
AC 2011-1129: IMPROVING THE QUALITY OF WRITING IN A CAPSTONE ENGINEERING DESIGN COURSE

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Improving the quality of writing in a capstone engineering design course

Abstract

In engineering programs, students develop skills in both technical design and writing, and a capstone design course gives students the opportunity to practice and refine these skills. In our course (a collaboration between faculty and students at the University of North Carolina at Chapel Hill and Duke University), students work in small teams to develop custom devices for people with disabilities. At the end of the semester, we give the completed devices to the client, free of charge. The final reports (written by each team) are not only an educational exercise; we also use them to disseminate students' work so that others can build similar devices for individuals with disabilities. Additionally, many students submit their final reports to national design competitions. Therefore, it is important that these reports are well written and effectively explain the goals, methods, and outcomes of the project.

Historically we have seen that students devote considerable effort to the design and development of their projects, but that they are not as motivated to devote time and effort to writing. As a result, their final reports often have significant problems with organization, clarity, and effectiveness. Therefore, we recently adopted several new strategies to improve the quality of student writing. Our goals were to 1) encourage students to work on their writing earlier and throughout the semester; 2) engage every student in each team in the writing process; 3) use writing as a tool to improve students' understanding of the clinical problem that they are addressing and how their design addresses their client's needs; and 4) improve the quality of the final reports.

To achieve these goals, we first designed a rubric that would help students understand the expectations for each section of the final report. We also imposed frequent deadlines for sections of the report to keep students engaged with their writing. To minimize the burden for the course faculty, we conducted several in-class "writer's workshops" in which students learned what was expected for each section of the report. Based on these workshops, students then peer reviewed each other's writing. Finally, we implemented more efficient methods of providing feedback on writing, such as using digitally-recorded audio feedback.

As a result of these strategies, the quality of writing in the final reports has improved significantly. Feedback from students indicates that they appreciated the opportunity to work on their technical writing, although some felt that the peer review feedback was not helpful and that the writing process distracted from their work on the projects. In the future, we plan to streamline the peer review process and to refine the evaluation rubric so that students provide more effective feedback to their peers. Our goal is to further improve the quality of writing, without compromising the students' focus on the design and development of their projects.

Introduction

It is essential for engineering students to develop a solid foundation in technical skills as well as "soft skills", such as technical writing¹⁻². These soft skills will be important for almost any

career they choose after graduation². However, many students enter engineering programs precisely because of their interest and confidence in areas of math and science and, frequently, they are not motivated to develop better writing skills. While some engineering programs have separate courses on technical writing, design courses are an excellent opportunity to give students experience in this area³⁻⁵. Students are typically required to write a final report as a record of their work on the project. This task is a little less daunting for students than other college writing assignments because they are familiar with the technical aspects of their work, they are writing from a position of expertise, and they have an authentic audience for their writing. It is consistent with the goals of the capstone design class as well as the requirements of Accreditation Board for Engineering and Technology (ABET) to have students practice and refine their skills in technical writing⁶.

It has been our experience that students are highly motivated to produce an effective, functioning device to help their clients, but they are less motivated to produce a high quality final report. There are a variety of reasons that could lead to this disparity. As discussed above, students may choose engineering as their major because they are more confident in their technical skills as opposed to their writing skills, and they think that these technical skills will be more important in their careers. In addition, they may assume that a project that doesn't work will hurt their final grade much more than a poorly written final report. Finally, our students have had few opportunities to practice and develop their technical writing skills in our curricula.

Therefore, we adopted new strategies to improve the quality of technical writing in our capstone design course. Our goals were to:

1. Encourage students to work on their writing earlier and throughout the semester
2. Engage every student in the class in the writing process
3. Use writing as a tool to improve students' understanding of the clinical problem that they are addressing and how their design addresses their client's needs
4. Improve the quality of the final reports

This paper describes the methods we used to implement several strategies to achieve these goals, and provides results from the first year of its implementation.

Course improvements to enhance technical writing

We teach a capstone design class collaboratively at The University of North Carolina at Chapel Hill and Duke University, in which students develop custom devices for people with disabilities⁷. Each device is built for an individual in the local community who has a disability. Teams of 2-4 students work closely with the client, the client's family, and local health care providers to develop a device that meets the client's needs. At the end of the semester, the students deliver their completed device to the client. Examples of past projects include a packaging system for Goodwill Industries, which enables the user to assemble and slide a set of documents into a Ziploc bag, and a lawn mower that can be used while seated in a wheelchair.

