Learning To Write: Experiences with Technical Writing Pedagogy Within a Mechanical Engineering Curriculum

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Abstract

This case study draws from a recent experience in which we critically reviewed our efforts of teaching technical writing within our undergraduate laboratories. We address the questions: "What do we want to accomplish?" and "So how might we do this effectively and efficiently?" As part of Clemson University's Writing-Across-The-Curriculum Program, English department consultants worked with Mechanical Engineering faculty and graduate assistants on technical writing pedagogy. We report on audience, genre, and conventions as important issues in lab reports and have recommended specific strategies across the program for improvements.

Introduction

Pedagogical questions continue about the content, feedback and methodology of the technical laboratory writing experience in engineering programs. In fact, there is no known prescription for success, and different programs try different approaches. Some programs delegate primary technical writing instruction to campus English departments, while others maintain such instruction within the engineering department, and hybrids in-between exist. But the approaches seem as much driven by financial necessity and numbers efficiency as they are by pedagogical effectiveness. While better-heeled departments can employ technically trained writing specialists to tutor students individually, the overwhelming majority of engineers are trained at quality institutions whose available resources require other methods. So how can we do this effectively and efficiently?

At the heart of the matter is the question, "What do we want to accomplish?" We find ourselves trying to accomplish two instructional tasks that are often competing and we suspect that we are not alone. The first task deals with communicating effectively. This task focuses on articulating through format, structure, grammar and syntax. Writing specialists are best trained in teaching this practice. The other task deals with communicating technically. This task focuses on technical substance, technical analysis and interpretation, and the overall use of engineering principles and concepts to explain and to conclude an answer to a posed question. Technical

specialists are best trained in this practice. Between disciplines, approaches to student learning of these two tasks are not well connected, particularly in terms of style, audience, and intent.

Undeniably, effective technical communication is the marriage of these two tasks. It is communicating the results of scientific inquiry in a manner that the audience comprehends and from which the audience can draw useful conclusions. Swarts and Odell[1] offer that capable technical writing means authors who are "advocates of the work" and not merely communicators of "data and facts." Can the instruction be effective unless the writing and technical specialists understand the other's needs?

Since the mid-1980s, faculty and students in the Mechanical Engineering Department at Clemson University have participated in interdisciplinary programs to improve students' communication skills, first within the College of Engineering's Effective Technical Communication Program and then, beginning in 1989, in the University-wide communication-across-the-curriculum (CAC) Program [2]. Our CAC program is similar to many writing-across-the-curriculum (WAC) programs, but in addition to written communication it includes oral, visual, and digital communication. The educational purpose is consistent with WAC programs throughout the country as described by McLeod and Maimon[3]: "WAC is a pedagogical reform movement that presents an alternative to the 'delivery of information' model of teaching in higher education, to lecture classes, and to multiple-choice, true/false testing. In place of this model, WAC presents two ways of using writing in the classroom and the curriculum: writing to learn and learning to write in the disciplines… ." Our CAC program is likewise consistent with innovative programs funded by the National Science Foundation at Drexel University, Arizona State University, and Texas A&M to promote significant pedagogical and curricular collaborations between English teachers and engineers[4].

Mechanical Engineering faculty at Clemson require students to "write to learn" technical concepts, applications, and problem-solving strategies[5] and collaborate with English faculty to design assignments in which students "learn to write"-- and thus to think like mechanical engineers[6]. In the past decade, Mechanical Engineering and English faculty together have developed several active-learning, communication-rich projects. Mechanical engineering students have written informal five-minute essays at the beginning or end of each class[5]; have enrolled jointly in ENGL 314 - Technical Writing and ME 313 - Instrumentation and Measurements, in which both teachers designed and graded joint assignments and attended each others classes to learn the language and conventions of each discipline[6]; and have submitted their writings in the ME 400 - Senior Seminar to an English graduate student for critique before revising them for the ME professor who grades it. Our long association in jointly developing CAC projects, led us recently to a new pedagogical collaboration between ME faculty, ME graduate students, and English faculty to attempt to develop, or at least improve, technical writing skills through the framework of the engineering laboratory.

