Facilitating Improvements in Laboratory Report Writing Skills with Less Grading: A Laboratory Report Peer-Review Process

Jennifer R. Brigati* and Jerilyn M. Swann
Maryville College, Maryville, TN 37804

Incorporating peer-review steps in the laboratory report writing process provides benefits to students, but it also can create additional work for laboratory instructors. The laboratory report writing process described here allows the instructor to grade only one lab report for every two to four students, while giving the students the benefits of peer review and prompt feedback on their laboratory reports. Here we present the application of this process to a sophomore level genetics course and a freshman level cellular biology course, including information regarding class time spent on student preparation activities, instructor preparation, prerequisite student knowledge, suggested learning outcomes, procedure, materials, student instructions, faculty instructions, assessment tools, and sample data. T-tests comparing individual and group grading of the introductory cell biology lab reports yielded average scores that were not significantly different from each other (p = 0.13, n = 23 for individual grading, n = 6 for group grading). T-tests also demonstrated that average laboratory report grades of students using the peer-review process were not significantly different from those of students working alone (p = 0.98, n = 9 for individual grading, n = 6 for pair grading). While the grading process described here does not lead to statistically significant gains (or reductions) in student learning, it allows student learning to be maintained while decreasing instructor workload. This reduction in workload could allow the instructor time to pursue other high-impact practices that have been shown to increase student learning. Finally, we suggest possible modifications to the procedure for application in a variety of settings.

INTRODUCTION

It is well established that students benefit from hands-on laboratory exercises (7), and undergraduates wishing to pursue a career in science need to be able to analyze data and communicate results effectively in written form (1). Businesses in the U.S. and worldwide consistently rank oral and written communication skills as being as important as quantitative and technical skills (5, 6). Grading lengthy laboratory reports is a time-consuming process, however, and professors often reduce or eliminate writing requirements associated with laboratories because they simply cannot keep up with the grading. Traditional laboratory report writing procedures also fail to prepare students for the actual process of writing a scientific paper, which usually involves multiple authors and a peer-review process. This is a problem if one considers that businesses responding to the NACE Job Outlook 2014 survey ranked “ability to work in a team structure” as the most important job candidate skill (6).

To address the shortcomings and challenges of using traditional laboratory reports to teach scientific writing to biology students, we have implemented a laboratory report writing process that involves peer review and requires grading of only one report from each peer-pair or group. The incorporation of a peer-review step into the laboratory report writing process is not novel, and several studies have presented data that indicate the quality of student lab reports improves when they participate in a peer-review process (3, 4). Studies have also shown that students benefit not only from receiving feedback on their work, but also from the process of critically reading the work of other students (2, 8). The use of peer review has been reported to help students improve their writing without taking up large amounts of the instructor’s time (10). Like other forms of cooperative learning, peer review is likely to increase assignment completion, foster discussion of content, encourage acquisition and use of appropriate scientific terminology, and give students a better idea of how science works in the real world (9). While adding a peer-review step to the laboratory report writing process clearly provides benefits to the students, by itself it just adds an additional task to the already lengthy to-do list of the laboratory instructor.

The laboratory report writing process described here allows the instructor to grade only one lab report for every
two to four students, while providing the students with the benefits of peer review and prompt feedback on their laboratory reports. In this process, students in self-selected pairs or groups each write a laboratory report, and then peer review each other’s work. After the students have an opportunity to make corrections, the instructor collects all of the drafts and final reports, and selects one final report to grade. The grade of this single report is assigned to all students in the group, and the report is returned to the students who peer reviewed the paper. These students then have the option of scheduling a short conference with the instructor to review the draft to see if there were corrections suggested that were not incorporated into the final report, and if so to earn back points that the writer lost. Here we present the application of this process to a sophomore level genetics course and a freshman level cellular biology course.

**Intended audience**

This lab report peer-review process is appropriate for use in any undergraduate laboratory course that requires the preparation of full-length laboratory reports.

