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Using a Collaborative Critiquing Technique To Develop Chemistry Students' Technical Writing Skills

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ABSTRACT: The technique, termed "collaborative critiquing", was developed to teach fundamental technical writing skills to analytical chemistry students for the preparation of laboratory reports. This exercise, which can be completed prior to peer-review activities, is novel, highly interactive, and allows students to take responsibility for their learning. In a collaborative critiquing exercise, students read writing samples from laboratory reports constructed by their peers and, through an interactive discussion, evaluate the quality of the writing by identifying the strengths and weaknesses of each passage. The second part of this lesson involves having students rewrite substandard laboratory report excerpts to practice writing in a technical voice. This lesson was believed to increase the class' ability to identify technical writing flaws and apply this knowledge base toward improving their own laboratory report writing.

KEYWORDS: *Upper-Division Undergraduate, Collaborative/Cooperative Learning, Communication/Writing, Inquiry-Based/Discovery Learning, Laboratory Instruction*

The enjoyment of scientific discovery is often suppressed by frustrations associated with the equally important task of communicating the corresponding results.[1] Although good technical writing is characteristically clear, concise, coherent,[2] objective, and formal, its application to a specialized audience[3] is what sets it apart from traditional academic pieces, such as personal essays and speeches. Many science students struggle with this latter aspect, finding the technical writing style awkward, at least initially, while assembling laboratory reports. Nevertheless, the essential characteristics of good technical writing are necessary for properly communicating experimental results.

Despite the inherent challenges associated with teaching students how to develop their technical writing, novel initiatives designed to facilitate this process have been reported. For example, scientific information literacy programs[4,5] provide students with the opportunity to practice writing in a clear, organized, and logical manner on a topic of their choosing after learning how to navigate primary literature sources. Similarly, writing consultant strategies allow students to collaborate with a writing "expert" (e.g., an upper-level peer) to gain valuable and specific feedback on their technical writing throughout the revision process.[6−8] Both of these initiatives offer instructors methods for helping students to improve their technical writing.

TEACHING TECHNICAL WRITING THROUGH PEER REVIEW

Perhaps the most reported strategy used to help students develop their technical writing is traditional peer review.[9−12] In these exercises, students (as readers) participate in critiquing writing samples from their classmates and, in turn (as writers), receive valuable feedback and encouragement in editing.[10] Peer review's allure lies in its simplicity, application to a variety of writing styles, and ability to accommodate varying degrees of writing experience among undergraduate students.[13] Moreover, peer review has been shown to promote conceptual understanding of the sciences and help students develop critical thinking skills.[14]

Most recently, calibrated peer review (CPR)[15,16] initiatives have proven successful in helping students develop their technical writing. In a typical CPR exercise, students submit their writing assignments electronically, and then participate in a concurrent review process wherein they rate writing samples from their peers according to instructor guidelines. The electronic nature of CPR makes it attractive to instructors who desire to help their students improve as writers, yet are constrained by either large class sizes or minimal one-on-one instruction time.

Given the benefits associated with both peer-review strategies, it is understandable why science instructors often use these techniques to help students improve their technical writing. However, on occasion, peer-review exercises may not be beneficial to the student. This notion became particularly evident one semester when the author's analytical chemistry class collectively struggled with writing good laboratory reports. In the first few weeks of the course, many students routinely submitted papers that were lacking in a technical voice. To help improve the quality of technical writing, the instructor conducted an hour-long peer review exercise in which student reviewers were given anonymous copies of laboratory reports and instructed to mark text for any technical flaws (e.g., use of first person, sentences that begin with numbers, ambiguous

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Table 1. Excerpts of Student Laboratory Reports and Corresponding Strengths and Weaknesses for the First Part of the Collaborative Critiquing Exercise

