

Improving Engineering Student Professional Communication through Mini-Laboratory Reports

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Abstract

A junior/senior-level course in the mechanical engineering department at a regional university has a laboratory component, and a portion of the curriculum includes a focus on professional communication. For many students, this course is the first one requiring a document outlining experimental procedures and results. This study looks at student performance on a full laboratory report over three semesters. In the first semester, the only preparation given was a review of the components of a full laboratory report. In the second semester, half of the prior laboratory post-lab assignments were converted from question/response format to mini-lab reports. A full laboratory report followed later in the semester. After student feedback, in the third semester the remaining post-lab assignments were converted to mini-lab reports. The performance on the full laboratory report will be evaluated, and student feedback on how the mini-lab reports prepared them for the full laboratory report will be presented.

Keywords

Communication, translatable knowledge, student preparation

Introduction

Engineering curriculum puts emphasis on problem solving, learning software, and other technical skills that may be useful in industry. Technical communication and writing skills are often neglected as these skills are not the main focus of study and prove to be an area of weakness for many young engineers [1]. An engineer that is a highly skilled technical communicator has a significant advantage in the job market over their counterparts. To have a successful professional career as an engineer, it is important to develop sufficient technical communication skills [2]. Often, engineering students find it difficult to present their results in textual forms as they focus more on performing the experiment and producing acceptable results and neglect the consideration of how to present their process and findings to others [3]. To develop technical communication in young engineers, instructors may implement technical writing assignments to produce a well-rounded student.

The ultimate goal of teaching technical communication to engineering students is being able to understand, collect, analyze and interpret data professionally. Students must first understand the purpose of their writing and its significance [4]. This could include conducting research or asking their instructor for further clarification. Once comfortable with this information, students should be able to explain step by step processes or procedures as to how they gathered the data. Laboratory procedures, or equations used to calculate results, should be referenced as supporting

documents. To ensure students include proper information in their medium of communication, discussion topics can be provided for fruitful content. Standard operating procedures (SOPs) provided with every mini-lab feature a series of questions and suggestions on how data should be analyzed. This direction encourages the production of figures and tables as well as real world applications that advances the students' knowledge of the topic in addition to providing different methods of interpreting data. Using these methods, students should be capable of successfully communicating in a professional manner.

One of the primary means of technical communication in an academic setting is a laboratory report. However, a complete laboratory report with department-set standards can be intimidating for a student to produce without adequate practice. To aid students in adjusting to expectations set for a full laboratory report, a mini-lab report can be given. A full laboratory report consists of an abstract, introduction, methodology, results and discussion, and a conclusion section. In the course presented, a mini-lab report includes an introduction, methodology, and results and discussion section. Mini-lab reports act as scaffolding, an educational practice of breaking down large goals and allowing students to complete a simpler version of that goal [5]. These mini-lab reports were assigned each week for six weeks of laboratory rotations. Students received their graded mini-lab back within a week and were provided with an annotated copy of their group's work. Providing thorough feedback for students allows them to receive clarification on their mistakes and better prepare for their next mini-lab leading up to the final full laboratory report at the end of the semester. In a study performed at The Ohio State University, professors found that the use of scaffolding practices for writing laboratory reports proved to be extremely beneficial for their students. This study saw a notable increase in performance between the students that practiced the scaffolding method compared to those who did not. Students using the scaffolding method also reported taking less time to complete their reports as they were more comfortable with technical writing assignments [5]. Using the scaffolding method, in the form of mini-lab reports, should result in improved technical writing skills and higher quality laboratory reports. It is of interest to see if scaffolding can be successful in a different format (multiple sections per week instead of one) and with a different age group of students.

Methods

Student performance on a full-length laboratory report was evaluated across three semesters in a junior/senior-level mechanical engineering course, Experimental Measurements and Techniques (EMT). For multiple semesters previously, one or two full-length laboratory reports were assigned during the course. Class time was not spent on the basics of writing full-length laboratory reports as it is a topic covered in the pre-requisite course Technical Writing. Instructors and graduate teaching assistants of EMT have observed that students need additional practice and guidance in the nuances of writing this kind of technical document that can come from repetition and feedback on previous submissions.