**Learning and preparation time**

In the genetics course, the peer-review process was used over the course of a semester (14 weeks). In class, time devoted to the peer-review process was limited to the following: 15 minutes during the first lab session to explain the process and the requirement to choose a lab partner for the duration of the semester; 10 minutes during a subsequent lab session for students to discuss peer-review deadlines and fill out partnership contracts; 1 hour during a lab session later in the semester to allow the instructor to make sure that all students had completed a draft of the initial lab report and to allow the students to begin their first peer review with the instructor available to answer questions about lab report formatting, content requirements, etc.

Most of the work related to the peer-review process was completed by students outside of class. This included writing the first drafts of each laboratory report, finishing the peer review of the first laboratory report, completing the peer review of all subsequent laboratory reports, and editing the drafts to make final copies suitable for submission. Some additional time was required by both the students and the instructor outside of class when individual students felt that they had made suggestions in a draft that were not sufficiently addressed in a final submitted laboratory report. This typically took 5 minutes per student, or a total of 30 minutes or less of instructor time per laboratory report.

In the introductory cell biology course, a 50-minute class session was devoted to preparing students to write their first laboratory report. During this session, staff from the library spent 25 minutes informing students about library resources and available databases and giving pointers on how to search for primary literature. The course instructor then spent 25 minutes talking about the mechanics of how to write a good laboratory report, including a discussion of the rubric used for grading. Outside of class, students completed primary literature summaries to aid them in learning how to find, read, and summarize primary literature as would be required in writing their first laboratory report. They then wrote their laboratory report and completed the peer-review process outside of class.

**Instructor preparation**

We have provided handouts that explain the peer-review process, lab partner contracts, a laboratory report writing guide, and the grading rubric used in the genetics course. To apply these materials to a new course, it will be necessary for the instructor to modify the process as appropriate for their course and adjust the laboratory report writing guide and grading rubric to fit the content and learning goals of their course. Using the documents provided as a guide, we expect this will take just a few hours of effort. Most instructors already have a laboratory report writing guide and rubric that they use, and their current documents would require little, if any, modification to work within the peer-review structure.

**Prerequisite student knowledge**

We have applied this procedure in both an introductory level biology course (no prerequisites) and a sophomore level genetics course (prerequisite of introductory cell biology and pre- or co-requisite of general chemistry). Students do need some basic writing skills, which at our institution are taught in a two-semester freshman English composition series.

**Learning objectives**

This procedure is used as a way to allow students to gain skills in scientific writing. In the framework of a typical learning-focused undergraduate biology laboratory course, at the completion of this exercise the students will:

1. Demonstrate knowledge of basic terminology, concepts, and quantitative analysis in the area of biology studied.
2. Summarize primary scientific literature and incorporate it appropriately into formal lab reports.
3. Acquire and apply a set of basic laboratory data acquisition, analysis, and presentation skills.
4. Communicate the results of laboratory experiments in written form.

**PROCEDURE**

This laboratory report peer-review process is designed to allow students to meet all of the same learning objectives typically associated with writing individual laboratory
reports, while reducing the amount of time the instructor needs to spend grading. Students are given the laboratory report writing procedure (Appendix 1), and it is explained, before they self-select pairs/groups. Students then fill out copies of the laboratory partner contract (Appendix 2), and each keep a copy. Students write reports, review each other’s reports, and make corrections to their reports. Students hand in their reports, along with the marked-up rough drafts on the due date. The instructor grades one of the reports from each pair or group, checks for cheating, and hands back the graded report to the student(s) who reviewed the paper. These students then have seven days to come to the instructor’s office and ask for a review of the draft to earn back points. Students earn back points if they made specific suggestions for improvement that were not incorporated into the final paper. Table 1 summarizes the elements of the peer-review process for both students and instructors.

Materials

- Laboratory report writing procedure (Appendix 1)
- Laboratory partner contract (Appendix 2)
- Laboratory report writing guide (Appendix 3)
- Laboratory report grading rubric (Appendix 4)

Student instructions

Written instructions for students are contained in Appendices 1–4.

