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Improving Student Writing Outcomes Through Dynamic Feedback, Design Oriented Projects and Curriculum Modification

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Abstract

Technical writing is an important skill for engineers that is often cited by employers as a weakness among college graduates entering professional practice. Students are often admitted to engineering programs based on capacity for learning STEM topics and with less regard for reading and writing ability, and comprehensive engineering program requirements for learning technical topics limits the amount of coursework for explicitly developing technical writing ability. To assess strategies to improve technical writing among upper divisions students, we report the response of three cohorts of engineering students to modifications of a fluid mechanics course with a hands-on fluid mechanics laboratory project assignment that involves the preparation of a technical report. We find that group format instruction on report preparation, with specific examples of good and bad writing styles and a clear standard for the expected level of performance, is equally effective as small group meetings with more personalized feedback and is substantially less resource intensive. Group instruction materials shown to be effective are presented herein. Data collected found that improvements in groups technical writing ability did not necessarily correlate with an improvement in students' perceived group effectiveness.

1 Introduction

Technical writing skill is a critical yet often overlooked outcome of engineering curricula. Technical writing is defined by the Society for Technical Communication as "1.) Communicating about technical or specialized topics, such as computer applications, medical procedures, or environmental regulations, 2.) Communicating by using technology, such as web pages, help files, or social media sites and 3.) Providing instructions about how to do something, regardless of how technical the task is or even if technology is used to create or distribute that communication [1]." Employers frequently mentioning the ability to communicate technical information as a critical part of any engineering position [2].

The University of California, Irvine has a diverse student body with 30,000 undergraduate students, of which 3,800 are in the School of Engineering. Of those 3,800 in Engineering, 55% are first generation students, with approximately 1/3 of the student body self-reporting English at their first language, 1/3 as English and non-English, and another 1/3 as non-English [3]. The diversity of languages spoken/written within the student body presents challenges in teaching technical writing, something that challenges even for proficient writers of English [4]. Moreover, students are often attracted and admitted to engineering programs based on perceived strengths in quantitative and analytical skill compared to oral and written communication skills, and this leads to cohorts of engineering students whose writing skills are relatively weak compared to undergraduate students outside of engineering [5]. While all engineering students must satisfy coursework requirements related to writing, this instruction tends to occur outside of engineering courses where little emphasis is placed on technical writing styles important for engineering [6]. Writing centers are another resource available to students that can be helpful for improving grammar [7, 8], but with limited potential to develop technical writing abilities [6].

Writing embedded within core engineering course curricula is considered a valuable exercise [9], but is often difficult to implement. Barriers to implementation include limited resources for grading and feedback, and limited technical writing skills/motivation among Teaching Assistants (TAs) and instructors [10]. In addition, despite group writing being an important skill set for engineers [11], emphasis on teamwork can lead to writing duties falling on only the strongest student writers and limited opportunity for weak writers to gain experience and develop proficiency [12, 13].

Here, we report the outcomes of several attempts to improve technical writing through integration into a junior level course in fluid mechanics, where students complete a hands-on laboratory project and prepare a technical report. Over a three-year period, the course was delivered three times with different types of technical writing instruction. This paper reports on the authors observed effectiveness of group versus individualized feedback on improving student technical writing, and shares the strategies used as a resource for the reader. This work raises an intriguing argument for using group instruction over individual instruction to improve technical writing for integrated engineering courses. Some preliminary data is presented in support of group instruction. In addition, the effects of improved technical writing ability (and corresponding student grade) on group dynamics (self-measured by students) is investigated.

2 Methods

2.1 Academic Setting

Fluid Mechanics is taught in the Department of Civil and Environmental Engineering at University of California, Irvine with three distinct sections. The first section is the traditional classroom lecture setting, taught by the professor with students (n=~120 students) all in one classroom learning important concepts and problem-solving skills. The second section is "discussion," where students come to a smaller session (n=~40) taught by the TA where they can ask more specific homework/problem questions and take an in-discussion quiz. The final section is a lab section, again taught by the TA. The lab section is the smallest section (n=15-25) and typically consists of a series of "real-world" experiments conducted by the students, along with one or more technical writing projects.