Mini-lab reports were introduced over two semesters as an intervention to help improve overall student performance and material comprehension on the full-length lab reports. Mini-lab reports were post-lab assignments for a selection of six procedures completed in lab. Each of the six lab

experiments were completed in a two-hour lab period each week. The format of the three semesters was:

- Semester 1 (Fall 2021): one full-length laboratory report
- Semester 2 (Spring 2022): three post-lab assignments (sequential question/response format), three mini-lab reports, and one full-length laboratory report
- Semester 3 (Fall 2022): six mini-lab reports and one full-length laboratory report

To assess the success of this intervention, performance on both the post-lab assignments from the rotation of six procedures and the full lab report was evaluated. The post-lab assignments were averaged by week. It should be noted that in one week, there are six different procedures completed with comparable but still varying levels of difficulty depending on student competency. Averages for each week were compared for each of the three semesters.

For the full lab report, the number of each letter grade assigned was compared for the three semesters.

Results and Discussion

Over the course of three semesters, Fall 2021, Spring 2022, and Fall 2022, students were required to complete post-laboratory assignments to analyze and discuss the data collected in each of the six EMT laboratory experiments. Figure 1 features the averages of the post-lab assignments calculated from each of the six weeks for the three semesters.

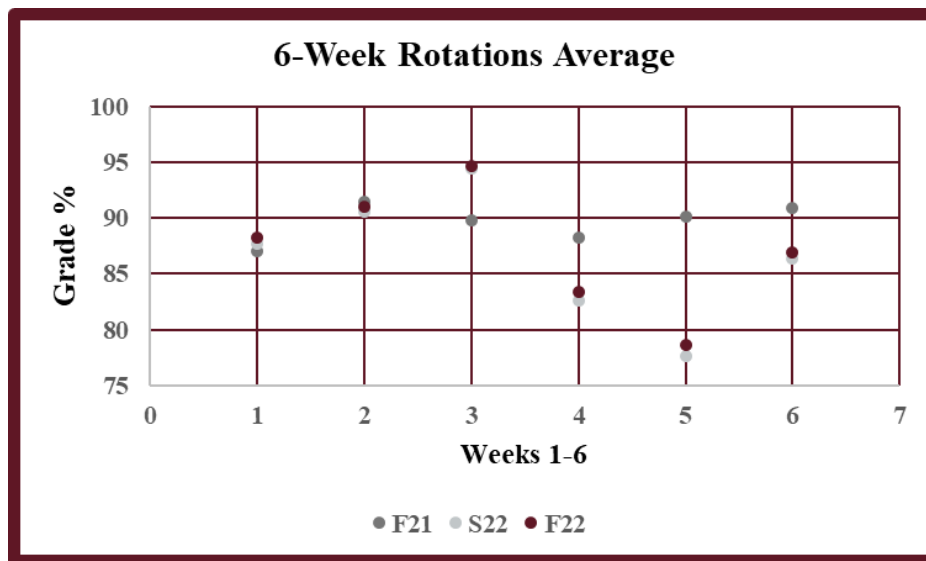


Figure 1: Post-Lab Report Grade Average

Grade percentage for F21, where students answered post-laboratory questions without format, stayed decently consistent throughout the six-week rotations. S22 and F22 produced a nearly exact trend, which was not expected as only half of the post-laboratory assignments were mini-

lab reports for S22. The time across Weeks 4 and 5, for both S22 and F22, saw a sharp decline in grade averages. This could be due to spring and fall break that would occur around these times in the semester. Week 4 was the first post-lab assignment submitted after each of the breaks. However, that does not explain why F21 did not follow suit. It is hypothesized that students in S22 and F22 were more fatigued from post-lab assignments at that point than students in F21 since S22 and F22 had more work-intensive mini-lab reports. Collecting data over more semesters can test this hypothesis.

It should be noted that every group does not perform the same experiment each week; there are six different experiments happening at once with six out of twenty-four groups in the classroom at a time. Each of the six experiments are set up at its own station and the groups rotate each week to complete their prospective lab. The declining trend weeks, from weeks 4 and 5, could also be related to the rigor of the post laboratory assignment and the groups that performed those experiments. Students struggle with the strain loading and industrial sensors post-laboratory assignments more compared to the other four experiments. These experiments also happen to be back-to-back in the experiment rotations which further explains the declining trend in weeks 4 and 5.

Figure 2 shows the grades for the post-lab assignments when grouped by the specific assignment. A different trend is seen here, as students from F22, all mini-lab reports, performed the worst in 66% of the post-lab assignments. The low performance is attributed to the formatting deductions students received on the mini-lab reports. Since all groups were completing mini-lab reports each week, more students received formatting deductions than in F21 and S22 where there were less mini-lab reports submitted.

