2018 ASEE ANNUAL CONFERENCE & EXPOSITION
JUNE 24–27, 2018
SALT PALACE CONVENTION CENTER
SALT LAKE CITY, UT

Paper ID #23615

Work in Progress: Improving Biomedical Engineering Student Technical Writing through Rubrics and Lab Report Re-submissions

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Work in Progress: Improving Biomedical Engineering Students' Technical Writing through Rubrics and Lab Report Re-Submissions

Introduction

Graduates from ABET accredited engineering programs are expected to demonstrate an ability to communicate effectively [1-2]. Technical writing skills are particularly difficult to teach and even more time consuming to assess [3], often limiting the number of opportunities students are given to practice and improve throughout their undergraduate education. Recent studies have reported positive impacts of using rubrics to measure student scientific writing skills [2-5]. Using rubrics provides educators grading consistency and students with guidelines on grading metrics. We have developed a student writing process that includes a robust technical writing rubric, formative feedback from graduate teaching assistants (GTAs), and an opportunity for students to revise and resubmit. Presented here are the details of this process, as well as preliminary analyses of the impact the process on improving students' technical writing.

Methods

Technical Writing and Assessment Process

In the third and fourth years of our Biomedical Engineering (BME) undergraduate program, students select and complete three of six available laboratory courses (Biomaterials, Biomechanics, Biotransport, Biotransport, Tissue Engineering, and Micro/nanotechnologies). Learning objectives and assessments are identical across each course, and include a focus on technical writing skills. The culminating assignment for each course is an individually submitted written laboratory report.

We have developed a robust, detailed technical writing rubric outlining the requirements for a full technical paper, including abstract, introduction, methods, results and discussion, and conclusions. An example of a results and discussion block was extracted from the biomechanics lab report rubric, and is shown in **Figure 1**. The rubrics aim to serve two purposes: 1) to guide the students in the technical writing process, and 2) as a tool for consistent and efficient grading.

Students were given two weeks to submit their laboratory report; during that time, trained technical writing-focused graduate teaching assistants (GTAs) were available for open office hours. After reports were submitted, the GTAs asseseds the writing submissions against the rubric and provided detailed formative feedback. Students were then permitted one revision and re-submission opportunity, during which they could address deficiencies in their writing and earn up to half the points back from their first submission. Students are required to follow this identical technical writing and assessment process throughout each of their three upper-level laboratory courses.

Measuring the Impact of our Technical Writing Process

Two analyses were performed to understand the impact of our process on student technical writing. First, a paired t-test was performed to compare first and second submission lab report

rubric scores from all students who completed at least one of the three most popular laboratory courses (Biomaterials, Biomechanics, and Tissue Engineering) between autumn 2015 and spring 2017. During this time, no major changes were made to the report rubrics or the laboratory experiments associated with these three courses. Second, we selected for students who completed all three of the aforementioned laboratory courses during the same timeframe (n=8). A one-tailed t-test was used to analyze the first to second lab submission performance and lab context performance across the three lab courses for this sub-population. All data sets were analyzed using JMP assuming a significance level of $\alpha = 0.05$.

Content	Poor 1 Point	Developing 2 Points	Average 3 Points	Adequate 4 Points	Excellent 5 Points
Overall data presentation	Data not obtained during lab (e.g. data forged or found on Google)	Data incomplete for experiments described in the methods	Data included for all experiments described in the methods	All data included, presented logically	All data clearly and concisely presented in logical sequence paralleling the structure of materials/methods section
Stress vs. Strain plots, Young's modulus comparison (Hint: use good graph vs. bad graph doc. on Carmen for help)	No graphs, charts or figures	Figures present, may show force vs. distance instead of stress vs. strain plots, Young's modulus comparison may be missing, graphs unlabeled, incorrect or no units	Stress vs. strain plots shown, statistics included to obtain Young's modulus, plots are mostly labeled correctly	Figures presented logically, labeled graphs, includes stats on figure, plots comparing means for each data group tested (Young's modulus), may include standard deviation instead of standard error of the mean (when appropriate)	Includes well- labeled plots of stress vs. strain and comparison of Young's modulus that allow figures to be understood without reading the report, includes regression, means and standard error of the means when appropriate
Discussion of Data	Data/graphs are simply pasted into document with little or no description, context or discussion	Missing discussion of experiments or data, discussion is an inaccurate reflection of the data	Discusses results w/ loose connection to theory, correctly states whether fits are good or poor	Discusses results with clear connection to experiments and theory, correctly states whether fits are good or poor	Discusses results with clear connection to experiments and theory, explains why the fits are good or poor in context of the limits of the model and/or the experiment
Discussion of Statistics and errors	Statistical values mentioned, but not discussed, or are incorrect	Includes statistical values with some discussion, missing discussion of sources of uncertainty or errors	Statistics put in context of experiments, author acknowledges differences in data and any lacks of fit, may attribute it to human or experimental error without giving details	Uses stats to show "goodness of fit" of elastic region of stress vs. strain plots, uses stats to determine whether Young's modulus of bones are different, differentiates between "human error" and measurement uncertainty	Uses stats to show "goodness of fit" of elastic region of stress vs. strain plots, uses stats to determine whether Young's modulus of each condition are the same or different, discusses measurement uncertainty and impact of that uncertainty on drawing conclusions from data
Overall flow and organization of writing	Illogical, difficult to read	Graphs, data are presented logically, written report fails to refer to the figures	Graphs are inserted at appropriate points in the text	Graphs are inserted and referred to sequentially by name (e.g. Figure 1, Figure 2b) at appropriate points in the text	Graphs inserted and referred to sequentially in text, text written in logical sequence paralleling the structure of the materials and methods section