Most students have not received any technical writing training by the time they are Juniors. The Junior level lab courses are often the first time they are formally exposed to technical writing. Some students may have had an internship or prior job which required them to prepare, revise, or edit technical documents, but for most students, the last time any form of a writing course was taken was during their freshman years. Furthermore, this freshman level course is not about technical writing, but rather series of basic writing courses where students are required to develop a writing portfolio based on readings. This coursework gap presents challenges when teaching technical writing to students who largely have likely forgotten the writing skills they learned during their first year.

2.2 Class project outline

The fluid mechanics classroom project is a 10-week, quarter long project designed to introduce students to basic engineering/modeling principles and technical writing communication. The students perform a total of three experiments throughout the 10 weeks. Randomly assigned students groups (3-7 students per group) conduct experiments to develop parameters for a computational model in conjunction with lessons on technical writing and written communication. These computational models are used to design and predict the motion of a cart/jet system, with extra credit given to student groups which produce the fastest cart and most accurate model.

Curriculum modifications are presented as follows. In 2016, only one lab report was due at the end of the quarter, with no preliminary draft due beforehand. In 2017 and 2018, the curriculum was modified to have three lab reports due throughout the quarter, with multiple layers of feedback built into the curriculum throughout the 10 weeks. There were little to no specific requirements for each report beyond basic formatting (requiring an intro, methods, results/discussion and conclusions section) to best represent "real world" conditions. Students were encouraged to make their reports as concise as possible, however there are no specific page minimum or maximum requirements. In 2017 and 2018, each report gradually increased in complexity, with students receiving feedback on report structure, grammar/spelling, conciseness, figures/tables, and overall argument through drafting, classroom presentations, peer review, and one-on-one group meetings.

In 2016 and 2017, students were given examples of "real world" technical reports and articles as examples of technical writing, and in 2018 students were only given other students reports (with examples of A, C, and F work) and encouraged to search articles and reports for additional examples.

2.3 Study Outline

2.3.1 Data

Three major data sources were used to evaluate the effectiveness of the interventions.

1) Anonymous course evaluation survey data. Course evaluations were conducted every year of the study (2016, 2017 and 2018).

2) Peer evaluation survey data collected during the last two years of the study (2017 and 2018).

3) Lab report grades were used as a measurement for improvements in student technical writing ability. Teaching methodology in 2017 and 2018 was significantly changed through the introduction of low-stakes drafting, therefore lab grades from 2016 were not used in the quantitative analysis.

University administered, anonymous course evaluations occurred during all three years of the study and contained a variety of quantitative data (instructor shows enthusiasm, meets objectives, stimulates interest, is accessible and responsive, etc., scale from A-F) and qualitative responses ("What are the instructor's teaching strengths?" and "how can this instructor improve as a teacher?"). Course evaluations were used to determine overall student satisfaction and investigate student responses for specific course modifications that improved their learning experience.

Qualitative and quantitative peer evaluation questions are shown in Table 1. Peer evaluations in 2017 were written responses (Table 1, left column) with both written and quantitative measures (Table 1, right column) used in 2018.

Table 1. Peer evaluation questions given at end of course to students

<table>
<tr><th>Qualitative Questions (2017 & 2018)</th><th>Quantitative Questions (2018)</th></tr>
<tr><td>"Explain how you contributed to your group (writing, data analysis, generating figures, etc.)"</td><td>"What grade would you give yourself?" (A-F)</td></tr>
<tr><td>"Were there any group members that stood out in a positive way (by this I mean they were crucial to the success of the project)."</td><td>"What grade would you give your group?" (A-F)</td></tr>
<tr><td>"Were there any group members that significantly hampered the success of the project (poor/no effort, fought other with members, etc.)"</td><td>Please evaluate the following aspects of your yourself
<table>
<tr><th></th><th>A</th><th>B</th><th>C</th><th>D</th><th>F</th></tr>
<tr><td>Ability to attend group meetings</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>Writing ability (spelling, grammer, sentence construction etc.)</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>Critical analysis ability (critically analyze data and interpret)</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>Coding ability (how good at MATLAB)</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
</table></td></tr>
<tr><td>"Any other comments or suggestions?"</td><td>Please evaluate the following aspects of your group
<table>
<tr><th></th><th>A</th><th>B</th><th>C</th><th>D</th><th>F</th></tr>
<tr><td>Ability to attend group meetings</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
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<tr><td>Coding ability (how good at MATLAB)</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
</table></td></tr>
</table>

The overall goal of administering the survey was to (1) evaluate the overall effectiveness of the groups and (2) identify students not contributing to the success of the project. For the purposes of this study, the peer evaluation surveys were used to determine the overall group effectiveness, efficiency, and cohesion. Written responses were analyzed for group cohesion and to consider whether or not a group was "dysfunctional." The criteria for a dysfunctional group was defined as if two or more members of the group were specifically called out for being ineffective, or if in the evaluation the group itself was discussed as being ineffective.

