Guided Peer Review of Technical Writing for Large Laboratory Course

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Abstract

Laboratory courses, and in particular laboratory reports, are logical choices to assess two particular student outcomes: ‘the ability to design and conduct experiments, as well as to analyze and interpret data;’ and ‘the ability to communicate effectively.’ If students can articulate a clear objective, demonstrate a sound experimental procedure, and offer analysis supporting reasoned conclusions, they will have demonstrated proficiency in both outcomes. However, though assessing these outcomes may be straightforward, actually teaching these skills can be a time-intensive challenge, particular when dealing with large sections. Simply engaging a single draft of one report to provide meaningful feedback can easily take 30 minutes (50 hours per 100 papers), if not more. Allowing groups reports can reduce the workload, but may not ensure that everyone is gaining the same level of practice. Delegating this job to teaching assistants is another option but can lead to issues with consistency. A final option is to leverage peer feedback, which has some obvious benefits and significant challenges.

This paper discusses the implementation of a guided peer review process in a junior-level experimental methods course with over 120 students. In the course format, students meet all together for two weekly lectures and then divide into seven sections to for a weekly 2-hour lab supervised by teaching assistants. The guided process was designed to improve writing instruction, feedback, and evaluation using a beam deflection experiment. Groups of three were responsible for designing and implementing an experimental procedure within the constraints of broad guidance and available resources. However, each student submitted a separate report. Four lecture periods were devoted to help them develop their reports including instruction on a report template and three focused writing workshops. This was followed by a draft submittal and two-stage blind peer review process. For the initial peer review, reviewers were guided by tasks that required they locate and restate key ideas from the paper prior to identifying specific weaknesses. For example, reviewers were required to underline the technical objective, circle the control variable(s), and box the response(s). For the second draft, the paper author assessed which of their main points were not successfully communicated, made corrections, and provided a rebuttal statement. The reviewers then assessed the resubmission, rated the papers, and provided minor suggestions for improvement. The paper will include details on the experiment and the guided peer review process, as well as logistical solutions to achieve the blind peer review.

Introduction

The ability to write effectively is a critical professional skill for the practicing engineer, and thus a vital outcome for engineering programs.[1] Though many programs require specific writing intensive courses to build these skills, it is also important that students practice writing as an integral part of the broader work of engineering in design and laboratory courses.[2] In particular, laboratory reports are a logical vehicle to synthesize the work of experiment design, analysis, and technical writing. However, simply requiring students produce written reports is of marginal value if not accompanied by effective formative assessment. Providing consistent, quality feedback on reports is a time-intensive endeavor which can be very difficult for large laboratory classes. Simply engaging a single draft of one report to provide meaningful feedback can easily take 30 minutes (50 hours per 100 papers), if not more. Allowing groups reports can reduce the workload, but does not ensure that everyone gains the same level of practice. In addition, group reports often suffer from a 'divide and conquer' approach which indicates that students have not gained an appreciation for the importance of cohesion within the document. Whether individual or group reports are specified, the job of assessing lab reports for larger lab classes typically falls upon graduate teaching assistants (TAs) who lack the experience or training to do it effectively. This often leads to student complaints about inconsistency between various sections.

This paper discusses the implementation of a lab report assignment using peer-to-peer feedback as the primary means of formative assessment for a large (120+ student) laboratory course. This option has two distinct advantages over traditional instructor (or TA) driven feedback. First, from a practical standpoint, peer feedback leverages the size of the cohort to accomplish a time-intensive task. Each student evaluates 3-4 papers rather than the instructor (or TA) having to evaluate over one hundred. More importantly, however, engaging the students in the review process enhances their metacognition with respect to standards for effective writing.[3] Implementation of the assignment involved four stages: (1) experiment design and execution, (2) writing instruction and workshops to build the draft, (3) peer review, rebuttal, and revision, and (4) summative assessment. The next section describes the course structure and outline. This is followed by a description of the activities in each stage, assessment results, and recommendations.

