LABORATORY SPECIAL TOPIC REPORTS

By D. M. McStravick, T. M. Volz
Rice University

Abstract

Often students in undergraduate mechanical engineering lab courses have trouble with proper use of significant figures and conversion of units. Additionally, they often don't fully recognize the importance of error analysis in experimental work. To counter these deficiencies, a new lab course procedure was initiated. In this program, the students are required to write initial library research reports that focus on some facet of significant figures, units, or error analysis. These reports are assigned the first week of the semester and are graded and returned before their first experimental lab report is due.

This process also identifies students who need help with their writing skills. Faculty who specialize in communications training collaborated in the planning and evaluation of this report writing project. They critically reviewed these initial reports and provided feedback to guide students' revisions. In addition, they were available to consult with students on their experimental lab reports.

After several semi-successful attempts, library research reports with more engaging topics have been used successfully to drive home the technical points and to make a more enjoyable student writing experience.

Introduction

Many Mechanical Engineering students at Rice University begin to fulfill their upper level engineering laboratory course requirements with a fluids lab. Prior to entering the fluids lab, students have taken science courses with labs in Physics and Chemistry, so they are expected to be well grounded in the basics of the scientific method, experimental procedures, etc. The fluids lab emphasizes report writing as well as the basic physics applied to fluid flow. Students in this course frequently have trouble with appropriate significant figures, units conversion, and error analysis. Also, their graphing skills are somewhat limited. To address these problems the initial lab meetings were used to describe the typical pitfalls to students. This approach included showing copies of previous lab reports in which students had used 8 to 16 significant figures throughout the lab report and showing the students an old slide rule (first asking if anyone knew what it was) and then pointing out that no one using this "calculator" ever got the idea that he or she could derive a result with 8 significant figures. At this session it was emphasized that in the fluids lab 3 significant figure results are probably somewhat optimistic and data should be recorded with this in mind. This problem with the correct use of significant figures is further exacerbated by our conversion to using computers for data acquisition. This modification leads to data files, which can have excessive significant figures, and if the students don't use good judgment, the results of their analysis will reflect this same excessive level of accuracy. Because the experiments in the fluids lab frequently require the use of Bernoulli's equation, units can be a problem for the students. Much of the equipment presents data in English units, and dimensional conversions are frequently required; plus handling lbm and lbf can lead to problems for many of the students. To defuse this potential problem, dimensional analysis is emphasized and required in all the sample calculations. To address dimensional conversions, copies of adequate conversion tables are made available at the start of the course.

One of the goals in this lab is for students to produce professional reports. This includes emphasis on writing skills and professional document design (report cover, organized presentation following an outline, high quality graphs, etc.). To achieve this goal, a fairly detailed outline is provided by the instructor and strongly recommended for use. Additionally, some short exercises in graphing are required early in the course. In the initial meetings, the value of a graph is stressed as compared to tabular data.

New Approach

The approaches described above were done within a limited timeframe of an initial group meeting and followed by a few initial exercises. Generally the results of these approaches were of limited success. To improve the results, the course was revised to include individual library research reports, which were completed during the first week of class. These reports addressed issues such as significant figures, error analysis, and units. Additionally, the resources of the Cain Project (see Appendix A) were enlisted to improve the writing skills of the students. The Cain Project provides a group of faculty members that specialize in communications training to be available for the evaluation of these initial reports. This approach allowed identification of students with report writing deficiencies before the formal laboratory reports were submitted and offered an opportunity to give feedback and suggestions for improved reports.

In spring 2002, the first library research report was assigned on significant figures. The students were required to write a report on the determination of an accurate value for a fundamental constant (*e.g.* the speed of light). The students could choose any topic, but they needed to give some history and discuss how the experiment(s) achieved the reported accuracy with emphasis on the difficulty of achieving the high accuracy. The students wrote the reports and were required to exchange papers and critique another student's report using a peer review evaluation form. The peer review exercise was used because many of the students have excellent writing skills and could mentor the weaker students. The reports and critiques were reviewed by a Cain Project faculty member, and the students met in small groups with the reviewer to discuss the reports overall and to respond to specific questions on individual reports. The organization and style of the reports were consistently good. However, many of student writers did not know what kinds of information ought to be included in an abstract. They did not provide specific evidence to support their claims. Their conclusions were irrelevant or exaggerated, and their sources were not documented properly. As a final step the students were encouraged to rewrite their reports based on the feedback provided, for which they received a partial credit to improve their final grade on the report. Most students submitted a revision, and the final products were evaluated. This grade represented one-sixteenth of the final grade in the course. The authors' evaluation of this first project was that it had a limited success; peer review was not of the expected caliber: most students offered little in the way of constructive criticism on the papers. Feedback from the students on course evaluation was not favorable (about 25% indicated that this exercise was not very productive); the quality of the papers was not as high as the authors anticipated. On further reflection, the authors decided to change the format so that less time would be spent meeting in small groups to discuss the students' papers and peer review would be dropped.