Lab report grades were used to evaluate overall student technical writing ability. Report grades and the rubric were strongly influenced by grammar, spelling, and technical communication ability. Technical communication ability included the above criteria, along with ability to effectively communicate using tables, figures and overall report structure. Each significant grammar and spelling mistake received a minimum of 1% off the paper's grade. Figures and tables were graded based on their readability, effectiveness at communicating complex data and experimental setup, and references to the text to support an argument. Statistics for comparing grades were performed using Students Two Sample t-test in MATLAB Version 2017b.

2.3.2 Changes in Teaching Methodology

In 2017 and 2018, two low stakes, preliminary lab reports were assigned throughout the quarter, with varying levels of group, individual and peer feedback given between the two years to evaluate each type of feedbacks effectiveness of improving students technical writing. In 2017, intensive individual and group feedback was given between Lab Report #1 and #2. Individualized feedback included mandatory, one-on-one group discussions (in and out of designated class time) and written comments on a paper copy of the report. In addition, extra credit was offered to groups who attended a writing center session between the 2017 Lab #1 and #2. Group feedback was in the form of an interactive classroom presentation ("The Good, the Bad, and the Ugly of Technical Writing," (Figure 1). A summary of the feedback given by year and lab report is given in Table 2.

Table 2. Feedback type by year and report

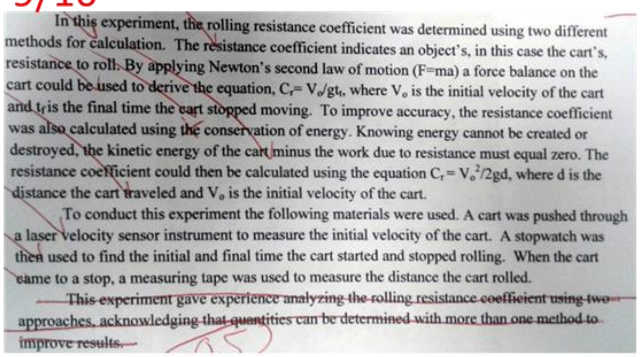
Year and Lab #	*Feedback Type*	*Description*
Pre-Lab #1	General,	Referred students to "real world" technical reports/articles
2017, Lab #1		
Post Lab #1, pre-lab #2	Group, Individual, Written, Writing Center	"Good, Bad and Ugly" Presentation, one-on-one mandatory group meetings, written feedback on reports, offered extra credit to groups that attended the writing center together
2017, Lab #2		
Pre-Report #1	General, Group	Referred students to prior years' work, gave "Good, Bad and Ugly" presentation
2018, Lab #1		

Post-lab, pre lab #2	Group, Individual, Written	Went over major mistakes in class, one-on-one mandatory group meetings, written feedback on reports
2018, Lab #2		

In 2018, general, group feedback in the form of the "Good, the Bad, and the Ugly of Technical Writing" presentation was given before Lab #1 was due, in addition to referencing students to examples of previous years work. After Lab #1, and before Lab #2, intensive feedback in the form of group, individual, and written comments were given on students Lab #1 report, with the intent that they would significantly improve Lab #2 reports.

