# Reframing the First-Year Engineering Laboratory

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The Fundamentals of Engineering for Honors program for first-year students at The Ohio State University identified a series of shortcomings in the laboratory and technical writing component of the engineering fundamentals class. These shortcomings were addressed by providing the students with the structure to focus more on the writing component of their laboratory reports than the formatting. This was accomplished by providing a scenario for each lab that related the exercises to a real-life engineering task, and by improving incentives to complete the pre-lab reading and work. Student and instructional staff responses to this structure were overwhelmingly positive. Student feedback suggested that the new structure provided better context for the labs and better support for learning technical writing. Over 85% of the students in the course reported that they developed strong communication skills and a strong ability to document results and use proper reporting procedures.

## Introduction

The engineering laboratory is an important part of an engineer's education. It allows students to gain practical, hands-on experience with engineering tools and methods. The Fundamentals of Engineering for Honors (FEH) program for first-year students at The Ohio State University has included a laboratory experience as part of its curriculum. These students have varied experiences prior to attending the university and many different intended engineering majors, including a large percentage that are undecided. In addition, most of these students have limited experience creating technical laboratory reports. These various qualities create a particularly challenging context for running multidisciplinary introductory engineering laboratories. Instructors need to ensure that the laboratory experience is relevant to as many intended engineering majors as possible, while addressing the universal core engineering principals. As a result, the program strives to create a laboratory environment that (1) is accessible to students with differing levels of technical expertise, (2) teaches fundamental engineering tools and skills, (3) introduces students to a variety of engineering disciplines, and (4) provides a strong introduction to technical writing. [1]

Traditionally, each laboratory experience was developed around a set of learning objectives. These objectives allowed the program to ensure that all four goals were met; however, in the process, the laboratory experiences became technical experiences without a framing context in which the students could understand the purpose behind the tasks they were performing. Similarly, the grading for the lab reports centered more on technical and formatting specifics rather than overall writing quality. As a result, students commented that the labs seemed irrelevant and disconnected, and that their grades were the result of "nitpicky" grading rather than the overall product.

Several authors have provided details on laboratory courses for first-year students in specific disciplines,[2] for students in multidisciplinary courses,[3] and for instructing engineers in technical writing,[4,5] but few authors have specifically addressed the complex issues of the first-year engineering multidisciplinary laboratory.[6] The purpose of this paper is to present the reframing of FEH's first-year engineering laboratory experience to provide context for the laboratory experiments and address shortcomings in the technical writing instruction. These changes coincided with a university-wide shift from quarters to semesters and a unit-wide transition to the inverted classroom, where students independently learned the material traditionally presented during lecture prior to arriving to class. Class time was then devoted to activities and more in-depth exploration of the topics.

The next section of this paper addresses how faculty identified the aspects of the laboratory that needed improvement. The following section details the overall structure of the labs, followed by a section that shows how the shortcomings were addressed. After this, the results of the changes are presented, followed by a conclusion and suggestions for future work.

**Identifying Areas for Improvement**

Prior to implementing these changes, the instructional staff within the program identified several key shortcomings in the laboratory experience through evaluation of student-submitted lab reports and discussions with the teaching assistants who assisted the students in lab and during the laboratory report writing process. First, the students struggled with the purpose and audience of their lab reports. Students were taught to treat the laboratory experience as a true experiment, such that the purpose statement in their laboratory reports might read "to evaluate the state of traffic on a specific stretch of road" rather than "to learn about speed studies"; however, even after several examples and several lab reports worth of feedback, many students still were unable to view the laboratory experience as an experimenter reporting results rather than a student writing to an instructor.

Second, the students frequently mentioned that they did not see how the labs related to "real" engineering and felt that much of the laboratory work was "busy work". As one student stated in an evaluation, "One change that I would make to the lab experience would be to explain more about the "why" behind the experiments. I mean, the lab write-ups explained that this concept is used in civil engineering or mechanical or whatever, but they don't really say how they are used in those fields, what the importance behind the experiment is and what … the significance behind the results are. So if I could change one thing, I would make it so that a relationship is shown between the experiments that we do and real life."

Third, students struggled so much with the small formatting and technical details that they neglected the overall flow and writing quality of the reports. Students would spend hours, both at home and in office hours, attempting to achieve proper formatting, but continued to struggle with appropriate use of technical language and producing a consistent story in their report.