Course Structure & Outcomes

The use of peer-to-peer feedback discussed herein could be used in any technical laboratory course and nearly any activity where a lab report is an appropriate submittal. The particular course discussed, *Experimental Methods*, is the first of a two-course lab sequence for Aerospace and Mechanical Engineering majors designed to be taken in the junior year. It teaches methods in engineering measurements and data analysis including sensor performance, data acquisition, measurement uncertainty, statistics, etc. Disciplinary topics for each lab activity vary widely but generally reinforce concepts from courses taken earlier in the curriculum. ABET learning outcomes assessed in the course include 'the ability to design and conduct experiments, as well as to analyze and interpret data;' 'the ability to communicate effectively;' and 'the ability to function in multidisciplinary teams.'[1]

The format for the course includes two 50 minute lectures (Monday and Friday) given by a single instructor to the entire cohort (126 students in Fall 2018). The students break into seven sections of no more than 21 students for a two hour lab in the middle of the week under the supervision of TAs. Lectures are used to refresh theoretical concepts needed to understand the lab and to discuss analysis techniques. In addition, as will be discussed later, a few lecture periods were reserved for writing workshops. All lab activities required a set of post-lab deliverables to include some form of data analysis. Writing standards were introduced mid-semester, and a full lab report was assigned for one lab activity. The philosophy was to devote time to perfect a single full lab report in the first lab course, then require full reports as the primary deliverable in the follow-on course.

The experiment on which the one full-report was assigned began mid semester to allow ample time for developing a draft, peer review, and revision & rebuttal before the end of the course. Students continued to engage in other lab activities and submit shorter post-lab assignments during this extended process. The particular experiment used for the full report is discussed in the next section.

Effective experiment design is the cornerstone of technical report

A beam deflection experiment was chosen as the basis for the full lab report. The experiment used built-up balsa wood beams with rectangular and I-beam cross-sections. The beams were simply supported at the ends, loads were applied by stacking half pound weights, and deflection was measured with a dial gauge. Students were asked to look at the effects of load, span, and cross-section shape on deflection (or stiffness). Smith and others provide detail on similar experiments.[4,5] The experiment chosen was not of particular importance. However, there are some characteristics that enhance learning objectives related to writing the report. For one, the beam deflection experiment has a clear experimental objective. The general method is also straight-forward, yet students can be given freedom over procedural details. This gives students greater accountability for the data they collect, and a better understanding of experimental errors. Finally, there are challenges in how to best represent results due to the variety of predicted relationships between deflection and the various controls (e.g. simple beam theory predicts deflection increases linearly with load, cubicly with length, and inversely with area moment of inertia).

It was important to give students ownership of the experiment design. One point of emphasis was that the report is the culmination of a complete process that begins with the experiment design and includes execution and analysis. Instructions based on Coleman and Mongomery's Pre-design Guide[6] were given at the beginning of the activity. Most importantly, the experiment design needs a clear experimental objective as this is the foundation for everything that follows and the thread that ties the report together. An effective experiment objective seeks to determine a relationship between control variables (what gets changed during an experiment) and the responses (what gets measured). For the beam deflection experiment, students are asked to study three control variables: load, span, cross-section shape. Mid-span deflection or stiffness (derived from load/deflection) is the response. The next step in the experiment design process is to research theoretical relationships to build a hypothesis or prediction about the relationship between the control and response variables. The design also needed to specify factors to be held constant (e.g. material, supports), identify nuisance factors, and consider how results will be analyzed. Though the basic objective was specified, they controlled other aspects of the procedure including what values of the control variables were used, the number of repetitions, etc. In many cases, students discovered after the fact that they had insufficient data to assess their hypotheses; this proved to be an effective lesson reinforcing why they must consider analysis and presentation during the design phase of the experiment.

Building a draft paper

After the experiment was conducted, four regular class periods were devoted to the development of the first draft of the report. The first included a lecture and class discussion on format and content of the report. This was supplemented by a lab report standard document which outlined four required sections: introduction, procedure, results & analysis, and conclusions; and a formatting guide for tables and figures. The next three periods were workshops in which students provided informal in-person feedback on partial drafts.