The Good

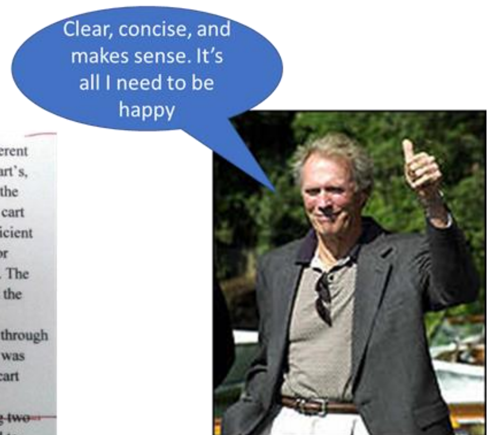
9/10



In this experiment, the rolling resistance coefficient was determined using two different methods for calculation. The resistance coefficient indicates an object's, in this case the cart's, resistance to roll. By applying Newton's second law of motion (F=ma) a force balance on the cart could be used to derive the equation, $C_r = V_o/gt_f$, where V_o is the initial velocity of the cart and t_f is the final time the cart stopped moving. To improve accuracy, the resistance coefficient was also calculated using the conservation of energy. Knowing energy cannot be created or destroyed, the kinetic energy of the cart minus the work due to resistance must equal zero. The resistance coefficient could then be calculated using the equation $C_r = V_o^2/2gd$, where d is the distance the cart traveled and V_o is the initial velocity of the cart.

To conduct this experiment the following materials were used. A cart was pushed through a laser velocity sensor instrument to measure the initial velocity of the cart. A stopwatch was then used to find the initial and final time the cart started and stopped rolling. When the cart came to a stop, a measuring tape was used to measure the distance the cart rolled.

This experiment gave experience analyzing the rolling resistance coefficient using two approaches, acknowledging that quantities can be determined with more than one method to improve results.



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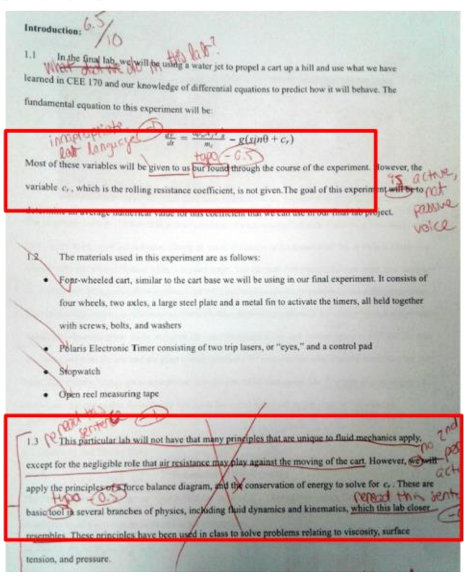
The Bad



Introduction:

1.1 In the final lab, we will be using a water jet to propel a cart up a hill and use what we have learned in CEE 170 and our knowledge of differential equations to predict how it will behave. The fundamental equation to this experiment will be:

$$\frac{dv}{dt} = \ldots - g(sin\theta + c_r)$$

Most of these variables will be given to us bur found through the course of the experiment. However, the variable c_r, which is the rolling resistance coefficient, is not given.The goal of this experiment will be to determine an average numerical value for this coefficient that we can use in our final lab project.

1.2 The materials used in this experiment are as follows:

- Four-wheeled cart, similar to the cart base we will be using in our final experiment. It consists of four wheels, two axles, a large steel plate and a metal fin to activate the timers, all held together with screws, bolts, and washers
- Polaris Electronic Timer consisting of two trip lasers, or "eyes," and a control pad
- Stopwatch
- Open reel measuring tape

1.3 This particular lab will not have that many principles that are unique to fluid mechanics apply, except for the negligible role that air resistance may play against the moving of the cart. However, we will apply the principles of a force balance diagram, and the conservation of energy to solve for c_r. These are basic tool in several branches of physics, including fluid dynamics and kinematics, which this lab closer resembles. These principles have been used in class to solve problems relating to viscosity, surface tension, and pressure.

