

Exploring Alternatives in the Teaching of Lab Report Writing: Deepening Student Learning Through a Portfolio Approach

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Introduction

The authors' goal was to develop a new way to teach writing to sophomores in an optics laboratory course, creating a method that would a) lead to more effective lab reports b) deepen student learning of course content and c) nurture a more positive attitude toward scientific writing. Previous approaches seemed to emphasize form over learning, and structure over meaning, formulas that often resulted in instructor and student frustration and little to no change in student writing or their attitudes toward it. Although books such as *Engaging Ideas* by Bean (1996) and *Assigning, Responding, Evaluation: A Writing Teacher's Guide* by White (2006) offered interesting ideas, they did not provide the conceptual method desired. As a result, the authors of this article, professors from two different colleges and two different disciplines, physics and English, joined forces to generate a method that would yield more effective lab reports; create confident, thoughtful writers engaged in a productive writing and editing process; and generally improve student learning. While several features led to the success of this new approach, the key component was a contemplative essay.

The Issue

To explain our incentive for creating a new method, it is useful to provide a brief overview of previous approaches and the ways in which they failed to achieve the stated goals. These traditional approaches have been implemented in science laboratory courses at academic institutions for decades and can be divided into two methods, the Formal Lab Report and the Lab Notebook. Although not always denoted by these names, they remain the norm in many science departments, including those of the authors.

The Formal Lab Report required a lab write-up for each weekly experiment. The formal reports consisted of the following:

- an introduction describing the physical concepts in the lab (a paragraph or more);
- a theory section consisting of a detailed explanation of the physics, including derivations of equations that were used for the data and analysis (normally two or three pages);
- data and analysis, which included all the data in tables, graphs where applicable, calculations, and detailed explanations of the physics revealed in the analysis (three to five pages, depending on the experiment); and
- a conclusion summarizing the results (essentially two to three paragraphs).

All sections of the report were due one week after the students completed the experiment in the laboratory. All of the sections were graded.

This method was notable for its emphasis on the structure of the lab report: its various sections and its style—an objective, scientific tone. Students struggled most with the theory section; repeated prompts to write theory in a manner that imitated the style of their textbooks were not successful. To students, it seemed, the lab reports were less about critical thinking and more about reporting. Put another way: they seemed to see themselves as clear conduits through which the events of the lab report were passing, untouched, with no analysis, no evaluation—none of the higher end cognitive skills that we associate with the upper reaches of Bloom’s or Anderson’s taxonomies. Not surprisingly, then, they almost uniformly resisted any invitation to revise their work; although students were encouraged to turn in a draft of their formal lab report midweek for penalty-free feedback, rarely if ever did the students take advantage of this. They had made their report. They had fulfilled the requirements. Their work was done.

Needless to say, this lack of engagement was frustrating to the instructor: providing feedback to the students was arduous and time-consuming, particularly since the instructor was intent upon not just justifying the grade, but giving students input that would allow them to improve their work on future reports. Unfortunately, the feedback provided had little to no impact on student writing. Instead, it seemed that most students simply saw the graded lab as a completed assignment—the results had been reported; their “work,” their thinking, was done. As a result, few if any took the time to review and interpret the suggestions provided by the instructor. Indeed, the perception seemed to be that this feedback was less constructive than destructive, designed solely to punish them. By mid-semester, the majority of the students were not improving, and their attitude toward writing and doing labs in general was increasingly unreceptive.

A second method, the Lab Notebook, was implemented in hopes of encouraging the students to use the instructor feedback to improve their writing and thinking from one report to the next. According to this method, the students submitted a lab notebook each week. The lab notebook consisted of a data and analysis section and a conclusion only. Formal lab reports were still submitted but only two to three times a semester. Before the formal write-up was due, students were required to meet with the instructor to review a draft. One strength of this method was that it de-emphasized the form-related elements of the lab report, instead placing an emphasis on analysis. Consequently, this approach did generate some improvement in the student writing from the draft to the formal lab submitted. However, with only two to three formal write-ups a semester, it seemed that the knowledge gained from the draft to the formal write-up was lost during the gap before the next due date; thus, overall improvement—to both thinking and writing—was inhibited.