In the first workshop, students brought in figures and tables. They then exchanged them with 1-2 classmates who answered questions related to their interpretation of the results shown. For example, one question asks reviewers to articulate the experimental result demonstrated by the plot, e.g.

"The data does/does not clearly demonstrate that there is a linear/inverse/cubic relationship between {insert control} and {insert response}."

In turn, the drafter was asked to reflect on whether the reviewers interpreted the results as they intended. In cases where there was disagreement, the group brainstormed alternative ways of displaying results. This technique was used to get students to focus on their papers as a way of communicating with others; if their message was received as they intended, the communication was successful. Formatting details were of secondary importance as they enhance the professionalism of the document.

A similar process was conducted for the second and third workshops. The second workshop was given for drafts of the Introduction and Procedure sections, and the third for the Results & Analysis and Conclusions. Again, reviewers were asked to interpret rather than evaluate the draft. For example, Fig. 1 shows the review form used for the Introduction section. A simple example for using this and a companion form for the Procedure review was demonstrated by the instructor to kick off the second workshop. Note from Fig. 1 that reviewers were asked to find and signify (e.g. by circle, underline, check, or star) key pieces of information within the draft. Difficulty with this task was a clear indication to the author that elements of their report were either missing or not clearly articulated.

By the end of the third workshop students had a nearly complete draft. As authors, they gained the benefit of peer feedback on all the major components of their paper. Perhaps even more significantly, as reviewers, they gained practice in identifying the key elements of a report. One area of concern was lower than usual class attendance during the workshops, likely from students who had not prepared drafts for review.

Formal peer review process

The next phase of the assignment involved a formal, blind peer review modeled after the process used for academic conferences. Authors uploaded their first drafts to the learning management system (LMS). Three papers were assigned to each student to review. An extensive template was provided that, as with those used in the workshop, first required reviewers paraphrase information gleaned from the report, e.g.

"Discuss the background content provided. E.g. What theories and/or equations were presented? Were any underlying assumptions mentioned? What sources were cited?" The template also asked for evaluative comments in response to questions like "Are hypotheses sufficiently supported by the background information provided."

Finally, reviewers provided a cursory evaluation of the quality of the draft by assessing responsiveness and completeness. A full list of questions used for the peer review is included in the appendix along with the summary sheet, Fig. 2.

Once receiving the initial review, authors were asked to provide a detailed rebuttal, a revised report, and an assessment of the reviews given to them. Example rebuttal letters were discussed briefly during lecture and links were provided to additional resources.[7] A short form was used to rate the review in terms of completeness and clarity. In addition to improving the paper, this exercise served a practice for courteous and professional disagreement.

Reviewers completed a final review in which they read the rebuttal and assessed the revision. This involved a much shorter, single page template including an assessment of the responsiveness of the rebuttal and an evaluation of the final paper using a Likert Scale as depicted in Fig. 3.

The most challenging aspect to executing the formal peer review phase was working within the existing LMS which is a derivative of Sakai. We opted to use the FORUM tool with anonymous contributions tracked by confidential author numbers. A FORUM *Conversation* was established for each author with viewing/response privileges limited to assigned reviewers. Thus, each student had access to 4 *Conversations*, one for their own draft and three additional papers they were to review. Only authors were allowed to start the conversation by posting their first complete draft. Reviews, rebuttals, and revisions were then posted as responses to this orignial thread. Despite some 'behind the scenes' work on the front end, the process worked well for the students. Translating the FORUM submissions to a grade for the activity was more challenging since documents could not be downloaded in bulk.

Assessment

The lab report activity was evaluated as 15% of the overall course grade in proportion to the total effort required including executing the experiment, writing, and review. This included 10% for active participation in the process (divided evenly between author and reviewer tasks) and 5% for the final document. Peer feedback was considered for the first 10% of the grade only. In that case, discrete standards were provided in the templates to limit controversy. For example, note in Fig. 2 that 1 point for timeliness and 2 points for completeness are allotted for the first draft. The TA grader made final judgments when there was disagreement among reviewers. Seventy-one percent of students received full credit for the first draft; that number rose to 90% for review and rebuttal stages. The number of late, missing, or incomplete first drafts is partially a result of a lack of accountability for participation in the workshops.