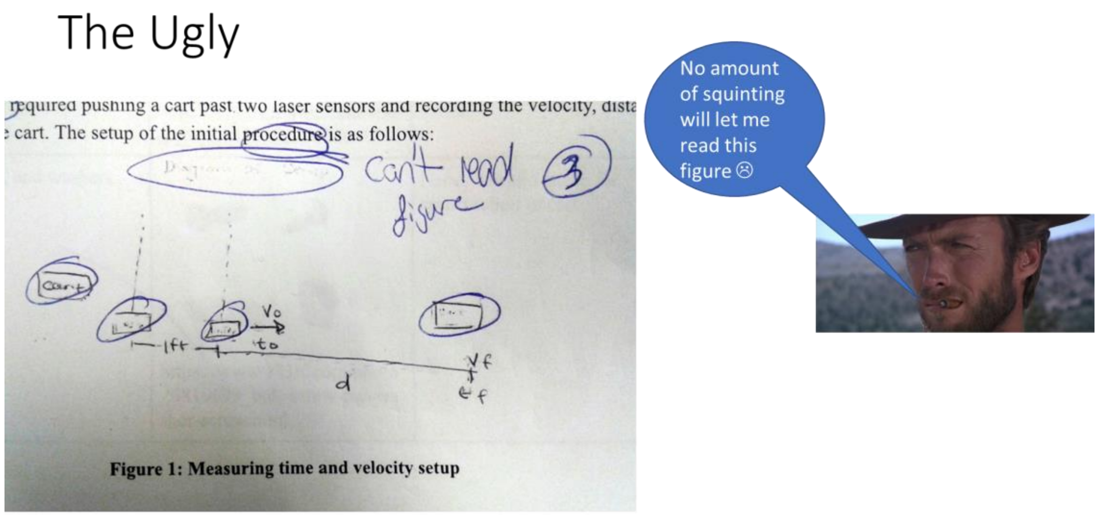


Figure 1. Example presentation slides on "The Good, the Bad, and the Ugly" of Technical Writing" for suggestions for improving student writing.

3 Results/Discussion

3.1 Baseline (2016 and Lab #1 of 2017)

The first year of the course (2016) displayed unacceptable levels of both comprehension, structure, and spelling and grammar within the reports. Examples of poor grammar, spelling and non-professional language from the pre-intervention student reports in 2016 and 2017 are shown in Box 1 below.

Box 1. Selected quotations from student reports (pre-intervention)

"This particular lab will not have that many principles that are unique to fluid mechanics apply, except for the negligible role that air resistance may play against the moving of the cart."

"Most of these variables will be given to us our found through the course of the experiment"

"The time takes to let the cart stop was record by one person in our group, but human has perception and reaction time, it is about 1 second even this person was prepared to record the time. So we should count this into calculation"

"We see that the cart has jetted away, and sometimes swerved to the left and not hitting all the time stakes in the right angle of direction. The cart jetted up as it blasted to its direction of motion. With a best out of three trials, we found

that the third trial was the best because it hit all 5 of the time indicators. The cart blasted up and jetted forward at the vertical direction of motion."

The above quotes contain multiple spelling and grammar mistakes, along with the use of first and second person, which are generally not allowed in technical writing documents. As a whole, the majority reports contained multiple formats, writing styles, and tenses, indicating that groups did not complete any peer review process, despite being strongly encouraged to do so. These mistakes were not relegated to just a few reports or examples, but rather were prevalent in the majority of lab reports. A box a whisker plot of the distribution of pre-intervention lab grades (2017, Lab #1) is shown by the yellow highlighted box in Figure 2.

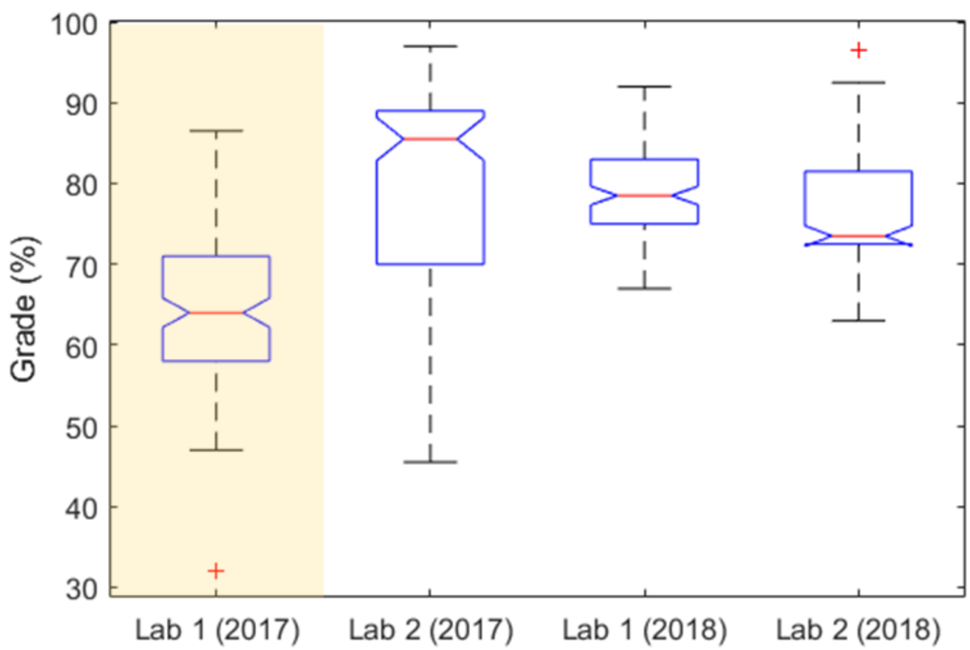


Figure 2. Pre (shaded yellow) and post-intervention lab report grades for the 2017-2018 lab years.