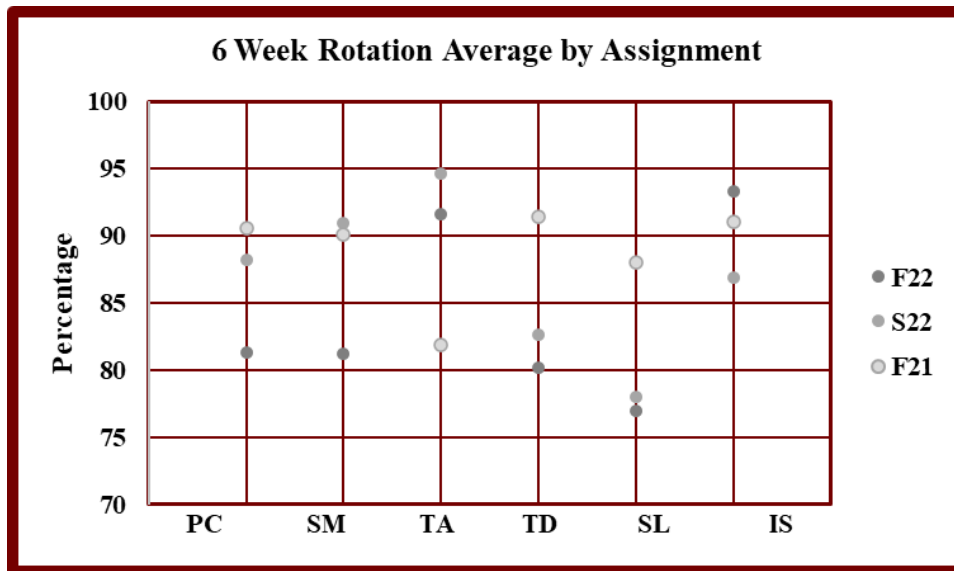


Figure 2: Mini-Lab Report Grade Average

Pressure Calibration (PC), Strain Materials (SM), Temperature Analog (TA), Temperature Digital (TD), Strain Loading (SL), Industrial Sensors (ID)

Results for the full laboratory report at the end of the semester can be found in Fig. 3. Both the mini-lab reports and the full lab reports were graded with consistent deductions over the three semesters. F21 students proved to have a significantly lower letter grade than those students in S22 and F22. Again, F21 students did not have any practice with mini-lab reports and S22 students completed three out of six post-laboratory assignments using mini-lab report format and requirements. F22 students completed six out of six post-laboratory assignments using mini-lab report format and requirements.

