An Integrated Approach to Improve the Scientific Writing of Introductory Biology Students

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Abstract

We discuss a pedagogical strategy to improve the writing of laboratory reports. Our multipronged approach gauges students' comprehension beforehand, rewards early success, and focuses feedback on the most serious writing issues. In preliminary studies, more students were able to achieve our threshold for success in our introductory courses, and students reported being more motivated to write well.

Key Words: *Scientific writing; laboratory reports; integrated pedagogy; student motivation; instructor feedback.*

The communication of scientific findings is the final critical step in the process of science. Consequently, education in a scientific discipline should also develop scientific writing skills, so that students can systematically organize their knowledge and demonstrate this through clear communication.

A standard approach for teaching scientific writing in an introductory course involves students submitting multiple laboratory reports written in the format of a scientific paper (Pechenik, 2006), which are graded and returned with extensive feedback. However, despite the copious comments, students too often fail to significantly improve their writing skills (Lindemann, 1995). In addition, papers that reflect the least student effort can often require the most instructor effort to critique.

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Why is it that student writing often fails to improve as a course progresses? First, if a student does not comprehend the relevant material, effective writing is nearly impossible (Kellogg, 1987; Tobias, 1994). In addition, while a common argument for multiple writing assignments is that practice makes perfect, repetition of poor writing practices seems of little value (Perkins & Salomon, 1998). Rather, students must be motivated to improve their writing, drawing on past experiences (Hidi & Harackiewicz, 2000; Ainley, 2006).

Given these considerations, how could we restructure our laboratory report assignments to foster the development of students' writing skills? Here, we describe a multipronged approach that seemed to improve the quality of lab-report writing and increase students' motivation to write effectively.

A Multipronged Approach to Writing Instruction

Focusing on the core learning objective of developing competency in scientific writing and keeping in mind the importance of student comprehension and motivation, we composed the following multipronged pedagogical approach:

- Before students prepare a formal report, we give prompt feedback on their comprehension of relevant material using short-answer "content questions."
- We use an "all or nothing" grading system that rewards students for successfully writing a high-quality paper, while providing multiple opportunities to succeed.
- We provide "prioritized feedback" on unsuccessful attempts that focuses student attention on the most serious writing difficulties.

Content Questions

Because it is difficult to write clearly about a topic that you don't understand, we wanted to give students prompt feedback on their comprehension of each investigation to correct any misconceptions before writing their report. In addition, previous work has suggested that students can achieve an understanding of scientific concepts and better cognitive skills through structured writing exercises that are not lab reports per se (Keys, 1999; Quitadamo & Kurtz, 2007). To this end, we developed a series of "content questions" for each lab exercise that assessed each student's comprehension of the investigation's objectives and their findings, helped them learn the scientific concepts, and improved their critical-thinking skills (Keys, 1999; Quitadamo & Kurtz, 2007). For example, a content question might ask the students to analyze their data or state what conclusions could be drawn. Each of the lab investigations spanned 2 to 3 weeks, and

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each student answered three to six of these content questions at the end of each week.

We graded the submissions and returned them promptly. In addition to a numerical grade, the students received a color-coded signal – green, yellow, or red – indicating their comprehension. Students who received a green light on the content questions demonstrated a strong understanding of the lab investigation and were clearly ready to begin writing a scientific report. By contrast, students who received a yellow light were cautioned to review the lab investigation (for example, by meeting with an instructor) before attempting to prepare a scientific report. Finally, students who received a red light were discouraged from proceeding with the writing assignment (see below). This helped reinforce the notion that content mastery is essential to good writing (Kellogg, 1987, 2001).

The "All or Nothing" Grading System

Given our focus on developing competency and our desire to give students a strong incentive, we implemented what we call an "all or nothing" grading system. Students were given multiple opportunities to write lab reports, but once they submitted a report of high quality (see below), they received full credit (5% of the course grade) for the scientific-writing assignment and were not required to submit further reports. We thought that students would consequently be motivated to produce their best writing from the start. Although successful students did not submit further reports, they were still required to complete the weekly content questions. As an added benefit, once we had identified the students who demonstrated the desired competency in scientific writing, we could focus our instructional efforts on the remaining students who most needed our assistance.

If a student's submission was not considered to be of high quality, the student received no credit and the paper was returned with specific comments for improvement (see below). After completing the next lab investigation, the student then had another opportunity to complete a lab report on the new topic, using the feedback received from the previous critique. This cycle was repeated until the student prepared a high-quality report or the course ended.