Faculty instructions

At the beginning of the semester, the laboratory report writing procedure (Appendix 1) was handed to students and explained. Students were told that they should self-select a partner or group with whom they would participate in the peer-review process for all required laboratory reports. Once student pairs/groups were established, each pair/group filled out copies of the laboratory partner contract (Appendix 2), so that each student would have a copy of the contract. Students were told to retain these contracts, and that they would need to present these to the instructor if at any time mediation between the partners became necessary.

Students were typically given two weeks to write their lab reports after data collection was complete. This allowed them time to write a complete first draft, review each other’s drafts, and make corrections. Students completed the peer-review process as dictated in the laboratory report writing procedure, using the laboratory report writing guide (Appendix 3) and laboratory report grading rubric (Appendix 4) to guide their evaluation of their partner’s work. The laboratory report writing guide and laboratory report grading rubric were both provided to students at the beginning of the semester through an online course management system, so they had access to these materials both when they were writing their initial drafts and when they were reviewing their partner’s drafts. Students were instructed to turn in all draft and final copies of the report, and the instructor quickly checked the drafts and final reports to make sure there were no signs of cheating (this could also be done with plagiarism detection software such as Turnitin).

Once all of the reports were turned in, the instructor graded one randomly selected lab report from each pair/group of students. After grading, the grade for the lab report was recorded for all students in the group, and the report was returned to the student(s) who reviewed the paper. The instructor retained all drafts and the ungraded final paper(s). Students who acted as reviewers of the graded papers were instructed to schedule a conference with the instructor within seven days if they thought they were entitled to additional points based on their review or their partner’s draft.

If a student requested a review of their partner’s draft, the instructor would work with the student and the draft/final copies of the lab report to determine areas where edits suggested by the peer reviewer and not made by the writer had led to a grade reduction. The instructor would increase the reviewer’s grade as appropriate. In rare cases, the instructor referred to the student’s own report to determine whether deductions for a lack of conceptual understanding were appropriate (for example, if the reviewer told the writer to add information about a specific concept, but the writer added incorrect information and this resulted in a grade reduction in the “conceptual understanding” category).

If a lab section in which students were working in pairs had an uneven number of students, the students were given the option of either having one trio or having one person work alone. In our experience, students have always chosen to work in a trio rather than alone, even though in a trio they have more work (each student having to review two drafts of each report).

Penalties for turning in laboratory reports late were assessed only on the individual who turned in a report late, and these penalties were applied to that individual’s grade even if their paper was not the one graded.

When cheating (plagiarism or unauthorized collaboration) occurred, we separated the pair of students for at least the assignment in question and sometimes for the remainder of the semester. Generally if both students cheated and faced the same consequences, they continued to work together successfully. If one cheated and the other did not, the student who did not cheat usually requested a separation, which was granted. Depending on the timing of the incident, the innocent student was offered the option of pairing up with a different student in the class (if there was an odd number), joining an existing pair to work in a trio, or having a peer of their choice edit their future drafts. Some combination of these options was also given to students who were left without a partner because their partner dropped the class.
Suggestions for determining student learning and sample data

Students’ improvements in laboratory report writing skills were assessed using the laboratory report grading rubric (Appendix 4). Student learning objective 1 (demonstrate knowledge of basic terminology, concepts, and quantitative analysis in the area of biology studied) was assessed using the “conceptual understanding” section of the rubric. Student learning objective 2 (summarize primary scientific literature and incorporate it appropriately into formal lab reports) was assessed using the “introduction” and “literature cited” sections of the rubric. Student learning objective 3 (show critical thinking in the construction and writing of laboratory reports) was assessed using the “organization” and “clarity” sections of the rubric. Student learning objective 4 (show skills in writing in the discipline of biology) was assessed using the “content” and “writing style” sections of the rubric.