Entry	Student Excerpt	Strengths	Weaknesses
1	In this experiment we weighted roughly 420 pennies with the analytical balance. We collected the masses and reported our data into a spreadsheet. After that, the standard deviation and mean was found for the set of data.	•Mentions using an analytical balance •Statistics were determined using a spreadsheet	•Use of first person •More specific than "roughly 420 pennies"? •What was the mean and standard deviation?
2	During lab this week we were figuring out the amount of precip in Calcium oxalate...we were to transfer 25ml of unknown to a 250 beaker, and dilute with ~75ml of 0.1 HCL...	•Reader understands that the point of the experiment was to determine the amount of precipitate in calcium oxalate	•Not very technical; not reproducible in lab •Units on all numbers •HCL is not a chemical; HCl is a chemical •More specific than "~75ml"?
3	Visible light spectroscopy qualitatively identified the presence of a couple FD&C dyes in Kool-Aid samples. Grape, berry blue, and lemon-lime were found to contain Blue #1, while analysis of black cherry and strawberry were found to contain Red #40.	•Appears to conclude results from an experiment •No use of first person •Condenses data into one, final answer •Mentions technique for analyzing Kool-Aid samples	•"A couple" is colloquial. Is there a more formal way to make your point?

sentences) while making suggestions for improvement in the writing. At the end of the session, before critiques were handed back to the original authors, all comments and suggestions were examined. It was surprising to observe that student editors felt their peers had written good reports, when, in fact, many of the writing samples contained many of the aforementioned mistakes. In this instance, the exercise failed to produce the desired result because, generally speaking, the students were ignorant of good technical writing expectations.

The peer-review process assumes that participants are capable of correctly identifying technical writing mistakes. For example, an overwhelming majority of students in the previous example failed to recognize that using first person was unacceptable in scientific writing. Additionally, on one laboratory report, the phrase "the white stuff was dissolved in water" passed by two reviewers without any indication that this language was particularly informal. According to the *Mayfield Handbook of Technical and Science Writing*,[17] both of these instances are considered nontechnical because the writing is subjective and ambiguous. If students do not understand that laboratory reports must necessarily be written in a lucid, objective, and formal technical voice, they will be unable to correctly identify mistakes during class-wide editing exercises, an aspect of peer review that has gained little attention in the literature. Ultimately, in order to gain many of the benefits associated with peer review, students must first develop a fundamental knowledge of technical writing. This observation underscores the need for alternative methods for developing technical writing in the event that peer-review exercises are not beneficial to students.

■ BUILDING A KNOWLEDGE BASE IN TECHNICAL WRITING

A highly interactive lesson, eventually termed "collaborative critiquing", was developed to help undergraduate analytical chemistry students recognize characteristics of good technical writing that they could apply to their own laboratory reports. The strategy involved leading a class of analytical chemistry students to simultaneously recognize common technical writing mistakes while building a working knowledge base of what not to do while writing laboratory reports. Students closely interact with the text as a cohort and ultimately share responsibility for learning, reminiscent of reciprocal teaching.[18] However, the main difference between the two techniques is that collaborative critiquing aims to improve technical writing, whereas reciprocal teaching is associated with developing reading skills.

Prior to the collaborative critiquing lesson, writing samples of student laboratory reports taken from current and previous semesters were compiled anonymously into a PowerPoint presentation such that each slide presented a different excerpt. Specific samples that exhibited technical writing flaws such as first-person usage, incorrect chemical symbols, and colloquialisms were chosen to highlight common mistakes in student laboratory reports, as seen in Table 1. Section 6 of the *Mayfield Handbook of Technical and Science Writing*[17] served as a guide in this process owing to its wide availability, both in print and online, and its utility to a variety of different technical disciplines (e.g., chemistry, biology, engineering). Additionally, Davis, Tyson, and Pechenik's *Short Guide to Writing about Chemistry*[3] was also used as a teaching resource because of its simplicity, multitude of practical examples, and format—offering commentary to highlight the strengths and weaknesses of each passage.

In the first part of the lesson, excerpts from student laboratory reports were presented to the class on an overhead projector. The instructor read a given passage aloud to the class, and students were guided in identifying its strengths and weaknesses through instructor-mediated Socratic dialogue. Examples of open-ended questions used to stimulate discussion are seen below:

- What three things did the author do correctly in this excerpt?
- What is your major criticism of this passage?
- Which information is relevant to the scope of the laboratory report?
- What details make this procedure reproducible in the laboratory?
- What grade would you assign to this excerpt?