The final reports are written by each team. While they are a useful exercise in technical writing, they are also important in a variety of other ways. They serve as a record of the students' work, in case we have to fix or modify the devices in the future to meet the client's needs. We use them

to disseminate the students' work because we get requests from around the country for information on how to build additional units of these devices for other individuals with similar needs. In addition, many students submit their final reports to national design competitions. Therefore, it is important that these reports are well written and effectively explain the goals, methods, and outcomes of the project.

The course faculty (Goldberg and Caves) met with Julie Reynolds, an expert in technical writing on the faculty at Duke University, to strategize ways to improve the quality of student writing. Each of our teaching interventions is described in detail below.

A. Logistics: Deadlines, grading, and team member's responsibilities

Previously, there were a number of factors in our class logistics that led to poor writing quality in the final reports. First of all, the students' final report (one per team) was not due until the end of the semester. While the course instructors offered to evaluate a draft copy prior to the due date, only a few teams took advantage of this opportunity each year. An additional factor was that near the end of the semester, students were devoting a significant amount of time to finishing up the work on the project itself, leaving the writing until literally the last minute. As a result, the final draft of the report was often the first draft. Because only one report was due from the team, the writing was sometimes the work of just one student, and the rest of the team did not gain any experience in technical writing. Finally, our grading system did not have individual accountability to insure that each student contributed to the writing effort.

We implemented a number of changes to address these issues. The writing of the final report was completed in three stages. The timing of these due dates was selected to coincide with the work that the students were doing on their projects (Table 1).

Table 1: Writing assignments

Final report section	Due date for first draft	Corresponding stage of project development
Introduction and Background	Week 4	One week before the students completed the problem definition phase of their project
Methods	Week 10	Two weeks after the students had to demonstrate a working prototype of their project
Evaluation and Discussion	Week 14	The same week that their final project was due, but 1½ weeks before final reports were due

For the Introduction, Background, and Methods sections, every member of the team had to submit their own drafts. This insured that every student gained experience in technical writing. At the end of the semester, the students decided how to combine their individual drafts into a single document for the final report.

We modified our grading system to incorporate individual writing scores in the final grade, and to better emphasize the overall importance of writing. With these changes, the final report represents 15% of the course grade, and individual writing scores count for 10%, for a total of

25% of the final grade devoted to writing (up from 20% in previous years). This is comparable to the importance of the final project, which counts for 30% of the final course grade.

B. Rubric

We developed a rubric (Table 2) to evaluate students' writing, based on the BioTAP (Biology Thesis Assessment Protocol) rubric used for evaluating the writing of honors theses in biology⁸. The rubric was intended to help the students to better understand what was expected of them, and to help the faculty provide effective and timely feedback. The rubric was also used to facilitate peer review. There is space on the rubric sheet for the reviewer to provide feedback for each criterion.

Table 2: EngineCAP, Engineering Capstone Design Rubric. Questions 1-5 are higher-order writing and critical thinking issues, and questions 6-9 represent mid- to lower-order writing issues (adapted from reference 8).

Rubric Question	No	Somewhat	Yes
1. Is the writing appropriate for the target audience? The target audience includes instructors, other faculty, peers, health care professionals, and people with disabilities	Excessive jargon, undefined terms, or insufficient background.	Some undefined jargon or terms, or some insufficient background	No undefined jargon or terms, and sufficient background.
2. Does the thesis make a compelling argument for the need for the device, within the context of the current literature?	No literature cited	Some literature cited, but no argument constructed	An appropriate review of literature, including literature cited that supports the need for such a device. Existing solutions/devices are described and cited, and an argument is constructed for the need for a new device
3. Does the report clearly articulate the project's goals?	The task is unclear, and the goals are not clearly defined as achievable objectives	The task is unclear, or the goals are not clearly defined as achievable objectives	The task is clearly described, and the goals are clearly defined as achievable objectives
4. Does the report clearly describe the design process and methods used?	The methods used for achieving the stated objective are unclear	The methods used are unclear at times, but the reader can follow the overall approach	The methods used for achieving the stated objective are clearly described