For the final paper, 86.5% of students met at least 'B' standard (80%). This was on par with those for the beam experiment report the previous year in which TAs provided a review of a single draft. However, the major advantage of the peer review process is the additional meta-cognitive effort required. When an instructor or TA provides feedback, the student simply ‘corrects’ the document as they assume this is what is needed to maximize their grade. However, when responding to feedback from peers, they must consider more closely how to use the advice. In addition, they can benefit from reading papers from more skilled writers as well as from helping improve reports that need more work.

Student feedback for the course remained positive with the implementation of the peer feedback activity. In contrast to the previous year, there were virtually no complaints about the timeliness of feedback. There was also a significant improvement in perceptions about the fairness of grading (a 0.4 point rise on a 5.0 Likert scale). There were a few comments that the process was ‘overly-complex’ or ‘excessively drawn out’ which are both fair criticisms to address in the future.

Conclusion and Recommendations

A peer-review cycle was implemented to enhance instruction in laboratory report writing for a large experimental methods course. The process leveraged students within the class to provide constructive review for early drafts of a report on a beam deflection experiment. Though there was no discernible effect on student performance for the final paper, the peer review process had some distinct advantages over an instructor or TA based approach. First, the grading workload was reduced considerably. As a result, students received much more timely feedback. Secondly, students benefited as much from reviewing the work of other as they did from the feedback they were given.

The lab report with peer review assignment proved to be effective in meeting two ABET objectives for the course: ‘the ability to design and conduct experiments, as well as to analyze and interpret data;’ and ‘the ability to communicate effectively.’ Students were required to design an procedure to meet specific experimental objectives, execute the experiment, analyze results, and communicate their findings in writing. Student ownership of the experiment design was an important aspect of the activity. They learned quickly how design choices enabled (or limited) their ability to satisfy their objectives. The templates used to draft the report, along with peer feedback, helped guide students through the analysis and interpretation of their results. Finally student communication skills improved from writing the report, providing feedback to their peers, and interpreting feedback from peers to improve their document.

There were a few aspects of the implementation that could be improved. First, there needed to be some accountability for participation in the early workshops. Second, the review templates should be refined to make the process more streamlined. Third, the interface used for the peer review needs refinement to facilitate grading. A third party application may be more suitable than the LMS. Finally, it could be beneficial to assign team-based reviews with a single reviewer designated as ‘chair’ or ‘editor’ to consolidate summary evaluations. Having a team meeting to discuss the papers could also strengthen the meta-cognitive aspects of the review.

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Appendix: Peer Review Questions, Sample Templates

IA. Introduction Section/ Objectives

a. Paraphrase the objectives as stated in the paper:

b. Was there a clear objective relating to each of the following control variables:

  i. Load?

  ii. Span/Length?

  iii. Area moment of inertia (or cross-section shape)?

c. Were the objectives properly presented, with clear control and response variables as in "… to determine the effect of …… on …….”?

d. Any suggestions to improve the clarity of the objectives?

IB. Introduction Section/ Background and Hypotheses

a. Discuss the background content provided. E.g What theories and/or equations were presented? Were any underlying assumptions mentioned? What sources were cited?

b. Describe any aspects of the background information which you think may be incorrect, or that you found confusing**.**

c. How would you rate the depth & breadth of the background information? E.g. was it too much? Not enough? Did it lack focus on concepts relevant to the experiment?

d. Paraphrase the hypotheses provided for each objective listed. If no hypothesis is found, write "none."

e. Are hypotheses sufficiently supported by the background information provided?

f. Any suggestions to improve the clarity of the background and/or hypotheses?

II. Procedure Section

a. Identify and paraphrase the topic sentence for the procedure.

b. Summarize procedural details that were included in this section. E.g. loads tested, beam geometry, loading and constraints, specifications for measurement tools used.

c. Was the section written in 3^{rd} person, past tense?

g. List any details you were looking for that you did not find in this section?

h. List any details included you think were not relevant?

i. Any suggestions to improve the clarity of the Procedure section?

