AC 2008-2436: ENHANCING THE LABORATORY EXPERIENCE USING PEER EVALUATION OF GROUP LABORATORY REPORTS IN A FLUID MECHANICS COURSE

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Enhancing the Laboratory Experience Using Peer Evaluation of Group Laboratory Reports in a Fluid Mechanics Course

Abstract

Peer evaluation of laboratory reports has been found to be a valuable tool in a junior level fluid mechanics laboratory. Readily available equipment makes it possible to have separate experiments investigating applications of the mechanical energy equation to nearly ideal venturis, an array of flow meters, an array of various fittings, and a single pipe. Having each group of students carry out all four experiments and report on the results can lead to equipment utilization conflicts, student exhaustion, and a lack of attention to detail in the final laboratory reports. In spring of 2006 the author decided to streamline this segment of the laboratory by having each laboratory group (typically teams of four students) perform and report on only two of the four experiments listed above. They were, however, required to provide peer evaluation of the reports of another student group for the experiments which they did not personally carry out. These peer evaluations were then compared with the instructor's evaluations of the same reports and feedback was given to both the group being evaluated and the evaluators. The expected benefits of this change were reduced stress on the students, increased student understanding of and appreciation for the laboratory report evaluation criteria, broader understanding of frictional losses in pipes and devices, and better utilization of the available laboratory equipment. Results from both spring 2006 and 2007 confirmed that the students did an excellent job of assessing the reports submitted by other groups, and exam performance confirmed their understanding of the processes involved in experiments which they evaluated but did not carry out. However, student performance on future laboratory reports did not improve significantly, as had been anticipated. In other words, although students could clearly identify the strengths and the weaknesses of laboratory reports written by others, this did not translate directly into an improvement in their own reports. Future efforts will focus on using this experience not only to reduce student work load and enhance learning, but also on using the experience to help students improve their own reporting skills.

Motivation

The importance of technical communication skills for engineering graduates is clearly recognized[1] and is emphasized in desired outcomes stated by departments, universities, and ABET. The time pressures of a typical laboratory course often lead to last-minute writing with little time spent in reflection and review[2]. Stephen Brookfield[3] speaks to the heart of the teacher when he describes our motivation to instill habits of self-evaluation and peer evaluation.

> *"Sooner or later students leave the intellectual enclave of higher education and return to the workaday world. For them to have acquired the habit of examining their own work critically as a detached observer is an incalculable benefit".*
> *"Likewise, for students to have learned something of the art of peer evaluation – of giving helpful critical insights to colleagues and intimates in a manner that affirms rather than shames – develops in them in them a capacity that will be sought out by their peers for years to come".*

Background

EGR 315, Transport Processes, is a required course in the mechanical and civil engineering concentrations and the chemical engineering program at Geneva College. It is an integrated approach to transport phenomena, taught in the semester directly after Thermodynamics and directly before Fluid Mechanics. The course is 4 credits, with 3 hours of lecture and 3 hours of laboratory per week. The catalog course description is:

> Transport of momentum, heat and mass; balances and equations of change. Applications to steady laminar and turbulent systems. Friction factor, heat transfer coefficient and mass transfer coefficient. Introduction to macroscopic balances, including Bernoulli equation and applications to heat exchangers.

A departmental curriculum audit for coverage of outcomes established that EGR315 is the main course in the mechanical and civil engineering requirements which addresses the outcomes related to

b. an ability to design and conduct experiments, as well as to analyze and interpret data
g. an ability to communicate effectively and ethically

This course has been offered as described above since 1994, with incremental improvement as new laboratory equipment and computer resources became available. The typical semester has included approximately ten experiments, one demonstration/film with written reflection, one computational (finite difference) project, and a laboratory final exam. Formal laboratory reports are typically required for eight experiments, and are submitted as group reports. The other experiments use pre-assigned flow prediction assignments with verification during the laboratory period. Laboratory groups are assigned based on common scheduling availability, which tends to cluster students of the same major together.

Accountability within each laboratory group is encouraged by rotating group leadership, with the leader receiving a doubly-weighted grade for that laboratory. The laboratory final is also used to help differentiate between students within groups. This final includes selected problems to illustrate knowledge of the experimental systems, statistical and graphing techniques, and the ability to discuss and draw conclusions from experimental results and has been a valuable tool in identifying cases where one or two students have taken the lead in writing the reports. As a last resort, there is also a policy governing appropriate group behavior, with the potential for removal of students who are unwilling to fully participate.

Course grading is as follows, reflecting strong emphasis on the laboratory-related outcomes.

Homework	5%
Test Average	35%
Laboratory Reports/Assignments	25%
Laboratory Notebooks	5%
Laboratory Final	10%
Final Exam	20%

Giving feedback on laboratory reports in such a course requires a significant amount of work, and the instructor would like to be certain that feedback is actually used by the students and results in improvement. It is reasonable to assume that laboratory report grades should improve through the semester, as students incorporate feedback from previous reports and correct recurring errors. Linear regression analysis of laboratory report grades as a function of number of assignments shows no general trend of improvement during the 2002-2005 academic years. Table 1 summarizes this analysis.