The quotes provided in Box 1 were not an anomaly restricted to just one or two lab groups, but rather were endemic of the majority of the lab groups, with nearly 30% of the lab groups failing the first assignment, and ~70% getting below a C- (C- = 70%, Figure 2).

Peer evaluations further indicated that writing abilities were either not at an acceptable standard and that "voluntary" peer evaluation did not work. Examples of feedback from peer evaluations are shown in Box 2.

Box 2. Selected quotations from student peer evaluations

"I could have turned in Star Wars Fan fiction instead of the second lab report and [the group] they would not have noticed"

"The rest of the group made minimal effort and contribution to the project. When they said they would complete a task by a date or time it would not be completed or it was obvious that they spent little effort working on it. Regarding the first lab, everyone did complete the task assigned; however, the other group members did not finish it until 2 am the day it was due."

"Groups, especially with people who do not know each other does not work out well. There were mistakes made and everyone pointed at each other as opposed to taking responsibility and recognizing that there is a lack of communication and groups need to meet up as opposed to communicate via text."

"I honestly think it would be more beneficial to do the lab individually than in a group, because working with a group can be detrimental when half of your group is hard to reach or lack the [sic] intiative to contribute with or without someone telling them what to do and/or how to do it."

"Group projects create an [sic] enviornment where there are certain students whom understand the material and where students who do not understand the material fall behind but get by on the work of others"

Indeed, many students found that group work actually negatively impacted their work and would have preferred to work independently instead. While there was no quantitative data collected during year 2, an analysis of the written responses found 14/21 lab groups had at least one member who contributed little to improve upon the reports, with 7 of those 14 groups considered dysfunctional (according to the criteria outlined in section 2.3.1).

3.2 Post-Modification (2017, Lab #2)

Post-course modification lab grades for the second half of 2017 (lab 2, 2017) showed significant improvements according to Students Two-Sample t-test ($p<0.01$, Figure 2). The second lab report showed a 14-point increase in the average grade, with a significant shift in the distribution – only 11% of lab groups failed, and 24% received below a 70 (C-), compared to 70% of groups receiving below a C- pre-intervention (Figure 2).

Student reception of "The Good, the Bad and the Ugly of Technical Writing" presentation was generally positive and listed in the anonymous course evaluation survey data as something that greatly helped them better understand technical writing. A review of the anonymous course evaluation survey data found six students specifically mentioning the presentation in the TA evaluation as a strength. Selected student quotes are shown below.

Box 3. Selected quotes from TA reviews on "The Good, the Bad and the Ugly of Technical Writing" presentation.

"His "The Good, The Bad, and The Ugly" slides were very creative and I hope he or another TA uses the same tactic in the future."

"I really appreciated when [the TA] criticized the entire class about their reports. The challenge helped me to think about how to approach my weakness as a technical writer, and I believe that through this hardship, I came out a stronger writer."

One-on-one group feedback were well received during the classroom and likely contributed to the improvement of Lab #2 grades in 2017. However, these sessions were not mentioned during the anonymous course or peer evaluation survey data, so their impact was likely not as memorable to the students as the "The Good, the Bad and the Ugly of Technical Writing" presentation.

No students mentioned the writing center helping them in the anonymous course or peer evaluation survey data, or student interviews. Student interviews suggested that while the writing center did not hurt them, the advice they received was too general to be helpful. In addition, the students mentioned that most of the tutors at the writing center did not know themselves how to write a technical report. Due to this feedback, extra credit for visiting the writing center was not offered to the 2018 class.

3.3 Post-Modification (2018, Lab #1)

In 2018, "The Good, the Bad and the Ugly of Technical Writing" presentation was given before Lab #1 was due. In addition, students were allowed to see previous years reports which had received high, medium, and low grades. Lab #1, 2018 showed a significant improvement over Lab #1, 2017 (Figure 2, $p<0.01$).