Through the authors’ collaborative efforts, a new Portfolio Method was created to improve student writing while reducing frustration and increasing students’ commitment to editing and revision—and the critical thinking catalyzed by effective engagement in these processes. The Portfolio Method uses a unique combination of formal lab reports, portfolios, and contemplative essays to meet the goals set by the authors. It incorporates the best of the previous methods and adds a new dimension that empowers the writer to embrace a more deliberate revision process that requires them to think more critically:

- Each week students submit a formal lab report that includes all of the traditional components listed above.
- The instructor provides feedback on the data and analysis section, as well as a grade based solely on that material and the conclusion.
- The instructor edits the introduction and theory sections as if these parts contribute to the grade.

- At the midterm, students are required to submit portfolios consisting of two revised formal lab reports and a contemplative essay. In the contemplative essay, students discuss the revisions they made to the physics (i.e. correcting scientific errors, adding additional theoretical information and or equations) and the writing (editing grammar, fixing poor word choices, carefully explaining the results using scientific terms or mathematical values rather than relying on comments like “the results were good”) as well as what they learned from the revisions. All sections of the formal reports are graded.
- This process is repeated the second half of the semester, with students turning in, just before finals, another portfolio, consisting of a contemplative essay and revised reports from the second half of the term.

All submissions are made in paper format, not electronically. Since there were no teaching assistants for the course, the instructor performed all grading and provided handwritten feedback on the student papers. This method was first implemented in 2011 and has been the sole method used for the optics lab ever since. There are two to three sections offered each year with a cap of ten students per section.

It should be noted that the portfolio submitted according to this method is more suitably thought of as a developmental learning tool, not simply a showcase of student work. This is important; in the methods outlined above, particularly the Formal Lab Report, the emphasis often appears to be on a final product that matches the style and form of professional scientists. While this form is of course essential to good scientific writing, to expect at this stage in their career that students can produce *both* perfect form and thoughtful analysis in a single draft is perhaps unwise—particularly when, if our impressions are correct, students seemed to default to form over content, style over thought.

Of the three methods discussed in this paper, the Portfolio Method requires the greatest amount of writing, but generated overwhelming student support, significant improvement in the scientific writing, and a greater understanding of course content. Students receive a weekly grade based solely on their knowledge of the experiment and the results, while not being “punished” (as they perceived it) for their lack of knowledge with regard to the formal demands of the lab report. Then, they have an opportunity to learn from instructor feedback and improve their writing. Finally, the key component, the contemplative essay, gives them an opportunity to reflect on their own learning—and to deepen that learning, something that will be discussed more momentarily.

Results

Unlike the other methods which yielded little improvement from one week to the next—either in the quality of student thinking or in their attitudes toward lab report writing and revision in general—the Portfolio Method generated significant improvement in student attitudes toward both their own texts and their approach to the writing and revision process. In his contemplative essay for his final portfolio, one student writes:

As I was rewriting and revising selected pieces of the labs, I wondered as to the purpose of the entire ordeal. I grumbled through the first phase of the process, muttering to myself about my frustration with having to re-do something I had already completed, turned in, and had a grade for. After a little time of doing this, however, I began to notice something about the lab report I was revising. It was

genuinely improving. The quality and clarity of the information increased, word choices were revised, and ideas were becoming more fully developed. The revision process was working without even my notice or intention. Upon this realization, I focused on my efforts to improve the labs. The point of correction became clear and I suddenly embraced the benefit of correcting the reports wholeheartedly.

Noteworthy here is a subtle movement from form to process to learning: at first, the student is frustrated because he has to revisit something that has already been completed. Then, he realizes that the process of revision is yielding results in terms of “quality and clarity.” And then, in the same sentence, he acknowledges that the “ideas” themselves seem to be improving by “becoming more fully developed.”