Table 1. Change in average laboratory report grade over one semester

Year	2002	2003	2004	2005
Change (%)	-4.4%	9.8%	-6.1%	1.5%

Some of the possible reasons for this lack of improvement include students' failure to address recurring problems in laboratory reports, student overload as the semester progresses, insufficient feedback, or student inability to understand and apply feedback.

In an effort to address this problem, a new approach to four of the fluid mechanics experiments was developed and tested in the 2006 and 2007 academic years. The four experiments are

1. Quantitative verification of Bernoulli's law (using Armfield F1-15)[4]
2. Flow meter characterization (using Armfield F1-21)
3. Loss coefficients in fittings (using Armfield F1-22)
4. Energy losses in pipes (using Armfield F1-18)

These experiments address important practical aspects of the mechanical energy equation and its application to piping systems, and were all considered to be critical elements in preparing students for future courses and engineering practice.

The new approach had half of the student groups do experiments 1 and 3, and the other half do experiments 2 and 4. Student groups were then given the task of peer reviewing a laboratory report for the experiments which they did not carry out, with their evaluations graded by the instructor and compared with the instructor's independent evaluation of the same report. This happened over a four week time period, with the essential pattern being alternating weeks of experiment/report followed by peer review. For example, the schedule for Laboratory Group I might be as shown in Table 2.

Table 2. Typical organization of laboratory activities during peer evaluation

Week	Task
5	Run experiment 1 and write report. Give one copy of the report to instructor and another copy to Group II.
6	Review report from Group II on experiment 2.
7	Run experiment 3 and write report. Give one copy of the report to the instructor and another copy to Group IV.
8	Review report from Group IV on experiment 4

Expected benefits of this approach were

- reduced stress on the students, since they had fewer reports to write
- increased understanding of and appreciation for laboratory report evaluation criteria
- broader understanding of frictional losses in pipes and devices, since they would be looking at the data and results from a different point of view
- better utilization of the available laboratory equipment

Implementation

Calibration is critical to any review process involving multiple evaluators. In this case, it was anticipated that students would be able to use the instructor's feedback on the first three laboratory reports as a tool in better understanding the criteria. A sample of the standard checksheet handed back with each laboratory report is included in the Appendix. This check sheet is a way of summarizing all of the comments written throughout the laboratory report in one place. The laboratory handbook, distributed electronically to the students via Blackboard, also provides detailed guidelines on format, covering writing style, guidelines for graphs, tables, and presentation of calculations. A set of guidelines for peer evaluation was also included, summarizing the approach to use of the checksheet.

Since the students were expected to fully understand the experiment they were evaluating, they received a grade with the same weight as any other laboratory report for the quality of their evaluation and feedback. Half of this grade was generated using a formula which accounted for the deviation of their evaluation from the instructor's evaluation of the same report. The other half was based on the instructor's evaluation of the quality and detail of their written comments. Use of the formula alone could have led to a process of educated guesses designed to match my evaluations, negating the possible benefit of increased understanding. Extra credit was also given for observations that led the instructor to change his assessment of the report being evaluated, giving the peer evaluators additional incentive to pay careful attention to detail.

The classes in 2006 and in 2007 were divided into laboratory groups of approximately four students per group, with four laboratory groups in each year. Total class enrollment in 2006 was 17, and in 2007 was 19.

Results

Student evaluations of laboratory reports were consistent with the instructor's evaluation. Using the method noted above, the groups in both 2006 and 2007 were approximately 94% and 92% accurate in identifying the important strengths and weaknesses of the laboratory reports evaluated. The most frequently occurring errors in assessment were associated with quality of tables and graphs, followed by evidence of understanding, followed by a four-way tie of grammar, organization, discussion/conclusions, and error analysis.

It is interesting to note that students were very good at evaluating "effective use of graphs and tables", which deals with proper placement within the text and proper reference to them in the discussion, while they were not as good at evaluating issues such as proper scaling, labeling, symbols and units.

When laboratory report grades were plotted as a function of time for the 2006 and 2007 groups, the slopes indicated average changes of +6.1% and +10.0% from the first laboratory report of the semester to the last. With only four laboratory groups per year during the period of this study, these results are not significantly different from those in prior years.

Table 3. Change in average laboratory report grade over one semester

Year	2002	2003	2004	2005	2006	2007
Change (%)	-4.4%	9.8%	-6.1%	1.5%	6.1%	10.0%

The absence of negative changes in 2006 and 2007 is certainly encouraging and, when combined with the positive comments of students both in course evaluations and in conversation, has led to making this approach an ongoing feature of the course. Additional data will be collected in the coming year as this course is offered again, this time with six laboratory groups.