Finally, it was difficult to choose an appropriate depth for the in-lab presentation prior to the experiment, partially due to inconsistency in student dedication to completing pre-lab work. If the presentations were too detailed, those students who read the assigned pre-lab documentation reported that they felt bored and that their efforts were useless. If the presentations were too brief, those students who did not prepare or did not understand what they read reported that they felt lost for the remainder of the lab.

**General Laboratory Features**

Under the semester format, the students met in the classroom three times per week and in the laboratory one time per week, with each meeting lasting 125 minutes. There were approximately 36 students in each class, with 15 sections program-wide. The laboratory rooms contained nine tables, each with four or five chairs and four computers. A graduate teaching associate was responsible for the lab, with three undergraduate teaching assistants helping supervise the students' activities. One of those undergraduates would assist the graduate teaching associate in grading the labs.

The course contained 12 labs, listed with descriptions in Table 1. The labs covered a variety of topics addressing the various engineering majors at the university. Each lab had a lab write-up to be read prior to class, which could include instructions to watch videos or simulations and described the post-laboratory report requirements. Once in lab, the graduate teaching associate gave a short presentation covering the topics relevant to the lab. Most labs had post-laboratory requirements, in the form of a formal report or an engineering memorandum. Some labs, however, consisted of only an in-lab worksheet. This allowed students to receive feedback on previous reports before writing the next report.

**Table 1:** Laboratory subjects and assignments

| **Lab Subject** | **Disciplines Covered** | **Post-laboratory Assignment** |
|---|---|---|
| Short design-build project | All | Writing worksheet |
| Spot speed study | Civil | Report |
| Product launch case study | All | Worksheet |
| Electronic power supply | Electrical | Spot speed rewrite |
| Data acquisition systems | All | Worksheet |
| Digital logic | Electrical | Worksheet |
| Design analysis | Mechanical | Report |
| Aerodynamics of a wind turbine | Aerodynamics | Report |
| Falling cylinder viscometer | Chemical, Mechanical | Report |
| Deflection of a cantilever beam | Mechanical, Material Science | Memo |
| Motor dynamics testing | Mechanical | Memo |
| Real-time control of a stoplight | Electrical, Computer Science | Memo |

**Addressing the Shortcomings**

The faculty implemented several changes in an attempt to address the concerns listed previously. The approach was constrained by several factors. The changes needed to be implemented during a time of unit-wide overhaul. Thus, due to limited resources, major equipment modifications were not feasible at this time. Due to limited time and resources, four sections were required to run the lab simultaneously. Thus, the changes needed to be easily implemented and consistently maintained on a wide scale. Finally, the changes need to incorporate the positive things that already existed in the labs, especially the consistency in grading between 15 different graders, the representation of a variety of engineering disciplines, and the introduction to fundamental engineering tools and techniques.

One initiative that had been started several years prior and was continued through the reframing of the labs was the lab report rewriting opportunity. The first laboratory report would be turned in, graded, and returned to the students. The students would then use the feedback from the report to modify their reports, turn them in a second time, and the final grade for the report would be the average of the original and the rewrite. This process allowed the students to write their first laboratory report and learn the fundamentals of technical writing and formatting with less of a grade risk.

For technical writing instruction, students were previously provided a new guide to lab reports and memos that addressed both content and format. To emphasize writing quality over formatting details, the guide was split into two parts. The first part discussed the various sections of a laboratory report and their content. It instructed the students on how to choose what information to include in the report and in what order to write it. Additionally, a class period outside of the laboratory experience was devoted to addressing the technical writing elements covered in this guide, as well as important formatting, grammar, and word choice principles.

The second component of the guide was a template created in Microsoft Word. This template already contained the desired formatting, with spaces left for modifying text. The styles in the document were set to match the styles required for the report. Sample tables and figures were presented and could be duplicated and modified by the students as necessary. Finally, the rubric provided to the students and used by the teaching assistants was modified to reflect the new priorities. Figure 1 depicts the rubric released to the students. The teaching assistants were given more detailed instructions and grading breakdowns to strive for consistency

| | POINTS POSSIBLE | POINTS EARNED | COMMENTS |
|---|---|---|---|
| CONTE | | | |
| INTRODUCTION | 5 | | |
| EXPERIMENTAL METHODOLOGY | 7 | | |
| RESULTS AND DESCRIPTION | 10 | | |
| DISCUSSION | 10 | | |
| SUMMARY AND CONCLUSIONS | 6 | | |
| LAB SPECIFIC REQUIREMENTS | 30 | | |
| LANGUA | | | |
| COMPLETE, CONCISE, CLARITY, FLOW | 5 | | |
| PROFESSIONALISM, TENSE, PERSON | 5 | | |
| SPELLING, GRAMMAR, PUNCTUATION | 5 | | |
| FORM | | | |
| CONTENT PLACEMENT | 5 | | |
| FORMATTING | 5 | | |
| LABELS, REFERENCING, CITATION | 5 | | |
| SURV | | | |
| COMPLETED ON CARMEN | 2 | | |
| | | TOTAL SCORE | /100 |