3.4 Post-Modification (2018, Lab #2)

Individualized feedback, both written and through mandatory meetings was given between Labs #1 and #2 in 2018. Despite the significant additional effort in delivering specific, individualized feedback to every laboratory group, there was no significant improvement between the first lab report (Lab #1, 2018) and the second (Lab #2, 2018, Figure 2). This result suggests that while the general advice from "The Good, the Bad and the Ugly of Technical Writing" presentation improved the class as a whole, the more specific feedback appears to exhibit diminishing returns for further technical writing improvement.

There could be numerous reasons for this result. The most likely reason is that the "Good, the Bad, and the Ugly of Technical Writing" group presentation seemed to work best with students who already had a solid writing foundation. These students already mastered the basics of writing and grammar, and simply needed more details about what makes a good technical document compared to other forms of writing. However, there was an additional group of students who were not far enough along in learning the basics of writing or communication, resulting in a negligible impact of the group presentation and individualized feedback.

This result is significant due to the major differences in efficiency of teaching the class as a group vs the much more labor-intensive one-on-one group feedback sessions and written comments. The additional time gained by just performing the group feedback sessions could be used for other valuable exercises, such as improving group dynamics, additional experimentation, allot more time for modeling exercises, or additional lessons specifically to reach students with a poor base of communication skills.

3.5 Impact of Intervention on Group Dynamics

The impact of the classroom modifications on group dynamics were evaluated by comparing mandatory group survey evaluations from the 2017 to 2018 cohorts. The hypothesis was that because the 2018 cohort experienced the post-intervention class modifications (and therefore higher grades) from the beginning of the course, group dynamics would improve over the 2017 cohort.

An analysis of group survey evaluations did not support this hypothesis. Table 3 shows a comparison between 2017 and 2018 with the number of groups with at least one ineffective member along with groups considered dysfunctional, based on criteria stated in Section 2.3.1.

Table 3. Comparison of pre and post-intervention group effectiveness rates

	2017 (pre-intervention)	*2018 (post-intervention)*
Proportion of groups with at least one ineffective member	67% (14/21)	67% (12/18)
Proportion of "dysfunctional groups" (≥2 ineffective members)	33% (7/21)	28% (5/18)

The described interventions had little impact on group dynamics, with no significant change between the two years. In addition, there were a number of students among both years who simply displayed a lack of motivation. The 2018 quantitative data detailing students' satisfaction with themselves and their group on a cross section of different abilities is shown in Figure 3.