Detailed data on the mid-term exam problem which focused on this subject area were only available for 2005-2007. It shows an approximately constant score on the two-reservoir piping problem used to test material related to the mechanical energy equation, after adjusting for the overall average performance of each class (the 2007 class had higher average scores on this problem, but that was also true of their performance on other exams, including the final exam).

One concern with an approach such as this is a perceived reduction in *content*, since the students are doing hands-on work with fewer experiments. Along with the results already presented, the instructor was also able to observe interactions between groups during the four weeks of experiments described here. Even though a group was not doing hands-on work with a particular system, they were still quite involved in understanding the experimental system. They would often watch and even talk with one of the groups performing the experiment which they were scheduled to evaluate. This may have been mostly motivated by the need to intelligently evaluate the report which they would be receiving, but it also engaged them with the subject matter of the experiment in a different way, potentially leading to improved learning. The group being observed was often asked to explain what they were doing, leading to better understanding on their part.

Conclusions and Recommendations for Future Work

The use of peer evaluation of laboratory reports can be a useful tool, especially when there is overlap between the subject matter of several experiments, as was the case in this study. It gives the students an opportunity to look at the laboratory report writing process from a different point of view, potentially leading to improved performance on future laboratory reports.

It also provides additional data to the instructor regarding aspects of report writing which may need clarification or additional emphasis, since weaknesses in peer evaluation will often point to poor understanding of the subject being evaluated or the criteria to be used in evaluation. As this approach is systematized, the data will be used for more immediate feedback to address particular weaknesses in understanding.

The peer evaluation process also changes the dynamics of the laboratory and the classroom, leading to increased interaction between and within laboratory groups, more discussion of the details of experimental technique, and students taking ownership of the learning process. The instructor's role in these interactions is also somewhat different from the typical grading of lab reports. While the instructor must still grade each laboratory report, his/her feedback is reinforced and complemented by the peer feedback and evaluation.

We will continue to use this approach to peer evaluation of laboratory reports in the coming year, and will add the use of a newly developed rubric to assess student success in outcome b, listed above. Additional data will allow us to observe whether the apparent trend of increased grades continues. We will also consider further modifications to this approach, such as the addition of an oral reporting component as suggested by one of the reviewers.

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[1] Sageev, P. and C.J. Romanowski, "A Message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills," *J. Eng. Ed.*, Oct. 2001: 685-93.
[2] Miller, D.C. and J.M. Williams, "Incorporating Peer Review in the Chemical Engineering Laboratory", *Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exhibition*, 2004.
[3] Brookfield, S.D., *The Skillful Teacher*, Jossey-Bass, San Francisco, 1990, p. 146.
[4] Armfield Ltd., http://www.armfield.co.uk/f1-10_datasheet.html, "Basic Hydraulics Bench Datasheet", July, 2007, accessed Feb. 28, 2008.

APPENDIX A - EGR 315 Lab Report Grading Criteria

Content

Raw Data - Complete and organized	5
Data Reduction - Accurate and well documented	20
Error Analysis - Accurate, based on reasonable error estimates, and well documented	10
Evidence of Understanding	10
Discussion/Conclusions - Meaningful, with no "snow jobs"; includes physically meaningful interpretations and recommendations	10
Effective Use of Graphs and Tables- (Well-placed and referred to at appropriate points	5

Style

Organization (Intro,..., Appendix) - This also includes overall appearance and organization	10
References - Are they noted when referred to, and are the citations complete and accurate?	5
Grammar/Spelling/Usage/etc.	10
Quality of tables and graphs - are they readable, well-labeled (including units), properly scaled? Are the main results neatly summarized in a single location (including error estimates and comparable literature values)?	15

APPENDIX B -

Guidelines and Grading of Peer Evaluation of Lab Reports

EGR315

- You will use the standard lab report evaluation form and criteria.
- Write comments directly on the paper as needed. Some examples follow.
  - Correct the grammar (spelling, usage, fragments, etc.)
  - Note logical inconsistencies
  - Correct style issues (repetitive structures, informal language, etc.)
  - Clarify figures and tables
  - Corrections to calculations
  - Missing information (raw data, summary of results, etc.)
- Summarize your comments on the evaluation sheet and assign a grade for each criterion. Think of each category as graded on an A-F continuum where
  - A – Professional presentation quality
  - B – Acceptable from a novice engineer (that is, accurate results, but presentation is not completely polished)
  - C – Basically correct, but needs significant improvement to continue in this job.
  - D- Unacceptable, but shows signs of knowing the basics of the subject. You would warn this person that he/she has 6 months to shape up before a special mid-term performance review.
  - F – Unacceptable and unprofessional.
- My evaluation of your evaluation.
  - Half of your score based on a formula that will be presented on Blackboard. This formula will be based on the difference between the score you assign and the score I assign for each criterion
  - Half of your score will be based on my assessment of the quality of your comments
  - Extra credit will be given for observations that lead to me changing my assessment of the report.