Although discussion was initially met with some resistance, the more outgoing students were usually first to participate and discussion soon spread across most of the classroom, lasting for approximately 3−5 min. Interestingly, when asked to propose a letter grade for a particular sample, students were fairly candid,

Table 2. Excerpts of Student Laboratory Reports and Suggested Revised Versions

Entry	Excerpt	Revised Version
1	During lab this week we were figuring out the amount of precip in Calcium oxalate...we were to transfer 25ml of unknown to a 250 beaker, and dilute with ~75ml of 0.1 HCL...	The concentration of an unknown solution of oxalate anion was determined...to a 250 mL beaker was added 25.0 mL of unknown, which was diluted using approximately 75 mL of 0.1 M HCl...
2	An analytical balance was used to obtain exact weights of potassium hydrogenphthalate. Bulb pipets were used to transfer aliquots of the sample. A hot plate was used to heat the sample simultaneously...	Exact masses of potassium hydrogenphthalate were obtained with an analytical balance. Solutions were pipetted then titrated with a 50 mL buret...
3	From a steam-distillation of 1.00g cloves, the steam-distillation yielded 56mg isolated clove oil. Even though the distillation was halted prematurely, the experiment's percent recovery was 5.6%, which proves the hypothesis true since clove oil successfully extracted from cloves via steam-distillation.	After steam-distillation and extraction of 1.00 g of cloves, 0.056 g of essential oil was recovered, resulting in a 5.6% yield. Improvements could be made to this experiment by allowing the steam-distillation to run longer.

yet respectful, in their responses. For example, when asked to assign a grade to Entry 3 in Table 1, one student suggested: "give it a B, because it could sound a bit more science-y". At the end of the discussion, lists of strengths and weaknesses, as seen in Table 1, were projected alongside the original excerpt. Surprisingly, many students did not understand that terms such as "roughly" and "approximately" were too ambiguous for laboratory reports, and that each number must have a corresponding unit.

In the second part of the lesson, students practiced writing in the technical voice by revising excerpts of substandard laboratory reports. Each passage was projected on an overhead screen, and students were asked to provide commentary, which was recorded on a nearby chalkboard. Students were then given 2−3 min to prepare their own individual revision of the excerpt. After this brief rewrite period, the instructor projected an example of how a revised version the original passage might look. Examples of excerpts and the corresponding instructor revisions are seen in Table 2. Although many students were timid about sharing their revisions with the class, some who elected to read their revisions were grateful to get immediate feedback from the instructor.

■ RESULTS AND APPLICATION TO OTHER CLASSES

In the weeks following the collaborative critiquing exercise, students appeared to be making fewer technical writing mistakes on their laboratory reports. Although this exercise was not beneficial for the entire class (less than a quarter of students could not be swayed to improve their writing), at the end of the semester during course evaluations, some students commented that their technical writing had improved because of the exercise. Additionally, during the same evaluation period, two students indicated that collaborative critiquing would be beneficial for all chemistry majors, and three other students suggested that all science majors should go through a collaborative critiquing exercise.

Given its generally positive feedback and success in helping students build a technical writing knowledge base, the collaborative critiquing exercise was repeated the following semester to three sections of general chemistry laboratory, with students of various majors—chemistry, biology, business, exercise science. As was done with the analytical chemistry class, general chemistry students submitted three weeks' worth of laboratory reports prior to the collaborative critiquing lesson so the instructor could assess the commonly occurring technical writing mistakes, the most common of which were excessive first-person usage, colloquialisms, and fragmented sentences. Each section then participated in collaborative critiquing as described above. Relative to the analytical chemistry class, all three general chemistry laboratory sections were noticeably quieter and less willing to participate in the exercise.

In the following weeks, the instructor observed minor improvements in the quality of the technical writing, particularly among the upper-level general chemistry laboratory students (i.e., third- and fourth-year). As above, improvements mostly involved a reduction first-person usage. One possible explanation for this outcome is that general chemistry students might require additional structure upon which to lay the substance of their technical writing. Methods that employ writing "scaffolds" to improve the quality of general chemistry laboratory reports have reportedly been useful.[19]

■ CONCLUSION

Despite the minimal improvements in technical writing among general chemistry laboratory students, analytical chemistry students benefitted from collaborative critiquing, as evidenced by a reduction of technical writing mistakes in laboratory reports written after the exercise. Senior-level analytical chemistry students claimed that this strategy was helpful in developing their technical writing skills and suggested that it would be beneficial for all chemistry majors. Future iterations of collaborative critiquing may involve devoting additional attention toward laboratory report structure.

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Notes

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