TABLE 1.
Timeline for implementation of elements of the peer-review process.

| Instructor Action | Student Action |
|-------------------|----------------|
| Prior to beginning first laboratory exercise | Explain laboratory report writing procedure (Appendix 1) and provide a copy of this document to students. Instruct students to choose a laboratory partner and fill out 2 copies of the laboratory partner contract (Appendix 2). Provide students with access to the laboratory report writing guide (Appendix 3) and the laboratory report grading rubric (Appendix 4), and review the expectations described in these documents. | Fill out 2 copies of laboratory partner contract and retain one copy. |
| During laboratory exercise | Remind students that they need to prepare complete individual laboratory report drafts before beginning the peer-review process. | Complete experiments and gather data with laboratory partner. Analyze data and prepare laboratory report draft without collaborating with partner. |
| Initial draft due date (as dictated by laboratory partner contract or instructor) | Instruct students to read the drafts critically, mark all errors clearly, and provide specific guidance for improving the paper. Give examples of “specific” versus “non-specific” comments students might use in reviewing a draft. Answer student questions regarding peer-review process and laboratory report requirements. May have initial review occur in class so additional guidance may be given to students and quality of drafts can be checked. | Provide partner with complete draft of laboratory report for review. Review partner’s laboratory report, making specific suggestions for edits when the report does not meet the guidelines provided in the laboratory report writing guide or the laboratory report grading rubric. Ask questions, in class or during office hours, if clarification is needed on the peer-review process or laboratory report expectations. |
| Peer-review due date (as dictated by laboratory partner contract or instructor) | None | Return marked-up draft to partner. Revise laboratory report as appropriate. |
| Due date for laboratory report | Check for plagiarism, randomly select one laboratory report from each pair/group to grade, and grade reports. | Hand in all draft and final copies of laboratory report. |
| ~1 week after laboratory report due date | Post grades so all partners can see their grades. Return the graded report to its peer reviewers, but retain all other documents. | Peer reviewer: examine graded report to see if the author made all of the suggested edits. |
| Up to 1 week after laboratory reports are returned | Meet with peer reviewers who believe suggested edits that were not incorporated in the final paper impacted their grade. Compare the edited draft to the final paper, and adjust the reviewer’s grade, if appropriate, based on the rubric. | Peer reviewer: make appointment to meet with instructor if suggested edits that were not incorporated into the graded report impacted grade. After meeting with the instructor, return the graded report to its author. |
| 1 week after laboratory reports are returned | Return all drafts and ungraded laboratory reports to students. | Ask questions, in class or during office hours, if clarification is needed on the peer-review process or laboratory report expectations. |
sections of the rubric. Student learning objective 3 (acquire and apply a set of basic laboratory data acquisition, analysis, and presentation skills) was assessed using the “results,” “methods,” “discussion,” and “format and style” sections of the rubric. Finally, student learning objective 4 (communicate the results of laboratory experiments in written form) was assessed using the “results,” “discussion,” and “spelling and grammar” sections of the rubric.

Laboratory reports are typically 35% of the course grade in genetics. In a randomly sampled set of lab reports in genetics, the average grades in each sub-section of the rubric are shown in Table 2. On these sample lab reports, two of the six students who acted as reviewers earned back points because they suggested corrections that their partner did not incorporate in their reports, with one student earning back 2 points and the other earning back 28 points. This demonstrates how even if a high-performing student is paired with a low-performing student, their grade will not be hurt. While the low-performing student can, indeed, have their laboratory grade pulled up somewhat by the high-performing student (when the high-performing student’s report is graded), the other 65% of their grade that is earned individually typically makes the impact on their final course grade very small.

**DISCUSSION**

**Field testing**

The effectiveness of this laboratory report writing procedure was assessed in a sophomore level genetics course (n = 22), and a modification of the procedure was used in a freshman-level introductory biology course (n = 23 for individual grading in one section, n = 6 for group grading in the other section). Initially we used the procedure in all laboratory sections for both courses, but after the pilot year, we were unsure whether the process was having a positive impact, a negative impact, or no impact on student learning. As a result, in the year these data were collected, we used two methods to evaluate the impact of the process on student learning. This data collection was approved by the Maryville College IRB.