At the onset, we recognize that there is no such thing as "good writing" that exists apart from readers and that engineers read in a particular way. Our experience builds on recently surveyed research on whether and how often writing skills transfer—crossing genre and disciplines and from school to the workplace and that the transfer of specific writing skills happens far less often than thought. Yet at the same time students transfer "rules" for writing from one discipline to

another, sometimes in a cavalier manner. Students in all disciplines need to learn that good writing for a particular group means following the linguistic conventions of that group and educators need effective methods to teach such conventions. The paper focuses on the observations, experiences and actions taken to promote writing pedagogy in our effort to join the dialogue and contribute on this ongoing subject.

Approach

In addition to understanding the technical aspects of the lab exercises being executed, our students are expected to become proficient in engineering writing. To this end, our writing goals in the lab courses are quite ambitious and include:

- developing audience awareness and using engineering language appropriate to that audience,
- understanding types, or genres, of writing, such as the executive summary, the lab report, the technical paper,
- developing effective argument through analysis and principles and with a clear presentation,
- clearly expressing logical thinking and deductive reasoning,
- defining a question and developing an answer to that question.

According to Winsor[7] in Writing Like an Engineer, audience is a difficult concept for engineering students. Technical reports center on the data and the results inferred from that data. These are directed towards other objective technical readers. The effect is that for the writer, the audience disappears. Winsor says that the apprentice engineers she worked with believe that since "the data speak for themselves," their job as writers is only to make the data clear. These students believe they do not need to persuade or to make an argument, since they are writing only for other engineers for whom presentation of the data is what "convinces." This is consistent with our own experience and, apparently, the concept that data need to be interpreted and results developed is a mature technical notion. Yet this ability is fundamental to effective technical writing. These novice engineers see "persuasion" as the task of managers whose audiences might include people who are not engaged in the technical work themselves. "Clear" presentation of the data seems to Winsor to be the most highly valued feature of writing among the engineering students she talked with. The young engineers she worked with developed more awareness of audience, she reports, when they were asked to write documents oriented toward other audiences, such as progress reports, users manuals, or procedures manuals brought.

In addition, understanding the audience should help to clarify the logic of the genre. Both Winsor[7] and Swales[8] point out that the concepts of genre and audience are closely related. Swales defines genre as a type or form of writing that becomes codified over time because the social situation it responds to keeps recurring. Winsor argues that genre is a means of actually prompting technical work and thus teaching or reinforcing a notion of audience: What kind of person wants an executive summary? Why? What does that person want in this highly condensed version? Why? What audience will read the formal report? Why?

As with many programs, the Clemson program intends to use technical communication as a vehicle to assess a student's understanding of a topic and provide an opportunity for the student to demonstrate his or her understanding in a forum expected by and needed within the engineering profession. These are stated as the last three goals above. There is an implication here that such communicative ability is inherent in the student or that, somehow, years of experience writing book reports and critical essays in literature can easily translate into technical prose if only we show them format. Such a position holds that if the student understands the subject material, then surely writing (and rewriting) about it should be clear. Yet Winsor demonstrates clearly that the students' concept of technical communication is not the same as this. And having a goal of clear presentation of data is certainly different from the goals of answering a question through logical deduction of the results and therefore becoming an advocate of the work.

Winsor[7] stresses "Turning physical reality into convincing written data is an impressive human accomplishment". Our young mechanical engineers are indeed learning a complex set of the literacy skills. The question is, how to help them become proficient in these specialized literacy practices?

During the past year, the Mechanical Engineering staff has worked closely with a writing consultant from the English department in an activity sponsored by our WAC Program. The consultant gathered information from a variety of sources within the Mechanical Engineering department —discussions with faculty and teaching assistants, review of lab assignments, observations of labs, review of student work, analysis of comments on graded lab reports, and end-of-semester student evaluations of their lab report writing. Her involvement was as an independent observer of the technical writing content of the labs and our interactions with the students. Just as students received feedback on their weekly work, she provided the staff with feedback and engaged herself with the staff on our goals and ways to better accomplish them. In the following semester, engineering faculty tried to implement some of the consultant's recommendations and to build on these in order to help students become not just technically proficient but also effective in their writing.