Similar shifts in student thinking were revealed throughout the contemplative essays. Several of the excerpts below, for instance, demonstrate a trend that appeared in nearly all of the student essays: namely, students were beginning to embrace the writing process:

In the revising of the actual writing of the lab, I saw that the bulk of the theory written was accurate and concise. However, a minority of the theory toward the end had been worded in an “awkward” way, causing the reader to either become confused, or misunderstand the physics entirely. After changing the wording in the passage in question, the physics behind the experiment became much more apparent.

I believe that prior to the revision, I had no conception of the actual physical mechanism of the selective absorption of incident waves not polarized along the transmission axis. The rectification of my ignorance in this area of optics was a positive ramification of performing the revisions that is required by the portfolio submission.

In the data section captions were added to the table and some analysis writing was revised. The conclusion saw a major-overhaul, again utilizing suggestions from the instructor to include pertinent data and incorporate conclusive results to give the report a polished and expert feel.

Looking back over my labs from the semester, it’s clear that there is at least once where I didn’t necessarily understand all the theory behind it, and it showed in the lab. For these two labs I really took the time to understand what was going on and not only did my labs turn out better, I had a better grasp of the physics involved. In this section, the labs were less about figuring out how to write as they were learning tools for myself. I took what was being taught in class and combined it with the work done in the lab and found that things made more sense than I thought they could.

Plainly evident here is the students’ understanding of how revising the theory and data analysis could lead to a deeper understanding of the physics and a more accurate presentation of the data. The contemplative essay, to put it another way, seemed to clarify for students the importance of thinking critically and deliberately during the revision process—as opposed, say, to simply making

the changes the professor suggested, without really considering why these changes might be valuable. Perhaps consequently, the moans and groans of the other methods were replaced by content writers ready to submit their work for a grade. By the time the final portfolio was submitted, the students were spending less time revising and were clearly able to see improvements in their own work. Revising a report to make it better began, it seemed, to feel natural and normal to them. The resentment created by the other methods was replaced by a motivation to do better, resulting in a positive lab writing experience for the students—and the instructor.

At the same time, it is worth noting, student understanding of the formal elements of lab report writing also improved—both from the perspective of the instructor and from the perspective of students.

While I feel that completing these labs reinforced my prior knowledge of the concepts discussed, another way I have benefited has been through the developing my writing skills. Since the first lab I have felt myself continuously improving the way I write. In the beginning, I feel my writing did not convey the information it was meant to efficiently because I frequently got off topic. Now I feel my writing has become more concise and direct so that the information that is meant to be displayed is easy to find and understand.

To sum up the portfolio, the changes that were needed in the lab write-ups were significantly smaller than the last portfolio. My writing has significantly improved which made the revisions much quicker.

To start this reflection off, let it be said that this time around was not nearly as painful as the first. It was a good bit easier to focus when I kept in mind my overall focus was to improve my writing as much as I possibly could. It also did not hurt that I felt I did not have as much revising when it came to the theory sections.

When using the traditional methods, many of the students repeated the same mistakes from week to week in their writing throughout the semester. The revising process was not a learning process. The Portfolio Method, on the other hand, created a path for the students to become more engaged in the writing process. As a result, the lab reports generally improved from week to week. Students quickly observed the improvement and noticed the decrease in time required to complete their reports. Combined, these observations seemed to yield a sense of accomplishment and generate confidence. As a result, preparing the reports began to be viewed not as a burden but as a project into which the students were eager and willing to invest their time and energy.