**Comparison of grades of students working in pairs with students working individually.** In the genetics course, students in all sections were provided with the same laboratory report writing guide and laboratory report grading rubric. Students in one laboratory section were instructed to follow the procedure described in this manuscript, while students in the other section were instructed to prepare their laboratory reports individually. Students prepared three laboratory reports using their assigned procedure. A third party removed student’s names and any indicators of course section from the laboratory reports and, for students working in pairs, randomly chose the paper to be graded. The papers were assigned a number, so that after grading was complete, the grades could be assigned to the appropriate students and the rest of the protocol could be followed. Grades assigned to the papers produced by students in each lab section were compared, as were the grades each student earned for each laboratory report, which in some cases included points earned back through evaluation of the reviewed draft.

Students in the group using the pair/peer-review process were informed that we thought this procedure was leading to better grades, but we were unsure so we needed to test our hypothesis. Initially students expressed concerns about not having their individual work graded, but these concerns largely dissipated once they understood that they could earn back points through the peer-review process. There were, however, a few students who consistently felt that the process was an undue burden and they would have preferred to work individually. These complaints were no greater in number than what was seen the year prior when both laboratory sections used the pair/peer-review procedure. This process has been used in genetics every semester (n = 4) since the data described here were collected, and student complaints are now minimal. Most students actually prefer to work in pairs or groups, as demonstrated by their consistent election to work as trios rather than alone when a lab section has an uneven number of students or a partner is lost mid-semester when they drop the class.

**Comparison of grades assigned in groups with grades assigned to individuals.** In the introductory cell biology course, students in each of the two lab sections were instructed to follow the protocol described in this manuscript, with the modification that they worked in groups of four instead of pairs. One lab section’s lab reports were graded individually and the other section’s lab reports were graded using the group grading process described above for the sophomore-level genetics course. For the group-graded section, a third party removed students’ names and randomly chose the paper to be graded. The papers were assigned a number so that after grading was complete, the
Laboratory reports are a classic component of science courses because they allow instructors to evaluate how well students understand how key scientific concepts apply to “real world” situations. They also give instructors an opportunity to evaluate how well students analyze data and prepare it for presentation. Further, it gives students a chance to improve their scientific writing skills, which are valuable both later in their academic career for writing theses and in their possible future career for writing journal articles and technical reports.

This lab report writing process was developed to give students a more realistic scientific writing experience while reducing grading for the instructor without having a negative impact on student learning outcomes. Student peer reviewers typically identify many errors in their partner’s drafts, and most authors improve their final reports by making the changes suggested by their reviewer (examples are shown in Table 3). After piloting the process for a year, we thought that it might be having a positive impact on student learning, so we decided to collect data.

In the genetics course, students in one lab section used the process described in this manual, while students in the other section wrote their reports individually. A student’s t-test (unpaired, two-tailed, assuming equal variances) indicated that the two groups of students did not differ significantly with regard to their exam scores ($n = 22, p = 0.96$) or overall course grades ($n = 22, p = 0.611$), suggesting that the academic ability of the two groups was balanced. Lab report grades, overall and by sub-section on the rubric (see Appendix 4), were tracked for each student. It was found that while there was some variability in grades between the two groups, there were no statistically significant differences between grades earned on each of the individual laboratory reports. Figure 1 shows that the average grade for each group on each laboratory report was quite similar, and even when the grades of all of the laboratory reports prepared by individuals and pairs were compared, there was no statistically significant difference between the two groups. While this indicates that the process does not have a negative impact on the class as a whole, it does not eliminate the possibility of negative effects on some of the groups.

One particular concern that we had with using this process was whether students’ lab reports would improve over the course of the semester if they were not receiving feedback from the instructor on the report that they wrote every time. To determine whether or not this was an issue, the improvement, in points, from the first lab to the third lab was compared for individuals and pairs. Figure 2 shows the average improvement of student lab report grades from the first lab to the third lab, and makes it clear that student improvement was not inhibited by the pair/peer-review process. The standard deviation here is large, making the difference between the groups non-significant, but the greater improvement of paired groups is reassuring. Also reassuring was that only one pair did not show improvement on the third lab report, which matched up well with the two individual students who did not show improvement on the third lab report.

