noting, that revision are averaged with the original grade. The individual lab report and the group design project each account for 25% of the final course grade; 40% is allocated to the technical memos for the other labs; the 10% remaining accounts for miscellaneous assignments and in-class learning activities.

Assessing Students Writing Process

The structure of the fourth-year, thermo-fluids lab has remained relatively unchanged and the faculty member has records going back to 2012; partial data is seen in Table 1. In addition to standard graded materials, the instructor teaching the course began to collect data in Spring 2019 on how students performed in writing aspects of the course and specifically on their process for writing reports (Table 2 & 3).

Table 1: Standard data collected from Thermo-fluids laboratory. Starting with Fall 2018, the students had prior lab as a W-Course.

	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019	Fall 2019	Spring 2020
Students enrolled in class	19	13	15	19	15	19	13	13
Number of reports & memos reviewed	48	NA	31	45	38	42	42	33
Unacceptable labs or memos submitted	6	8	4	4	7	3	8	4
Average grade on individual lab report	83	79.5	80.7	82.8	78.8	80.4	79.5	NA

Table 2: Survey responses when posed to students in fourth year, thermo-fluids lab.

	1st write a draft?			**Ask someone to read?**			**Read what your team members wrote before submitting?**		
	Spring 2020	**Fall 2019**	**Spring 2019**	**Spring 2020**	**Fall 2019**	**Spring 2019**	**Spring 2020**	**Fall 2019**	**Spring 2019**
Always	9	4	0	2	0	0	4	2	0
75%	3	3	7	3	0	0	2	0	7
50%	1	4	7	0	4	5	5	4	4
25%	0	0	3	5	5	3	1	0	0
Never	0	2	2	3	4	11	1	7	8

At each of the lab meetings, the instructor asked the students various questions regarding their writing habits. At the first class meeting, after discussing the syllabus, students were asked to indicate how often, when engaged in technical writing (defined as either a lab report or a tech memo) did they write a draft and then revise it before submitting the assignment. Then, in class after the first report due date, the students were asked how often they ask a friend or tutor to read what they wrote prior to final submission. Lastly, after the five guided labs are completed (about halfway thru the semester), the students were asked if doing a group project or assignment, how frequently they read the contributions of their team members.

Additionally, students were asked two open ended questions. First, the students were asked to reflect about their writing habits and on the first day of thermo-fluids lab to describe how the go about writing lab reports. Later in the term the students were asked to reflect about working on projects with team members; they were then asked to describe the process by which they write a team tech memo. The responses were thematically coded. Their responses are summarized in Table 3.

Table 3: Tally of student responses to short surveys regarding their writing habits.

	Describe your process for writing lab reports?	
	Spring 2020	**Fall 2019**
Carry out analysis 1st	8	6
Plan what to write	5	3
(Just) write	2	4
Follow Guide or Template or Rubric	1	3
Reread what I wrote	10	5
Revise (explicitly mentioned)	1	0
ask professor to read what was written	4	2
The order in which items are done (i.e. abstract last; formatting)	4	3

Summary & Conclusions

In summary, the writing component across a 3-course laboratory sequence at the University of New Haven has evolved to emphasize *writing in the discipline*. The impact of the reformatting of the courses on the quality of the students writing is examined through data collected from the students in the fourth-year labs. The average grade (approx. 80) on the individual reports has essentially remained the same as prior to the modifications. The number of unacceptable labs or memos submitted over the past eight semesters appears not to be correlated to changes in the courses. A close look at the writing/revisions habits of the students reveals that there are still many who do not engage with practices known to be *a good idea* – such as writing drafts, asking someone else to read and provide feedback, or reading what others write when assembling a group writing assignment. Investigating this further may yield ideas for how to *teach* and emphasize these habits in the prior labs.

Though the various faculty involved in teaching this set of courses has worked together to generate a coherent set of resources, a caveat that is worth mentioning is that there may be differences in expectations and recommendations from each faculty member. The message to the students is - that's ok. It is important for the students to also learn that requirements are specific to the situation, or, in this case, instructor, much as we adapt to the formatting requirements of specific journals or proceedings.

Acknowledgement

The authors want to thank Dr. Jenna Sheffield, Director of the Writing Across the Curriculum Program, and Dr. Judy Randi, Coordinator of the Project to Integrate Technical Communication Habits, for their mentorship and guidance. Their expertise and insight have been vital in the successful transformation of these courses.

References

1. Ford, J. D., and Riley, L. A. (2003). "Integrating Communication and Engineering Education: A Look at Curricula, Courses and Support Systems." Journal of Engineering Education, ASEE, 92(4), 325-328.