**Figure 1:** General laboratory rubric used in the course

To address the disconnect many students felt regarding the purpose of the labs, each lab's handout was rewritten and framed around a scenario. Each scenario was written as if the students performing the experiments were employees or researchers at a company that were asked to solve a problem, such as designing a solution or investigating a research question. For instance, for the spot speed study lab, students were given the background story that follows:

"The University has received complaints from several pedestrians walking on stretches of [two roads]. The pedestrians are concerned about the speed of traffic in these areas and suggest that further traffic control measures should be implemented.

Due to budget and personnel constraints, the university would like to ensure that such measures are actually necessary before dedicating valuable resources to the effort. Thus, the university is asking your team to conduct a spot speed study in one of the affected areas. You are then to perform a thorough statistical analysis of your results and provide your recommendation on whether the current levels of speed limit enforcement are sufficient. The following guidelines should provide you with enough information to complete the task and produce a proper report that concludes with your recommendation."

For another lab, students were asked to "provide [their recommendation] on whether or not the current amount of material used in manufacturing the crutches can be decreased, and if so, to what extent. As safety and reliability are [the] top priority, be sure to take these into consideration when making your recommendation." Through these scenarios, students were given better examples of how the work that they were doing in the laboratory would be used as an engineer in "real life".

Finally, to encourage students to be better prepared when arriving at the laboratory, each lab had a preparatory assignment associated with it to be completed once the students finished reading the lab write-up and viewing any associated material. This assignment was a tutorial, a problem, or an online quiz. These assignments and quizzes were primarily used to ensure that the students had the necessary background information, and thus were designed to focus on the lowest levels of Bloom's Taxonomy.[7] This structure closely matched the structure applied to the classroom component of the course as part of the inverted classroom implementation.

**Evaluating the Changes**

Attempts to quantitatively evaluate the effects of the lab restructuring were made difficult by the drastic changes that were implemented. The labs used in the semester were chosen from two quarters' labs, the grading keys were changed to emphasize content over format, and student evaluation prompts also changed. Thus, most of the evaluation was based on student feedback on the labs as well as comments from the instructors and teaching assistants.

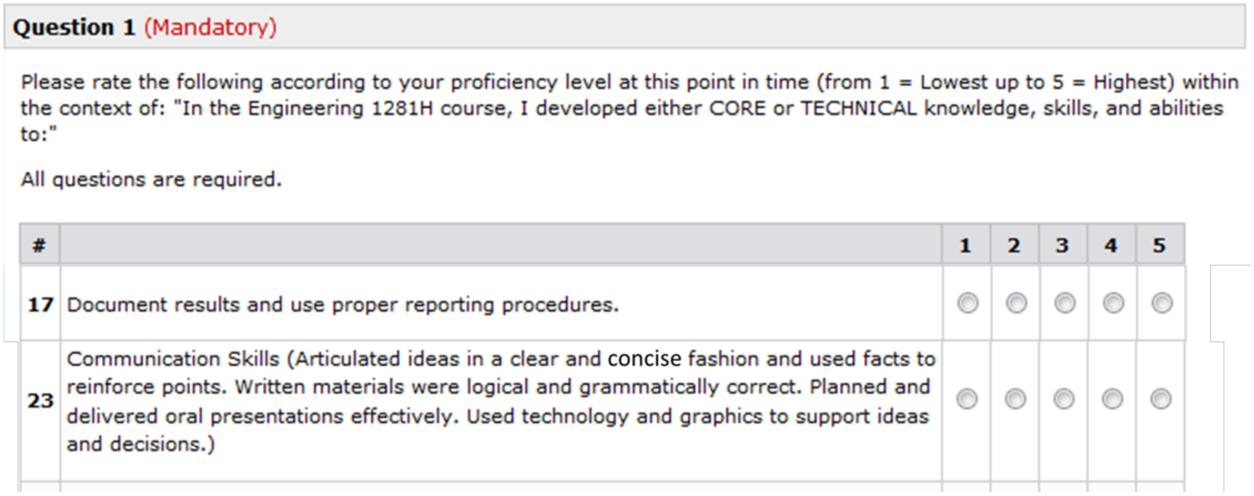
Student feedback was gathered in two ways. First, the students responded to an online, anonymous "journal" question.[8] These journals allowed the students to provide open-ended feedback each week throughout the semester. The journal about labs asked the students, "What did you find valuable about the engineering labs? ... Did the labs make you a better technical writer? How helpful were the lab write-ups and the guide to writing lab reports and memos?"