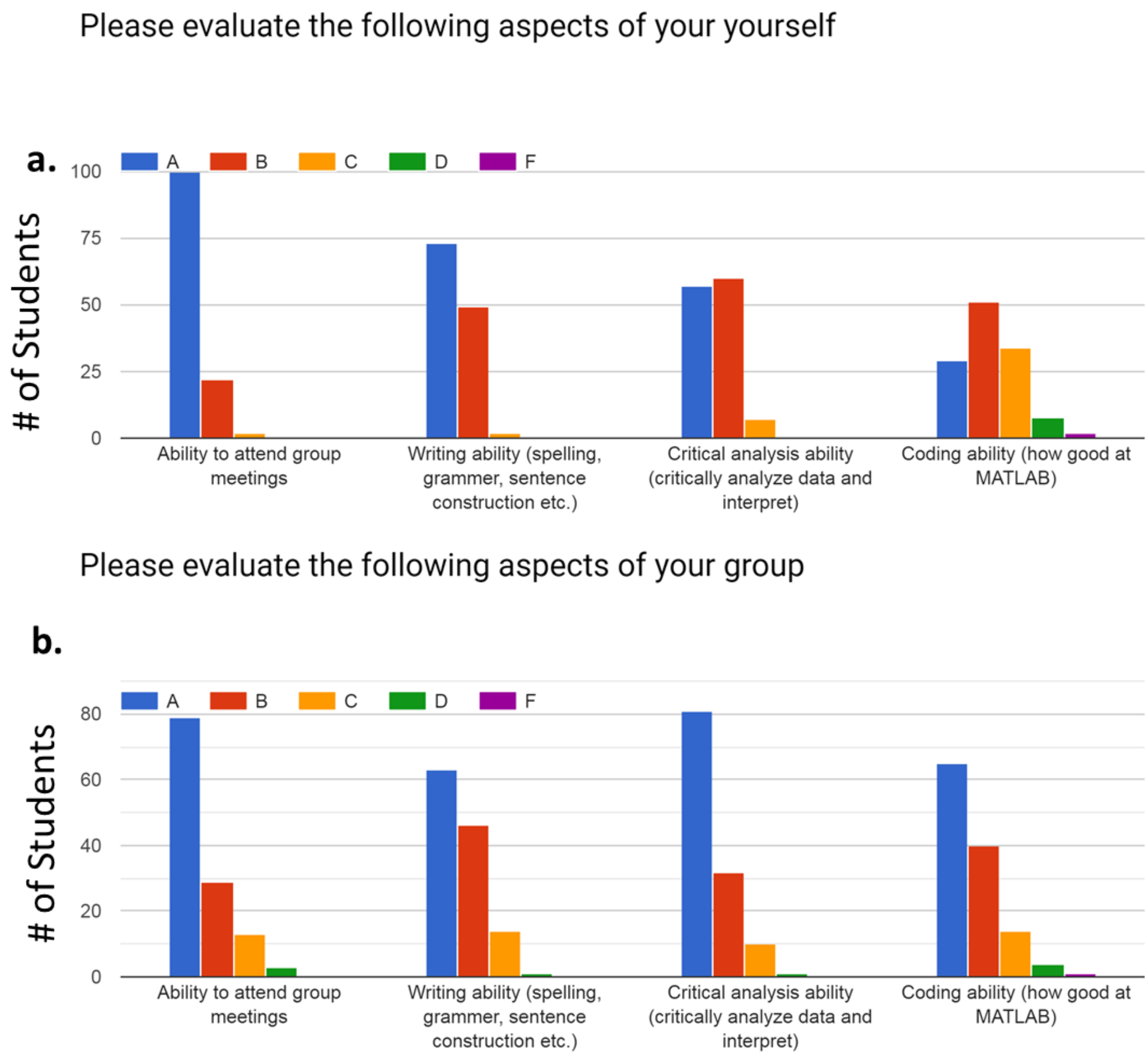


Figure 3. Students satisfaction with a cross section of different skills with between themselves (a) and their group (b).

Surprisingly, visual analysis shows that the biggest difference in student responses between their self-rating and their group rating was “Coding ability,” with students clearly believing themselves to be worse at coding compared to their group. “Critical analysis ability” was the second biggest difference, whereas writing ability and ability to attend group meetings were the closest in terms of student’s personal expectations meeting their groups. These results suggest that students were able to accurately judge their own and others writing abilities.

Most likely, the lack of improvement of group dynamics stems from the lack of a targeted approach to address group issues. Future classes will be tested using calibrated peer review, curated groups, and other experiments to try to improve group dynamics. A notable result is that improvement in the groups’ grades did not improve students’ feelings of group dynamics. Future studies using the 2019-2020 cohort will seek to confirm this theory.

4 Conclusions and Further Work

A series of interventions to improve student technical writing were implemented over a three-year period to assess their effectiveness. The study found that low stakes drafting and dynamic group level feedback in the form of class presentations (via “The Good, the Bad, and the Ugly of Technical Writing) were effective in significantly improving students technical writing. In addition, the results found that labor intensive, mandatory one-on-one group meetings and written feedback were less effective and much more time consuming compared to classroom-wide interventions. An analysis of survey results found that interactive, group class presentations and corresponding improvement in student grades and technical writing had no effect on improving group dynamics.

Detecting which students lack writing ability could be addressed by administering short, in-class essays where students must write upon a random topic. These essays could then be graded, and groups could be curated to ensure a good mix of strong, medium and weak writers compared to the randomized methodology implemented in the study.

Interviews with students found that generalized, lower division writing courses were ineffective at improving the writing skills needed for technical communication, a finding that is established within the literature [6]. Universities should re-evaluate the efficacy of holding these courses for engineering and science students, and focus on integrating technical writing into the core curriculum [10].

Further work on evaluating effectiveness of curriculum changes is strongly recommended. In addition, it is strongly recommended that universities give more attention to students writing abilities when determining admissions standards into engineering programs, as well making a more concerted effort to improve their writing abilities once they are in the program. Finally, instructors should take note of the fact that the less intensive classroom-wide presentations were most effective in improving technical student writing compared to the more labor-intensive one-on-one group meetings and written feedback.

Acknowledgements

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