This overview summarizes the exchange of information between the staff, consultant, and students over two consecutive semesters working with both a sophomore laboratory and with the first of two junior laboratory courses. The technical mission of the sophomore course is to be a "discovery" lab consisting of simple experiments to develop basic engineering principles and to provide hands-on familiarity of how basic engineering devices are constructed and operate. A typical semester involves nine writing exercises that now range from writing sections of a report to writing a full report. As a form of early technical writing instruction, students are offered samples of good and poor lab reports and group time is spent with writing exercises aimed at improving them. Students are introduced to reporting formats and genres. The technical mission of the junior lab is on measurements and engineering science concepts. The junior lab course requires 4-5 complete (~750 word) lab reports. Each of our lab courses involves 72 to 96 students in 6 to 8 sections directed by three to four graduate assistants and one faculty instructor/coordinator.

Results

Following observations of the first semester in this effort, we attempted to build on the consultant's recommendations in the next semester. We discuss some lessons learned from each of the two labs but, for simplicity of presentation, we present the information together. The consultant offered an independent and fresh opinion on this material, thus reinvigorating the engineering staff's approach to the writing pedagogy in our labs.

On the first lab report submitted, based on a simple sensor calibration exercise, the consultant commented on the difficulty the students had with the concept and purpose of an Introduction. She noted that instructors included one or more of the following statements on almost all papers: "state objective concisely," "keep it succinct," and "put your introduction into your own words." The consultant also observed that the feedback given was overwhelmingly on what was wrong in the report. Overall, the usual miscues, such as failing to cite figures and referencing work, were common. Students struggled with data presentation, discussion of results, the extent of detail required, and a conclusion that presented a logical inference.

The consultant observed that the students tended to be conversing with the instructor with their report rather than making the report stand on its own ("I connected the sensor to the amp…"), a clear reflection of their not understanding the intended audience. As a consequence, the instructors were found to be encouraging the use of the third person and more use of passive voice. This observation was quite important. The reliance on the passive voice appears to be a reaction to a problem even though it is not necessarily a solution for more effective communication. Instructors were made aware that this presentation problem was as much a matter of addressing the correct audience and context than it was one of language.

In consequence, the instructors added a scenario to the lab exercise so as to help students better associate with an audience. A re-write of the calibration lab report was assigned and this time included a scenario. The scenario presented an automotive application for the sensor and provided explicit sensor performance requirements as a component within an electronic seat memory system with the implied question: Will the sensor meet the application need? Students produced better papers on the second version of the calibration assignment in part because it was a rewrite and because, as student comments made clear, the scenario helped provide a context for the lab exercise thereby making it easier for them to construct and to write. Intent and audience became clearer and understanding what the audience needed promoted better writing. In effect, providing usable scenarios better defined the intent of the exercise. Because the rewritten papers were better constructed, corrective feedback to the students focused more on format issues, such as what goes where, and technical proficiency issues related to the need for better presentation of results in answering the question.

To better address the former issue, a few writing assignments, in the second semester, were changed from complete lab reports to focused writing of a section: abstract, results with discussion, or a conclusion. Focusing on only one section at a time allowed for substantial instructor-student feedback and student practice without substantial workload on either party. Also, in the second semester, we made more use of peer review. Our logic here was that students

continue to learn to write more effectively by reading the work, good or bad, of others. And students take attentive interest in the work of their peers.

By the last paper most of the comments focused primarily on what the students were leaving out -- discussion of results, particularly in the significance of the graphical figures, quantifying the impact and propagation of error, and adjusting the right amount of detail in the approach section. The majority of students appeared to have an improved proficiency in format and style that was an acceptable foundation for growth. Technical proficiency was seen to be developing but was still weak. We hope that this should improve with maturity and additional writing experience within our curriculum. Overall, we saw that learning was going on through our guided practice approach both for the student and instructor.

At the end of each semester, we administered a Report Writing Survey as an assessment tool. A substantial majority of students felt that their technical writing skills improved significantly. Aspects which they conveyed as effective included the opportunity to revise and resubmit ("practice, practice, practice") with good feedback and an opportunity for generous grade improvement; good sample papers to use as models; emphasis on audience ("helped to keep the forest intact for all the trees"); use of the passive voice; and peer review.