Many students responded that they found the laboratory experiences helped expose them to a variety of engineering disciplines and engineering tools. One student wrote, "I thought that the engineering labs were a good sample of the kind of problem solving that different engineering fields would involve. This was good because as a freshman I'm still looking around for what interests me so the labs were a good way to kind of identify the different engineering fields." Another wrote, "In the engineering labs, I found the hands on aspect the most valuable. I had never used the majority of the equipment before, so gaining experience using these different tools and methods gave me better perspective as a future engineer."

Most students acknowledged that the labs helped improve their technical writing skills, usually referring to the guides and write-up at the same time. One student compared the experience with high school chemistry: "Yes, I believe that the post-lab assignments made me a better technical writer. While in high school, I had a limited experience with technical writing when I took my chemistry courses, but not to the level on this… course. Also, the lab write-ups and guide to writing a lab report and memo greatly helped my technical writing. I felt as though I had a better idea of what was expected of the assignment, and I had a set outline of how my report should look. I simply needed to practice filling in the content." Another wrote, "The labs honestly did make me a better technical writer. I always got A's on the [concurrent] chemistry labs and I think the engineering lab reports really helped. The lab write ups were extremely helpful and so was the guide." A third responded, "There is no question that the lab reports and memos made me a much better technical writer as the semester progressed. With help from [teaching assistants], my professor, and the guide to writing lab reports, I found that daunting technical writing assignments weren't so bad after all."

Some students still felt that there were areas for improvement. Some students felt that there was too much emphasis on electrical engineering, writing, "If I could change anything about [the labs], I would have fewer labs that were directly related to electrical engineering. Many dealt with circuit boards or bread boards." Other students still expected the labs to be directly related to in-class material. One responded, "Labs were not very helpful in learning the material covered in class." The primary complaint was about the workload. As a student wrote, "To change something, I would not make all of the lab criteria so stressful when we have everything else going on in engineering."

The second avenue for student feedback was an end-of-semester student evaluation. The evaluation, shown in Figure 2, asked students to rate their proficiency level in a variety of course subjects. Specifically, two of the questions asked about proficiency in (1) documenting and reporting results and (2) communication skills. The results of the survey found that over 85% of students responded with a four or a five on each question, as can be seen in Figure 3.



**Question 1** (Mandatory)

Please rate the following according to your proficiency level at this point in time (from 1 = Lowest up to 5 = Highest) within the context of: "In the Engineering 1281H course, I developed either CORE or TECHNICAL knowledge, skills, and abilities to:"

All questions are required.

| # | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 17 | Document results and use proper reporting procedures. | ○ | ○ | ○ | ○ | ○ |
| 23 | Communication Skills (Articulated ideas in a clear and concise fashion and used facts to reinforce points. Written materials were logical and grammatically correct. Planned and delivered oral presentations effectively. Used technology and graphics to support ideas and decisions.) | ○ | ○ | ○ | ○ | ○ |