5. Does the discussion provide compelling evaluation results?	No evaluation was reported	An evaluation was reported, but it was anecdotal	An argument – based on a systematic evaluation of the device – was constructed as to the appropriateness and effectiveness of the device, given the need articulated in the introduction.
6. Is the report clearly organized?	Material was often not presented in the order in which the reader expected it	Material was sometimes not presented in the order in which the reader expected it	All material was presented in the order in which the reader expected it
7. Is the report free of writing errors?	Excessive grammar, punctuation, or spelling errors	Some minor errors	No errors
8. Are the citations presented consistently and professionally throughout the text and in the list of works cited?	Missing citations, or excessive formatting problems	No missing citations, but minor formatting problems	No missing citation or formatting problems
9. Are the tables and figures clear, effective, and informative?	Tables or figures were unclear, or lacked appropriate captions and labels	Tables and figures were clear, but sometimes lacked appropriate captions and labels	All tables and figures were clear, with appropriate captions and labels

C. Writer's workshop

During the semester, we held two writer's workshops during class time. These were held on the days that the first drafts of the Introduction / Background, and Methods sections were due. The objective of these workshops was to give students the information they needed to improve their first drafts, and to prepare them for evaluating the writing of their peers.

In the first workshop on the Introduction / Background sections (figure 1), Dr. Reynolds gave an overview of the evaluation rubric. Then, a student volunteer read out loud the draft that she/he had submitted that day while



Figure 1: Writer's workshop #1, student reads their draft out loud and receives feedback from class.

the rest of the class read along on hard copies provided by the instructors. Dr. Reynolds facilitated a discussion of the strengths and weaknesses of the draft, using the rubric as a guide. By modeling how the rubric could be used to assess writing, students were able to learn more about the expectations for their own writing. After this workshop, in which 2-3 different drafts were read and discussed, students were asked to revise their own writing based on what they learned in the workshop.

In the second workshop on the Methods section (figure 2), we expanded on the in-class writing workshop. In addition to having a volunteer read his/her draft for the whole class to critique, students also engaged in small-group peer workshops. We divided the class into groups of 3-4 students, making sure that students were not in the same group as their project team members. Each student took a turn reading their draft out loud to the group and received feedback from their peers. The groups spent about 20 minutes discussing each paper.



Figure 2: Writer's workshop #2, students doing peer reviews in small groups.

D. Peer review

Based on feedback from the Writer's Workshop, students wrote a second draft, which was submitted to a Blackboard online discussion group for peer review. Students were instructed to use the rubric to evaluate their peers' writing, and to provide positive, effective feedback to the student. Each student's work was reviewed by two peers and those reviews were submitted back to the students online, where they were also available for faculty to view them.

E. Faculty review

Based on the feedback from the peer review, students then submitted a third draft for review by the faculty, who used the same rubric to evaluate the writing. Our goal was to provide feedback that was useful for students, but less time-consuming than our traditional approach of marking student papers. Given the pedagogical value and efficiency of digitally-recorded feedback⁹, we opted to use Jing, free software (<http://www.techsmith.com/jing/>) that creates digital screencasts. This consists of a video that captures what we are doing on the computer screen and audio from our computer microphone. In this manner, we provide feedback as though the student were sitting next to us, listening to us and looking at our computer screen. We scroll through the writing sample on the computer screen, and describe what was effective and what needs improvement.

In the free version of Jing, the length of the screencast is limited to 5 minutes, which is adequate to give effective feedback on a short sample of writing. If more time is needed, a second video can easily be made. The software uploads the screencast directly to their servers, and we send the link to the students so they can view the video through a web browser. Both instructors found this technology to be easy to use and, after adjusting to the awkwardness of hearing our

recorded voices, significantly more efficient than our traditional approach to editing student writing.

Preliminary assessment: methods and results

Given that our class size is fairly small, and students write their final reports in groups, we do not currently have a large enough sample size for a rigorous assessment. Nevertheless, we did conduct a preliminary assessment to determine if our teaching interventions appear to be beneficial. We compared the quality of 4 final reports written by groups of students in our revised course (spring 2010), versus 4 reports written by groups who enrolled in this course prior to implementing the enhancements described above (spring 2009). Each group was comprised of 2-4 students, and in each case, the 4 final reports were randomly chosen from a total of 10 in the class.

To assess the quality of reports, we used the EngineCAP rubric (table 2). The rubric contains 9 questions, assessing writing and critical thinking skills. EngineCAP questions 1-5 are higher-order writing and critical thinking skills, dealing with issues such as audience, evidence, and argumentation. Questions 6-9 are mid- to lower-order writing concerns, dealing with issues such as writing errors, formatting, citations, and design.