Rationale

So why did the Portfolio Method prove such a success? Several reasons are perhaps self-evident. The first is that the portfolio approach is designed to emphasize “coaching” over “judging.” Second, the weekly lab report grade is weighted heavily on the physics, not on the writing. Consequently, students who successfully complete the experiment, obtain good results, and present the results in the appropriate graphs with the correct analysis earn high marks. At the same time, students who do poorly on the writing and have a significant amount of revision on the introduction and theory sections are not penalized in the weekly grading and as a result are not frustrated or resentful toward the writing and revising of the labs for their portfolios. The feedback

is accepted by the students because it is perceived as coaching rather than judging/grading. The paper is full of red ink, but students generally seemed to believe these comments were helpful, rather than punitive.

Another reason this method is successful may be because the portfolio may have generated in students a sense of pride in the product they created. For the majority of the students, the portfolio contained the largest volume of scientific writing they had ever generated. Students often walked into the lab with a smile the day the portfolios were due, and as one student said, “I can’t believe I was actually able to put together an entire portfolio of scientific writing.” The time invested in the revisions is valued in the mind of most students because there is an entire portfolio to submit, a substantive product that reflects a lot of hard work.

The success of the Portfolio Method is also the result of decades of thinking in the field of composition pedagogy. This method recognizes the value of writing as a tool of learning, rather than as a purely communicative tool. This distinction is important; when writing is viewed as a tool of communication, it seems simple. Such a model assumes that ideas are clearly formed in the writer’s head and all that writing does is put those words down on the page. The implication is that writing should be simple: all one need do is “translate” ideas to the page. Consequently, when asked to do a lab report using the formal method outlined above, students may assume that the real work occurs when running the lab—that all the thinking exists in the set up and activation of the lab—and that the report itself is simply a thoughtless translation of events onto the two-dimensional page.

Of course, very few writers—regardless of field—find this to actually be the case: as we attempt to transfer ideas to the page, what once seemed clear becomes increasingly amorphous. Perfect words are illusive, flaws begin to appear in the logic, and new solutions and understandings begin to emerge. Writing-Across-the-Curriculum scholar Chris Anson puts it this way: “As writers formulate thoughts into written propositions, their emerging texts loop back into their own thinking. Words written become words reconsidered, ideas put to new tests” (x). As such, writing is less about “translation” or “communication” than about learning: writing leads to reconsideration, to testing, to discovery. Or more accurately, these two concepts, learning and communication, exist on a continuum: at moments in a particular writing act, the ideas are clear and come easily and stand up to the light of day. At other times, the writer must revise and analyze, evaluate and reconsider and reattempt before a clearer understanding is achieved.

Complicating all of this is that the actual *act* of writing is immensely complex. As psychologist Ronald Kellogg makes clear in his iconic “Training Writing Skills: A Cognitive Developmental Perspective,” “Writing an extended text at an advanced level involves not just the language system. It poses significant challenges to our cognitive systems for memory and thinking as well” (2). Indeed, Kellogg compares writing to cognitively challenging skills such as playing chess or becoming a concert violinist: “Becoming an expert typist, chess player, or, say, violinist, requires a minimum of ten years of intensive learning and strong motivation to improve. The very best violinists, for example, have accumulated more than 10,000 hours in solitary practice” (2).

One of the benefits of the Portfolio Method outlined here is that it addresses this complexity of learning by breaking the writing process down into a number of more manageable stages. As James Zull notes, working memory, the cognitive function applied to a given task at a given moment (78), is limited in terms of “capacity, tenacity, and time. It can only hold a few (about seven on average) isolated items, such as unrelated words, at once. And it doesn’t hold tightly to anything. All it takes is a slight distraction to knock something out of our working memory” (183).

The portfolio process—at least as the authors have developed it—reinforces this style of

task management: in the early stages, students are simply concentrating on running the experiment, collecting the data, and drawing conclusions about the significance of that data—in short, they are able to concentrate on the critical thinking required to develop as scientists. What students are *not* thinking about at this time mainly relate to the appropriate form-related components of a lab report: tone, word choice, sentence structure, paragraph structure, voice (passive vs. active), and a thousand other smaller choices related to sentence-level writing.