**Figure 2:** Subset of the questions asked during the end-of-semester course evaluation survey

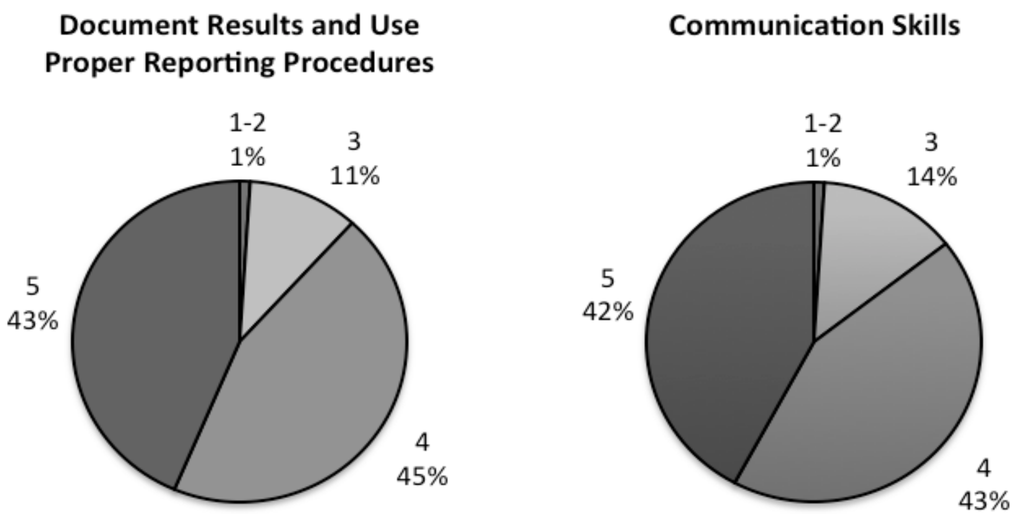



**Figure 3:** Student evaluation of knowledge, skills, and abilities on the final course evaluation relative to technical writing skills

The instructional staff response to the new format was also generally positive. The teaching assistants grading the labs were able to focus their feedback to the students on higher-level problems, such as how to write an effective "funnel" in the introduction, rather than merely helping students find an appropriate purpose for the lab. According to the instructional staff, students seemed to be prepared for the labs and tended to be more positive about the experience.

One of the instructors' concerns during this transition was that the more holistic approach to laboratory grading would affect grading consistency between the various sections of the course. In reality, the averages for the fifteen sections had only a standard deviation of 1.5 points out of 100 (Figure 4).

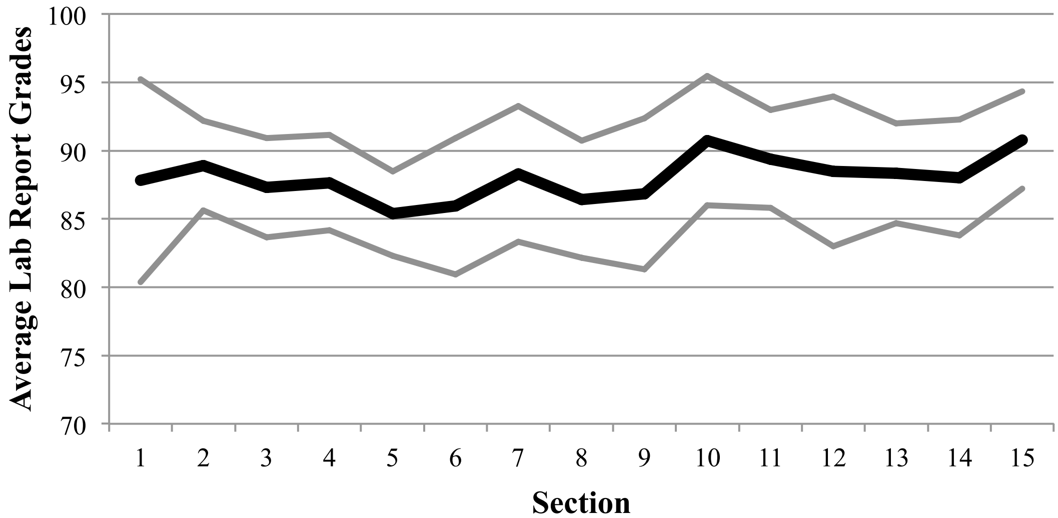



**Figure 4:** Student lab report grades were quite consistent across the sections, with a standard deviation of only 1.5%. The dark like represents the average lab report grade in each section, and the gray lines represent +/- one standard deviation.

**Conclusions and Future Work**

The FEH instructional staff at The Ohio State University identified several shortcomings with the existing laboratory experience. A series of changes were implemented to addresses these issues and appear to have been largely successful in doing so. Student and instructional staff responses to the changes were overwhelmingly positive. This new format may be useful to other first-year engineering programs with similar laboratory difficulties, particularly in the areas of improving student engagement and technical writing.

This report was unable to provide a concrete statistical comparison between the system prior to and following the implemented changes. Since the qualitative analysis of the students' experience suggests that this system is beneficial to the students, future work would address this by providing a more quantitative analysis of the system. Additionally, some students still felt that their majors were underrepresented in the laboratory. Further development would improve the diversity of the labs, particularly by including a meaningful chemical engineering lab that could be performed in a dry lab on a large scale.

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