III. Results/Analysis Section

a. Summarize the key results, i.e. the answers to the objective questions posed by the author? How easy was it to find the key results in this section? Were there any objective questions not answered in this section?

b. Describe the evidence (e.g. plots & tables) provided? Do you agree with the authors conclusions? Also comment on the clarity of the figures and tables as presented.

c. Describe how the author quantified error? E.g. R^2 values on trend lines, uncertainty bounds for experimental measurements and/or theoretical predictions, etc.

d. Were there any aspects of the results presented that the author should address in more detail, e.g. any “elephants in the room” that may have been glossed over?

e. Other suggestions to improve the quality of the Results & Analysis section?

IV. Conclusions

a. Does this section contain the key results you identified in the previous section?

b. What design implications were presented? How applicable are these implications, in your opinion?

c. What suggestions for future work or improvement are provided by the author? Comment on whether you feel this would be an appropriate direction based on the results provided in the paper.

d. Other suggestions to improve the quality of the Results & Analysis section?

Lab Report Introduction & Procedure Draft Review

Introduction Instructions: Find and number each objective found. Circle the control variable and box the response(s). Then, search for a prediction/hypothesis and background material to support that hypothesis. Place a star next to the hypothesis. Include a check mark next to support background; make it a double check mark if sources are correctly cited. Finally, fill out the table below with your findings.

Table 1: Synopsis of Report Introduction Review

Objectives						
#	***Control Variable***	***Response***	***Particular conditions***	***Prediction/Hypothesis***	***Supporting Evidence***	***Cited?***
Additional feedback						
*List **terms/concepts** unfamiliar to you:*						
*For any **equations** presented:*						
Was it formatted well (e.g. numbered, uses Eqn. Editor)?						
Were all variables defined?						
*List stated **assumptions/limitations** to the background theory presented:*						

Figure 1: Workshop Review Form for the Introduction Section of the Beam Lab Report.

Peer Review Summary

1. *Author #:* ___________

2. *Responsiveness*:

   a. Enter date/time stamp for submission: ________________

   b. Circle one based on submission by Nov 2, 11:59 pm deadline:

   Submitted before deadline – 1 pt

   Submitted within 3 days of deadline – 0.5 pt

   Not submitted/submitted after 3 days – 0 pt

3. *Completeness*:

   a. Assess completeness; circle one:

Complete & polished draft – 2 pts. E.g. Includes all 4 sections of report, well formatted tables and figures, shows evidence that author has proofread prior to submitting.

Moderately Incomplete – 1 pts. E.g. One section substantially incomplete, OR missing tables & figures, OR has significant grammatical/spelling issues that suggest author has not proofread.

Substantially incomplete – 0 pts. E.g. More than one section substantially incomplete.

4. *Summary of review comments*:

   a. Strengths of paper:

   b. Suggested areas of improvement:

Figure 2: Summary form from Initial Peer Review Template.

Likert Scale

1 – Strongly disagree, 2 – Disagree, 3 – Neither agree nor disagree, 4 – Agree, 5- Strongly Agree

Statement	**Likert Scale**
The author provides a proper objective that clearly identifies the control variables and the response(s) for the experiment.	
The author makes specific predictions for answering the objective(s) supported by background information/analysis.	
The procedure section is properly presented to include a topic sentence, correct person (3^{rd}) and tense (past), and an appropriate level of detail.	
The author has a clear Results/Analysis section which includes quantitative results, trend lines or other metrics to compare results to theoretical predictions, a discussion of error, etc.	
Graphs presented adequately address the experiment objectives, are easy to follow, and can be understood independently of the narrative.	
Conclusions section reiterates main results, provides implications, and discusses improvements or other future work.	
References are properly cited, formatted	
Appendices introduced	
In general, paper is well written grammatically.	

Of the papers I've reviewed, this one ranks ____ out of _____

Figure 3: Final Evaluation Form for Peer Review