Our students offered suggestions for improved learning, including more feedback, particularly positive feedback; more report and report section examples; better feedback on style. Students continued to be confused on the difference between "presenting" and "talking" to the reader. An important student observation was that a couple reports required too many sections, as if the format was too prescribed for effective communication ("the whole report lost meaning. It gets hard to see the forest through the trees"). The teacher often learns from the student!

The format of the scientific article, according to Gross[10], and of the engineering article, according to Ding[9], is a machine for comprehension. These articles embody a set of reading habits typical of technical communities who look for information more than for an aesthetic experience. The machine helps readers find the information they want quickly and efficiently. So format has a strong purpose and this needs to be conveyed. But report format draws from conventions that can be deviated from to best support the information that needs to be conveyed.

In summary, the consultant has offered the following suggestions for improved technical communication pedagogy, which we continue to incorporate in our labs:

1. *Students need to spend time reading examples of the genre they are expected to write*. In lab sections, that means both assigning and discussing lab reports and various forms of technical reporting. In these discussions, instructors can draw attention to genre features and audience needs. They can focus on the relationship of the Introduction, where the writer develops his or her objectives, and the Conclusion, where the writer talks about the impact of the results. Students new to a discipline need to have logical connections among the parts, or sections, of the report explicitly pointed out to them. This might help the students in three ways: they might begin to see the "forest" through the "trees"; they would have good models to follow, knowing what was strong about the model; they would see why the Approach section must include the right amount of detail. As students mature as technical writers, we believe that this will also

provide them the confidence to deviate from aspects of format when they see it as too prescribed for effective writing.

2. *If students are expected to write in various genres, then those genres should be assigned*. This can be accomplished within a class or across the ME curriculum and not just in labs and design classes. Lectures should be explicit in explaining the differences between and among the various genres, emphasizing audience needs. In the English department, instructors find that students have little awareness of genre--plays, poems, novels, short stories, essays, autobiographies, scientific or critical articles, or books are all, for many first-year and second-year students, "stories." Thus we infer that engineering students, too, must be explicitly taught the concept of different genres. In this way, students come to associate the appropriate genre for the application.

3. *Students learn more from re-writing than from merely being told what they did wrong*. Rigorous grading along with specific feedback on the first report helped students realize expectations for a lab report. Reviewing the lab report format, students seemed eager to learn to correct their weaknesses on the first paper. This seems particularly true when they are motivated to improve their grade or understand that they will not be penalized for trying. Practice leads to improved writing.

4. *Explicit positive explicit feedback works*. Mentioning what students are doing correctly helps students learn explicitly to repeat the patterns of effective writing. To say, for example, "This is an excellent diagram" means that the student will probably continue to produce excellent diagrams. "A fine Introduction here, concise and complete!" will mean more such Introductions. "You've done a good job here of giving the logical steps between the raw data and the Conclusion" will yield logical steps spelled out in future papers. Too often we found the feedback focused only on what was wrong.

5. *Some lab assignments should begin with a scenario problem*. The added scenario for the re-write of a sensor calibration lab report helped students see a purpose in the lab and in the report. And it impressed on us, as instructors, the need for a focus to facilitate better writing. Students seemed to understand that they were not just trying to find "the right answer" as an exercise for class, but that there was in fact purpose for the calibrations, that these kinds of efforts answer real needs and that this needs to be communicated. With this suggestion, we build from Winsor's[7] notion about genre fitting the audience and from Swale and Odell's[1] idea of becoming an advocate of the work to stressing an understanding of what the audience needs. Writing seems to improve when a scenario is provided.

6. *Use some peer-review.* Writing strengths and deficiencies appear to be more easily identified in peer work and teach students as much "what not to do" as "what to do" and "how to do" it. By far, students seem to be able to identify the good and bad traits of peer writers than they are able to see these traits in their own work. Just as important, the students read these technical works with more interest, learn from these readings, and give attention to peer comments. Interestingly, they can often be far more critical of the work than the instructor.

7. *Spend more time focusing on certain sections of a report.* Each section of a report has a purpose. With longer reports, the workload placed on the student often precludes the

development of the logical sequence expected within a technical paper. To the novice writer, report sections impose constraints rather than facilitate better writing. The suggestion is to spend some time practicing sections rather than only full reports. For example, rather than a full report one week, ask for a 50-word conclusion, possibly with data sheets. Then spend time rewriting until the purpose of the section is understood. This not only helps the student focus through a reduced workload (as opposed to writing a full report), but it reduces instructor workload to the point that we can provide very thorough feedback and instruction.