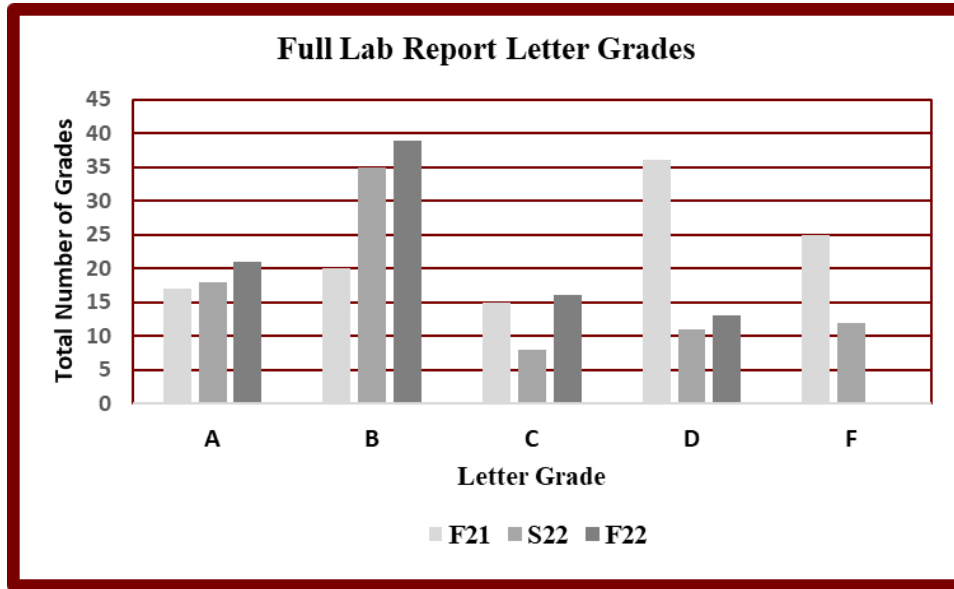


Figure 3: Full Lab Report Grade Breakdown

Students in S22 saw an incline in average to above average letter grades (A, B, C). These students reported feeling prepared for this full laboratory report as they had practice with their mini-lab reports. The F22 full lab reports continued to show improvement in quality. As expected, there was an increase in the amount of A, B, and C letter grades in the full lab report and there were zero F letter grades, which was an improvement from F21 and S22. This preliminary data suggests that implementing the mini-lab reports did improve student performance on the full lab report. These results do not show what specifically about the intervention was responsible for the improved performance on the full lab report. It is hypothesized that the multiple opportunities for formative feedback improved the performance on the summative assessment. Performance can be tracked for more semesters to test this hypothesis. The continued return to a “normal” learning environment may also have affected the student performance. The authors showed a drop in student performance across multiple classes after the return to face-to-face instruction after the onset of the Covid-19 pandemic. Student performance has improved as more semesters pass. Regardless, these results show that the format of smaller assignments given students more opportunities for practice has success in this course.

The results shown in Figures 1, 2, and 3 paint an interesting and surprising picture of student performance. Student communication and data presentation skills did improve; the full lab reports in F22 were considered holistically good by the instructor and graduate teaching

assistant. Students may have performed worse in the lower stakes, formative assessment mini-lab reports, but ultimately they applied what they learned in the full lab report.

At the end of the Spring 2022 semesters, students were surveyed about the introduction of the mini-lab reports. Overwhelmingly, students said the mini-lab reports helped them feel more prepared for the full lab report. Students frequently mentioned how the multiple opportunities to practice were helpful. They felt more familiar with formatting requirements for the full lab report. A few students mentioned that the schedule resulted in them having multiple mini-lab reports in a row, which was a heavy load. Selected responses are given below:

“YES! Being able to slowly learn by doing reports made it so we really were just applying knowledge for the first order [full lab report] instead of having to learn all the little details.”

“I think the mini-lab reports did prepare us for the full lab report. I didn’t have much knowledge about lab reports and I always had questions about them, so getting to practice with the mini labs definitely answered questions I had that I knew for the full lab report.”

“I feel like formatting wise it helped a lot because we knew how to format it and stuff like that. Content wise it helped too because we knew what type/relevant info to put on there. So, I would say yes the mini-labs helped.”

“Yes. The feedback and format feedback specifically was very helpful. Maybe something to improve would be graph understanding prior to the lab. I feel that would have helped me understand visually more of the lab.”

Overall, the student performance on the full lab reports has improved since the introduction of the mini-lab reports. Course instructors and teaching assistants have also noticed an improvement in the communication and data presentation abilities of the students. This improvement is attributed to the multiple opportunities for formative feedback.

Future Plans

Many students requested an example report to give them a better idea of what their finished product should look like. Spring 2023 semester will receive an outline of a mini-lab report with key details that should be included in each section. For the past three semesters, students have received a standard laboratory report requirement document that has explanations for the formatting expectations with verbal clarification of expectations. However, students still request further written clarification to reference and will receive examples of formatting in the outline for the mini-lab report.

Data from performance on the full lab report will continue to be gathered to see if trends continue to show an improvement in student performance. Data suggests there may be more work to do in developing the mini-lab reports to be most beneficial to student learning. Focusing on more standardized feedback may help as well as adjusting the length of the assignments.

Conclusion

A scaffolding approach was integrated into a junior/senior-level combined lecture and laboratory course to improve student technical writing skills. Over the course of three semesters, post-lab assignments were transitioned into mini-lab reports, requiring students to write three of the five sections of a full-lab report. Later in the semester, students completed the full lab report that was typically assigned in the course. Student performance on the post-lab assignments was analyzed as well as on the full-lab reports. Results showed an improvement in student performance on the post-lab assignments with the integration of mini-lab reports, but only for the first half of the weeks they were assigned. A drop in performance was seen in Week 4. This may be contributed to student fatigue in the semester or students having lower competencies with the material covered in later post-lab assignments. The performance on the full-lab report did improve from the Fall 2021 (question/response post-labs) to Fall 2022 semesters (all mini-lab reports).

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