2. Harichandran, R. S., & Adams, D. J., & Collura, M. A., & Erdil, N. O., & Harding, W. D., & Nocito-Gobel, J., & Thompson, A. (2014, June), *An Integrated Approach to Developing Technical Communication Skills in Engineering Students* Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana. https://peer.asee.org/20060

3. Erdil, N. O., & Harichandran, R. S., & Collura, M. A., & Nocito-Gobel, J., & Adams, D. J., & Simson, A. (2016, June), *Preliminary Assessment of and Lessons Learned in PITCH: an Integrated Approach to Developing Technical Communication Skills in Engineers* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.25944

4. Randi, J., & Harichandran, R. S., & Levert, J. A., & Karimi, B. (2018, June), *Improving Senior Design Proposals Through Revision by Responding to Reviewer Comments* Paper presented at 2018 ASEE Annual Conference & Exposition , Salt Lake City, Utah. https://peer.asee.org/30633

5. Wallace, R., & Adams, D. (2002, June), *Small Steps And Big Strides* Paper presented at 2002 Annual Conference, Montreal, Canada. https://peer.asee.org/10084

6. Adams, D. (2003). "Across the Great Divide: Embedding Technical Communication into an Engineering Curriculum." *Proceedings*, Annual Conference of the Council for Programs in Technical and Scientific Communication (CPTSC). 2-4 October, Potsdam. http://www.cptsc.org/proceedings/2003/

7. Council for Programs in Technical and Scientific Communication https://cptsc.org/about-us/

Appendix A: Sample Checklists for students to use before submitting their assignments

MECH Technical Report Checklist

Last updated February 15, 2017

This document is meant to help you construct a good technical report. Your instructor may have specific requirements that change those listed here.

Overall format

- ☐ Length: 6-12 pages, plus appendices.
- ☐ Single spaced, 10-12 point font size, consistent fonts throughout, 1/2" - 1" margins.
- ☐ Title page includes report title, author (only those submitting the document for a grade), course/assignment, affiliation, and date.
- ☐ Front matter uses lowercase Roman page numbering: Abstract (fewer than 250 words), Table of Contents (including appendices)
- ☐ Abstract has objective, approach, results (generally numerical with associated uncertainty), and interpretation
- ☐ Resize images to submit as a single reasonable-sized PDF file.

Figures, tables, references

- ☐ Figures and titles have full sentence, descriptive captions (no titles). Figure captions go below, table captions go above. Each are numbered independently and referred to in the document as Figure 1 or Table 1.
- ☐ Figures and tables are referenced in the text before they appear on the page.
- ☐ Figures are legible and clear with properly formatted and appropriate axis labels, units, legends, trendlines, error bars, and data points.
- ☐ Tables are clean – minimize the use of vertical lines.
- ☐ References are to original sources and formatted as a list at the end of the main document.

Main body

- ☐ Main document uses Arabic page numbering and is divided into numbered sections with descriptive titles
- ☐ Overall layout (suggested): Introduction, methods, results and discussion, conclusion, list of references, appendices.
- ☐ Discussion of methods in prose (not a list of steps)
- ☐ Discussion of measurement uncertainties
- ☐ Equations formatted correctly and uniformly
- ☐ Concluding section restates results and places them into context
- ☐ Appendices are correctly formatted, with descriptive text or captions.

MECH TECHNICAL MEMO CHECKLIST

Last updated February 15, 2017

This document is meant to help you construct a good technical report. Your instructor may have specific requirements that change those listed here.

Overall format

- ☐ Length: 2-3 pages, plus individual attachments.
- ☐ Single spaced, 10-12 point font size, consistent fonts throughout, 1/2" - 1" margins.
- ☐ Header block with appropriate information including author (only those submitting the document for a grade), affiliation, date, recipient, and a brief but descriptive subject.
- ☐ Individual attachments added to end of memo and submitted as a single PDF

Figures, tables, references

- ☐ Figures and titles have full sentence, descriptive captions (no titles). Figure captions go below, table captions go above. Each are numbered independently and referred to in the document as Figure 1 or Table 1.
- ☐ Figures and tables are referenced in the text before they appear on the page.
- ☐ Figures are legible and clear with properly formatted and appropriate axis labels, units, legends, trendlines, error bars, and data points.
- ☐ Tables are clean – minimize the use of vertical lines.
- ☐ References are to original sources and formatted as footnotes.

Main body

- ☐ Overall layout: Descriptive first paragraph, main figure, methods, results and discussion, conclusion, attachments.
- ☐ First paragraph has objective, approach, results (generally numerical with associated uncertainty), and interpretation
- ☐ Discussion of methods in prose (not a list of steps)
- ☐ Discussion of measurement uncertainties
- ☐ Equations formatted correctly and uniformly
- ☐ Concluding paragraph restates results and places them into context
- ☐ List of attachments

Appendix B: Sample grading guide for MECH4415

	Max Points
Organization & Coherence (e.g., formatting, language, abstract, TC, Equipment & Procedure, citations, etc)	15
Theory & Published data	20
Presentation of data (formatting of tables & graphs)	10
Analysis (incl. details of error analysis)	35
Discussion & Conclusions/Recommendations	20
TOTAL	**100**