Once the students have had a chance to address the content of their lab reports and the complex underlying logic and thinking that is so crucial to developmental learning in the sciences, they then have a chance to return to questions of form and structure, refining and polishing, making adjustments in word choice and sentence structure—not to mention paragraph structure and the clarification of logic implicit therein.

Finally, though, the most important reason for the success of the Portfolio Method is the contemplative essay. Some might be tempted to view this essay as a secondary feature, a “cover letter” of sorts, that is much less important than the lab report itself. This would be a mistake. Consider: students write their initial lab reports; then, they receive feedback from the instructor; next, they make changes to their lab reports, in response to the feedback they have received. If the process ends there, the basic authority for the quality of the revised reports remains in the hands of the instructor; if the revised report is “no good,” a student likely thinks that’s the instructor’s fault: “I did what she told me to do. Why didn’t I get an ‘A’?” In this case, “expertise” remains located in the professor. The students are passive, assuming no responsibility for their learning.

What the contemplative essay does is shift the locus of responsibility to the students. Now the students must not just *make* changes, but *justify* those changes. And simply saying, “I made X change because the professor told me to,” is not enough; students must be able to articulate why and how these changes improve the work. As a result, the responsibility for both the course content and the articulation of its meaningfulness has shifted from the instructor to the students. Put another way, students are no longer able to remain passive in the learning process; rather, they must engage it through revision. Whereas in the other lab writing methods described, in which this sort of engagement is optional, here it is required. The result is deeper, more substantial learning of *both* the lab content and of the skills related to writing effective lab reports. Without the contemplative essay, students often go through the process of revising without the kinds of critical thinking associated with higher-level cognitive processes like analysis, synthesis, and evaluation. The contemplative essay reinforces the revisions—and any learning associated with these revisions—in the students’ minds, deepening their learning with regard both to the lab itself and to the writing process.

Peggy Maki states this act of contemplation thusly: “Self-reflection reinforces learning by engaging learners in focused thinking about their understanding *and* misunderstanding” (48). As students are writing their contemplative essays, they—as well as the instructor—are getting a clear sense of what they have learned that semester—and of what they have not learned, of the gaps in their knowledge. This is important because seeing their own accomplishments creates a sense that all the work they did actually led to something meaningful, that it was more than just jumping through academic hoops. In an educational context where too many students view the university as a certification process, creating an environment where students recognize that they are engaging in real work and real learning can radically change their attitudes toward their own education.

In short, the contemplative essay empowers the students. It makes them think about revision and allows them to understand the purpose of revising their reports. In addition, it reveals the positive impact that revision has on the quality of their reports, and it seems to result in a feeling

of confidence as they realize that the revised report is so much better than the original product. Without the contemplative essay, students often go through the process of revision without thinking—as a result, the lab report simply feels like busy work. The contemplative essay aims to secure a permanent place in the students’ minds for revision and its purpose, which perhaps translates into a long-term change in the way the students write—and think about writing. It bridges the gap that often frustrates the students, between writing and learning.

Conclusion

After several semesters of use, the Portfolio Method continues to enhance the quality of student writing through the process of revising. Equally important, however, this approach appears to lead to deeper learning of course content. By critiquing their editing in a contemplative essay, thinking carefully about the writing and how it conveys the science to the reader, students using this method likely become more committed to using the forms of scientific writing to effectively communicate important ideas. The form, to put it another way, serves the ideas, allowing the latter to be dominant. As a result, students become committed to the editing process and begin to appreciate the feedback provided by the instructor, understanding that the goal is to increase the overall quality of their work. There is minimal student resistance or frustration. On the contrary, students generally become quickly engaged in the editing process. As quality of their work improves so does their attitude toward writing and revising.

Key here is the contemplative essay: this component of the portfolio paves the path from form to thought, allowing the student to travel back and forth between them. By discussing the revisions in the contemplative essay—rather than just performing these revisions—the students are pushed to write, think, and learn. This is a dramatic improvement over the previous approaches, leading to better writing, better learning, more engaged students, and more satisfied instructors.

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