Figure 1: Result and Discussion Section of the Biomechanics Lab Report Rubric

Results and Discussion

We seek to measure how our rubric-driven feedback cycle influences student technical writing performance within one lab course and in subsequent lab courses. For the former, we observed a

significant ($p < 0.05$) improvement in students' second lab report performance relative to their first submission (**Figure 2**). This suggests the one-semester rubric-driven writing and revision cycle had a measurable impact on student performance.

We also tracked and analyzed individual students' first and second submission rubric scores as they subsequently progressed through all three of their laboratory courses (n=8). Results showed that all students' had a significantly improved second submission report rubric score, compared to their first submission report rubric score in their first lab course ($p < 0.05$). Additionally, there were significant improvements between the second submission report in the first course and the first submission of the second course ($p<0.05$). This signifies that students continued to improve their technical writing from their first lab course to the second. However, these same students showed no significant improvement (p-value=0.88) in rubric scores between their second and third completed lab course (**Figure 3**), suggesting that our process may reach peak effectiveness in improving student technical writing after only two cycles (i.e. two subsequent lab course completions). It should be noted that all students were satisfied with the first submission report scores in course 2 and course 3, and therefore did not submit a revised second submission report.

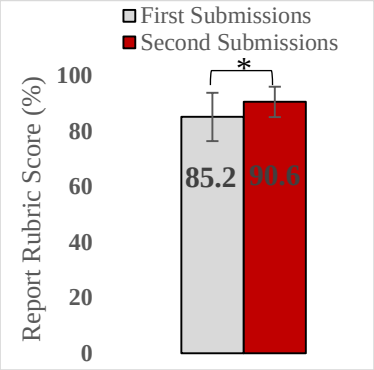

Figure 2: Lab report first and second submission rubric scores (*p<0.05).

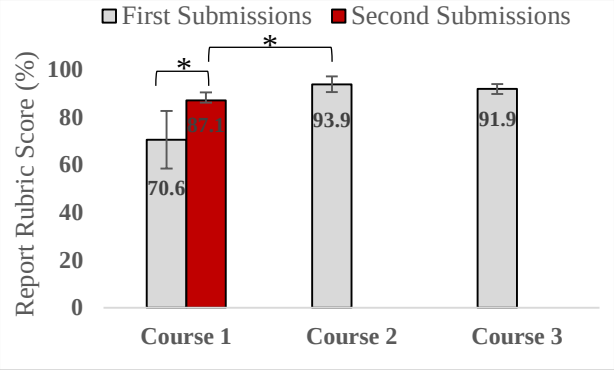

Figure 3: Lab report first and second submission rubric scores as students progress through three courses (*p<0.05).

Conclusions

We have developed a rubric-driven technical writing process that provides a means for teaching and assessing students' abilities to communicate effectively. This process is rooted in robust writing rubrics, formative feedback, opportunity to revise and resubmit, and repetition across multiple courses. The preliminary analyses of the impacts of our process has indicated significant improvement in technical writing between a student's first lab report submission to their final report submission in one course, as well as between the final report submission in the first and second of three subsequent lab courses. Our results suggest that two iterations of our rubric-driven feedback process may be optimal for maximizing students' improvements in technical writing. Future work includes surveying students and GTAs on their perception of our process. Deeper student performance tracking in specific rubric sections (i.e. results and discussion) will also be investigated to monitor performance variations across lab courses and subsequent report submissions.

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