In fall 2002, the revised approach was used in a senior laboratory course, which contained essentially the same students as in the previous spring fluids lab course. The topic chosen for this paper related to error analysis. The students were required to write a short paper on "Cold Fusion" (see the assignment in Appendix B). This topic was chosen because it was felt that it would be new to these students and engage their interest. The students were asked to report facts related to the incident and give an opinion regarding the culpability of the Cold Fusion researchers. Also, they were required to relate the consequences of this event to engineering work in general and to this laboratory course in particular.

The results of the revised approach represented a significant improvement over the previous spring's project: the reports were of a higher caliber and the students showed a strong interest in the topic. The majority of the reports contained complete abstracts, well-supported arguments, and references. The progress made by several student writers in the course can best be illustrated with a specific example. The abstracts submitted for the two library report assignments by the same student appear below. The student's first abstract on significant figures is wordy and leaves many key questions unanswered: Why was this problem significant? Why was it difficult? What were the experimental milestones? How does the accuracy of the constant relate to significant figures? The same student's second library report abstract on Cold Fusion summarizes many of the key points and does so in half the words. While a couple of questions do remain unanswered, such as what experimental result led to Pons and Fleischmann's announcement, the Cold Fusion abstract explains who did what, why it was significant, and what lesson was learned.

Significant Figures Abstract:

This report addresses the importance of significant figures in laboratory work. The number of significant figures in a calculated quantity reflects the precision of the experiment performed. The determination of an accurate, experimentally determined value of the speed of light required many years of evolving experiments and sophisticated technology. After many years of study, the speed of light was known with such precision that it became a defined quantity for measuring distance. On the contrary Young's Modulus for steel cannot be determined to the same degree of certainty because of differences among steel samples and the relatively cruder measuring devices.

Cold Fusion Abstract:
The experimental "discovery" of cold fusion in an electrochemical cell by Stanley Pons and Martin Fleischmann yielded nothing but embarrassment. Instead of teaching the world how to tap an essentially limitless source of energy, they serve only as a cautionary example to all experimentalists. They have shown that thorough error analysis and peer review are essential in the creation of any experimental report.

Comparing this student's two abstracts demonstrates an increased ability to select appropriate content and to adopt a concise writing style.
At the end of the senior lab in the fall, the students were offered an opportunity to write another report on a topic that addressed units. The topic chosen was the loss of the Mars Climate Orbiter. The assignment is shown in Appendix C. In this case, a miscommunication about English units and Metric units led to an expensive loss of a NASA satellite just as it was about to go into orbit around Mars. This assignment was done on a voluntary basis so only about one third of the same group of students submitted a report. The quality of the reports was quite good, and it was clear that the students put considerable effort into the assignment. This was a preliminary test of the topic for the spring fluid lab. This topic is particularly appropriate for the fluids lab due to the need for units conversion required in most experiments.

Cain Project

The Cain Project in Engineering and Professional Communication is a 10 year experiment to enhance communication skills for both undergraduate and graduate students at Rice University. Appendix A gives some background on the Project. The Cain Project supported the library research report activity in the fluids lab by providing faculty to critically review the reports and provide feedback to help students rewrite the paper. Additionally, one-on-one sessions were made available to the students for the experimental lab reports. Generally the reports were of high caliber and only one student was requested to take advantage to this service. The support of the Cain Project was a valuable component in this effort to improve the students' writing skills and awareness of pitfalls related to units, significant figures, and error analysis.
Most universities do not have a Cain Project to support writing instruction in science and engineering. However, many universities do provide alternative resources that can be deployed to achieve the same goal. Engineering faculty can consult with writing across the curriculum (WAC) faculty at their institutions to learn strategies that will minimize the time and effort required to evaluate students' research reports. For example, if commenting on students' reports seems too time consuming, students can be informed in advance that they will receive feedback only on two sections of their reports, such as the introduction and discussion sections. If weak student writers are identified through this type of assignment, arrangements can be made for them to meet with peer tutors in the university writing center or academic skills center. If a writing center is not available on site, students can receive one-on-one assistance from tutors working in on-line writing centers at other institutions.