Each question was scored on a scale from 1-5. A score of “1” indicated that the report did not meet the course’s minimum acceptable standards for that question. A score of “3” indicated that the minimum standards were met, and a score of “5” indicated that the standards were mastered. A score of “2” or “4” was assigned if a report contained sections that fit into more than one category. Given that questions 6-9 dealt with mid- to lower-order writing issues, they were weighted half as much as questions 1-5. Therefore, the maximum possible score a report could receive was 35 points.

A previous study reported moderate to strong agreement between different raters using BioTAP’s rubric⁹, the rubric used as a template for this assessment. Given the small sample size of this preliminary study, we opted to have only one rater assess all de-identified reports. The rater was not an instructor of the course, and therefore did not know which reports were written in 2009 versus 2010. Additionally, our rater was well-versed in assessment technique and the use of this rubric.

The scores (out of a total of 35 possible points) for reports written in 2009 were: 26.5, 21, 19, and 17. The scores for reports written in 2010 with our writing interventions were: 32, 29, 27.5, and 24.5. We compared the mean scores using a two-tailed t-test assuming unequal variance. Even with such a small sample size, we found that the mean score was significantly higher for the 2010 reports versus the 2009 reports ($p=0.03$).

Discussion

Overall, we believe the effort put into the development of the tools and strategies greatly improved students’ writing, and also helped students produce higher quality devices for their final projects.

A. Overall impact of writing activities on the course

There were a number of positive outcomes to the course enhancements described above. First of all, they led to a clear improvement in the quality of the final reports. These enhancements were implemented in a way that was consistent with the goals and the overall flow of the course. We did allocate two class periods for writer's workshops, but the rest of the writing activities were implemented outside of class. The due dates of writing assignments were synchronized the timeline for project development. As a result, the activities actually enhanced their project work by requiring the students to document their thinking and effort on the project design and development. It also forced the students to complete a significant portion of the final report more than one month before it was due.

B. Feedback to students on their writing

The EngineCAP rubric was helpful in guiding the students on their writing assignments, and providing a framework for students and faculty to give feedback. The out-of-class peer review system ran itself with minimal effort from faculty. However, students were not experienced in doing peer evaluation, and the peer evaluations were not graded, so the students had little motivation to set aside enough time for this task. As a result, these peer reviews often did not provide meaningful feedback to the writer. In contrast, the peer evaluations done during the writer's workshop were more helpful because we set aside 20 minutes to discuss each person's writing and the faculty were supervising this activity. During these sessions, students also reported that it was helpful to read their drafts out loud. This helped them to hear for themselves when their writing needed more work, and many of them subsequently tried this on their own when working on their reports.

Because some students did not get effective peer review feedback, the quality of the writing was sometimes poor after two drafts. Therefore, faculty did have to devote significant time to review the third draft.

C. Student impressions

Every student gained experience in technical writing. Many students reported that they appreciated this opportunity. However, some students felt that the additional work was too great, given the already significant time demands involved in completing their project. In particular, there were mixed reviews on the out-of-class peer evaluations, in which some students devoted a lot of time to giving evaluations to others, while getting little helpful feedback in return.

Students did report that they liked getting feedback from faculty via the digital screencasts. They felt that faculty were able to give a significant amount of feedback in a 5 minute screencast, and they liked being able to watch it several times to be sure that they did not miss anything. In most cases, the students effectively incorporated the feedback into their final reports.

D. Future changes

We plan to continue with these course enhancements in spring 2011, with a few small changes. We will eliminate the out-of-class peer evaluations. Since they were not graded, many students did not take this assignment seriously, yet we do not want to add another graded assignment to their workload. We will continue to do the more successful peer reviews during the writer's workshops in class, and then students will submit their second draft to faculty for review.

We have also modified the EngineCAP rubric for 2011. While conducting this study, we realized that in addition to making the criteria for success explicit, we wanted to specify the point totals and reorganize the questions to better correspond to the sections of their report. We hope that these revisions will help students use the rubric more productively for their own writing and for the peer review.

Conclusion

This paper describes enhancements to a capstone design class to improve the quality of technical writing. These enhancements were successful in meeting our goals. Students worked on their writing throughout the semester and completed a major portion of their final report more than a month before the deadline. Every student was engaged in the writing process. The writing assignments were timed to coincide with project milestones so that the writing enhanced their progress in the project work. Finally, a small-scale assessment demonstrated that these enhancements resulting in significant improvements to the quality of writing in the final reports.

This was accomplished by restructuring the course logistics, developing a writing rubric, implementing a peer review system, and using two class periods for writer's workshops. Some minor improvements are planned for 2011.

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