While the peer/pair process clearly allows for students to hone their laboratory report writing skills on a level equal to writing individual reports, we wanted to know whether this process could be used with larger groups. In the introductory cell biology course, students were instructed to write a lab report in groups of four, peer reviewing their three group members’ reports before one was selected for grading. In this pilot study, grades for the selected reports were compared with grades for all of the individual reports. As shown in Figure 3, there was no statistical difference between average grades determined using the peer/group method and average grades obtained by grading individual reports. A student’s t-test (unpaired, two-tailed, assuming equal variances) comparing the individual grades of one lab section with the group grades of the other lab section showed no statistically significant difference between the two sections ($p = 0.13$). For the first section, individual lab reports had an average score of 83.3% and a standard deviation of 7.9 ($n = 23$ individuals). For the second lab section, 24 students worked in groups of four to conduct the lab and each submitted their own individually written
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Examples of corrections made to final reports as a result of the peer-review process.

| Grading Rubric Category                  | Copy from Initial Report                                                                 | Reviewer Comment                                                                 | Copy from Final Report            |
|-----------------------------------------|------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|----------------------------------|
| Spelling, punctuation and grammar       | E. coli:MM294/pKan and E. coli:DH5α/pUC19                                               | Are you sure a colon is needed?                                                   | E. coli MM294/pKan and E. coli    |
| Format and style                        | E. coli (throughout report)                                                              | Remember that E. coli has to be in italics!                                      | DH5α/pUC19                       |
| Content (introduction)                  | (none on an important topic relevant to the report)                                      | Need to talk about mechanisms of how plasmid DNA is transferred to other bacterial individuals—transduction, conjugation, transformation. We used transformation. | There are three different ways in which bacteria can transfer genetic material, including conjugation, transduction, and transformation… (student went on to describe each mechanism) |
| Conceptual understanding (text)         | The transformation of plasmids by bacteria was also examined.                            | We didn’t transform plasmids.                                                    | The transformation of competent cells with plasmids was also examined.          |
| Conceptual understanding (figure)       | Y-axis of graph incorrectly labeled as “Size of DNA Fragment (bp)”; plotted points connected with a meaningless line that obscured the reader’s ability to see the line of best fit. | No, it’s the log_{10} of the DNA fragments (with arrow pointing to the incorrectly labeled axis); Don’t connect the points because you can’t see the line of best fit. | Log_{10} size of DNA Fragment (bp); line connecting the plotted points removed. |
| Literature cited                         | In-text citation: (Laroche-Ajzenberg, Ribeiro, Bodilis, Riah, Buquet, Chaftar, Pawlak 2014) |                                                                                 | (Laroche-Ajzenberg et al. 2014)     |

**FIGURE 1.** Average lab report grades (before adjustments) of student pairs and individuals. No statistically significant differences were found between average grades of students working in pairs and students working as individuals on any single lab report or all lab reports combined. (two-tailed t-test; \( p = 0.45 \) for report 1; \( p = 0.61 \) for report 2; \( p = 0.64 \) for report 3; \( p = 0.98 \) for all reports). Error bars indicate standard deviation.

**FIGURE 2.** Average improvement of individual-student and student-pair lab report grades between the first lab report and the third (final) lab report. There was no statistically significant difference in improvement between the two groups (two-tailed t-test, \( p = 0.11 \)). Error bars indicate standard deviation.
CONCLUSION

Possible modifications

This process can easily be modified to use the rubrics and laboratory report writing guides currently in use at another institution. It can be adapted to work for groups of up to four, although it is easiest for the students when done in pairs. The peer-review process can be done in or out of class.

SUPPLEMENTAL MATERIALS

Appendix 1: Laboratory report writing procedure
Appendix 2: Laboratory partner contract
Appendix 3: Laboratory report writing guide
Appendix 4: Laboratory report grading rubric

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