8. *Writing conventions ought to be taught as conventions.* When students come to us at the university, they bring with them a strong belief that there is one right answer and their job is to find it. We need to explain clearly that an introduction in a lab report serves a different purpose from an introduction in, say, a history paper or in a literary analysis. It isn't that one kind of introduction is right and the other wrong.

Ding[9] suggests that engineering writing focuses not just on things (theory, procedures, and so forth) as scientific writing does but also on actual objects (machines, materials, gauges, and so forth). We try to promote active voice to help enliven our writing, but passive voice can be effective in technical writing when used correctly. So when a mechanical engineering student says that learning to employ the passive voice helped him with his writing, s/he may be right. In passive voice, the agent, the do-er of the action, is no longer the grammatical subject of the sentence and in fact often disappears entirely; for example, "The pressure was measured at five-minute intervals." The focus of the writing is on the objects, which now become the grammatical subjects: "The apparatus was stabilized by securing it to a base." What is emphasized here is the thing or the procedure. Readers expect a lab report to be object-centered—to contain grammatical subjects that are in fact material objects, which thus require passive verbs. Certainly, students need to understand that writing in engineering embodies objects. Students need to understand that the customary use of using the object as the doer of the deed is a convention that reflects a certain attitude.

The disadvantage in using the passive voice to achieve an impersonal tone can mean that the agent/observer is absolved of responsibility: The measurements were taken, heat was applied, force was delivered, merchandise was conveyed, the profits were calculated.... What we want to teach is that the data do not speak for themselves; they speak, they convince, only through the intellect, the reason, of the observer. In effect, the writer must become an impartial advocate of the work. On the other hand, making the object the doer of the action does not always require passive voice; indeed the use of active voice is often less imposing and should be encouraged where appropriate: The results show, the pressure increased…. Use of the correct voice does require practice, however, and it may well be that our novice engineers need to learn first to use the passive voice to create an objective template and then learn not to overuse, allow it to obscure responsibility, or allow it to stifle the communication flow.

Another issue that emerges from our work is the transferability of writing skills from the English composition class to the engineering laboratory. Young[11] has recently surveyed research on whether and how often writing skills transfer—from genre to genre, from discipline to discipline, and from school to the workplace. What the research indicates, Young says, is that the transfer of specific skills happens far less often than we would wish. Yet at the same time, as our work

shows, students are transferring "rules" from one discourse community to another without the knowledge that different discourse communities have different standards for writing. We need to focus on the de-mystification of writing, while we investigate what transfers in writing in engineering. Students across the curriculum need to learn that good writing for a particular group means following the linguistic conventions of that group.

Conclusions

We embarked on an experiment to help us answer the question: How can we help students learn technical writing skills in a more effective and efficient manner? This paper reports on a program in which engineering faculty and English faculty cooperated to improve the technical writing of Mechanical Engineering students. An English writing specialist acted as a course consultant to review student work, instructor feedback and interaction, and then to offer suggestions for improved pedagogy. Writing style and communication are tied closely with genre, audience, and context, issues we found to be obstacles in need of better definition within the lab exercises. The consultant offered a number of specific suggestions to enhance the writing experience: Reading of expected genre, writing exercises, rewriting with constructive feedback, use of scenarios to define context, and peer review. All of the suggestions can be implemented within our current lab structure and department resources, but do require a change in our current pedagogy of writing instruction. We recognize that there is no such thing as "good writing" that exists apart from readers and that engineers read in a particular way; thus we try to teach novice engineers to be aware of those ways of reading in the discipline. Our experience builds on recently surveyed research on whether and how often writing skills transfer—crossing genre and disciplines and from school to the workplace and that the transfer of specific writing skills happens far less often than thought. Our work contributes to efforts to de-mystify writing and the teaching of technical writing, while we investigate what transfers in writing from the composition class to the effective communication engineering concepts.

Acknowledgements

The authors gratefully acknowledge the support of the Clemson University Communication Across the Curriculum Program and the Department of Mechanical Engineering. We also acknowledge the valuable contributions of Professor D. E. Beasley.

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