Conclusions

The main thrust of this program was to address the pitfalls related to significant figures, units, and error analysis, as well as, improve the students' writing skill in preparation for the formal lab reports. This process also was used to identify students weak in these areas and provide an opportunity for remedial consultation. Although this effort is still in the early stages, some conclusions that can be made:

- A lecture addressing the experimental process stressing the importance of proper use of units, significant figures, and error analysis was not satisfactory.
- Writing a report addressing experimental issues caused more student review of these topics with a

positive impact on the lab reports.

- The peer review was not successful in fostering better writing skills among the students.
- The Cain Project was important in this program by providing a resource to critically review the students' reports and improve writing skills.

The process to improve the students' understanding of the importance of error analysis, proper use of significant figures, and units conversion is on-going. Other report topics are being evaluated and will be used in future lab exercises.

References:

1) Taubes, Gary, **Bad Science**, Random House, New York 1993.
2) Huizenga, John R., **Cold Fusion**, Oxford University Press, New York 1993.
3) Cain Project Web Page: **http://www.owlnet.rice.edu/~cainproj/**
4) http://www.cnn.com/TECH/space/9911/10/orbiter.02/ (Date: Oct. 02)
5) http://mars.jpl.nasa.gov/msp98/orbiter/
6) http://mars.jpl.nasa.gov/msp98/news/mco991110.html
7) http://www.cnn.com/TECH/space/9909/30/mars.metric/
8) http://spaceflightnow.com/news/0003/14mcoreport/

APPENDIX A
CAIN PROJECT AT RICE UNIVERSITY

The Cain Project in Engineering and Professional Communication was established through a generous gift from the Gordon and Mary Cain Foundation in 1998. The Project's mission is to prepare Rice science and engineering students to lead through excellence in communication. Instead of teaching stand alone courses in technical communication, Cain Project instructors collaborate with faculty to integrate written, oral, and visual communication into existing science and engineering courses at the undergraduate and graduate levels. They support this effort by assisting with assignment design, communication instruction, and student assessment. In addition, the Cain Project provides a presentation studio and one-on-one communication coaching for students. The Cain Project tests a new curriculum model that encourages high levels of voluntary commitment to excellence in communication. An on-going research project tracks the progress of the Project and changes in student performance.

APPENDIX B
ERROR ANALYSIS REPORT

Cold Fusion

In 1989, a startling announcement was made by Fleischmann and Pons at the University of Utah. These two scientists announced they had discovered "Cold Fusion" in a simple electrochemical experiment. Cold Fusion is the process of making helium from deuterium or hydrogen at essentially room temperature (as you are aware, a hydrogen-to-helium nuclear fusion reaction occurs in the sun at about 10,000 degrees Fahrenheit!). This process at room temperature was an unbelievably important discovery especially in a simple electrochemical experiment. These scientists submitted a paper to *Nature*. The newspapers made it front page news for weeks. This concept electrified the scientific community. Many people at various universities tried to duplicate the results; some reported they had and others said the discovery was bogus. Ultimately the experimental results were shown to be false.

Your assignment is to research material on this topic in Fondren Library. Also, research the Internet and discuss this topic with your group members plus anyone else that you think might have some knowledge of the subject. Then write an original, short paper (two-three pages) explaining what was wrong with their results, and how this fiasco relates to laboratory test results in general. The outline for your paper is attached; be sure to follow the outline in your report.

References 1) and 2) represented the main resources for this assignment.

APPENDIX C
UNITS REPORT

Loss of the Mars Climate Orbiter

The Mars Climate Orbiter (MCO) was launched December 11, 1998, and began its long journey toward the red planet. Along the way, engineers on the ground sent instructions to the craft to fire rockets to correct its path toward Mars. It was in these rocket firings that the error occurred.

On September 23 a final rocket firing was to put the craft into orbit, but the signals disappeared, leading engineers to believe that it traveled too close to Mars and was captured by the red planet's atmosphere (4).

The MCO was never heard from again after the final rocket firing on September 23, 1999. Your assignment is to research the Internet (references 4,5,6,7, and 8) and report on the loss of the Mars Climate Orbiter. Discuss this topic with your group members plus anyone else that you think might have some knowledge of the subject. Then write an original, short paper (two-three pages) explaining what went wrong with this mission and how the cause of this fiasco relates to engineering, in general, and lab work, in particular. The outline for your paper is attached; be sure to follow the outline in your report.