Prioritized Feedback

Students can easily become overwhelmed by the surfeit of comments on a teacher-reviewed paper (Walvoord & Anderson, 1998; White, 2007) and the teacher, in reviewing student papers, can become focused on lower-order writing issues, such as misspellings and grammatical errors, to the detriment of proper organization, relevant content, and concise language (McAndrew & Reigstad, 2001; Stern & Solomon, 2006).

Consequently, we developed a prioritized review form for assessing student papers, based on the writing guidebook for the course (Pechenik, 2006). This form prioritizes the proper preparation of the Results section and the inclusion of relevant content in a clearly organized manner. If the Results section was properly prepared and well written, we proceeded to subsequent items in order of priority (Discussion, Introduction, Title, Abstract, Methods; paragraph construction, sentence structure, grammar, language). If a section of the paper was considered to be of insufficient quality (i.e., improperly prepared or poorly written) at any point, the evaluation was terminated and instructions were given on how to remedy the identified deficiencies. To ensure that a student would focus on the most significant issues first, the remaining sections were not evaluated. An added benefit of this approach for the instructor is effective time management, as excessive amounts of time and energy are not spent making copious comments that are unlikely to benefit (and indeed may dishearten) the student.

Our intention, through this methodology, was to clarify issues of content knowledge and writing ability in our students' lab reports. By separating the work into content questions and report writing, we were able to gain useful clarity and direct our students' work more effectively. This approach helped pinpoint our students' writing issues and gave us a discrete means of addressing them.

○ Methods

Course Structure

The courses included in this project were introductory courses in biology with enrollments of 20–50 students. The students were asked to write up to six lab reports in the courses using the traditional format, or had three or four opportunities to write a lab report in the courses using the multipronged approach.

Evaluation

Papers submitted in courses that used the traditional format were assigned a letter grade, with B+ or higher identified as the threshold for high quality. No formal measure of inter-rater reliability was administered; however, an examination of the distribution of grades given by individual professors and between different introductory courses over several years revealed little variation in the range of grades given. For example, the percentage of students who received at least one lab report grade of B+ or better averaged 33 ± 8% (standard deviation) even when comparing different introductory courses taught by different professors over a 3-year period.

Survey Design

To assess the students' attitudes about writing, we adapted a writing survey available at the "Field-tested Learner Assessment Guide for science, math, engineering, and technology instructors" website (http://www.flaguide.org/), making the survey specific to our courses and adding questions about motivation (the modified survey is available from the authors). The survey asked the students to self-report their understanding of the mechanics of writing a lab report, their attitude toward the instructor's comments and grading, their attitudes about the value of writing and revising, and their motivation to write well. The students responded to each question using a Likert response instrument by selecting the item that most closely corresponded to how they felt about the question or statement. A total of 115 students completed the survey, 24 in the treatment group (integrated course structure) and 91 in the control groups (traditional course structure).

Statistical Analysis of Survey Results

The survey results from courses using traditional writing pedagogy were pooled and compared with the results from courses using the integrated pedagogy. All statistical tests were performed with the JMP IN statistical package (SAS Institute, Cary, North Carolina; Sall et al., 2005). Each data set was tested for a normal distribution using the Kolmogorov test.

○ Results

Students who understood the scientific content performed better on the lab-report assignment

We designed our pedagogical approach to give students feedback on their comprehension of the laboratory investigation before they

Table 1. Student survey responses with significant differences between courses.

Question	Traditional[a]	Integrated[a]	t-test[b]	χ^2 test[c]
Instructions were (A) clear OR (B) not clear	4.00 ± 1.51	3.17 ± 1.52	p = 0.02	p = 0.01
The structure of the writing assignment provides (A) a strong OR (B) a weak incentive to write well	2.77 ± 1.48	1.90 ± 1.14	p = 0.01	p = 0.004

[a] Likert score of 1 = Only A; 7 = Only B; 4 = Equally A and B; 8 = Neither A nor B. After removing no. 8 responses, means and standard deviations within a group were calculated for each question.

[b] After removing no. 8 ("Neither A nor B") responses, a Student's t-test was conducted for each question.

[c] A chi-square test was conducted for each question using all non-zero values.

prepared the formal lab report. The decision-making process of choosing which lab reports to attempt seems to help students consider carefully their depth of knowledge about the content of each lab. Empowering students with the capacity to choose which assignments to complete may also increase their motivation to succeed (Katz & Assor, 2007).

We first analyzed the relationship between a student's performance on the content-question assignments and the decision to submit a lab report. Students who received a green or yellow light on the content questions submitted a lab report much more frequently (15/24 and 21/37 opportunities, respectively) than those who received a red light (2/11 opportunities). Students were apparently considering whether to direct their efforts toward preparing a report or toward better understanding the next lab investigation.

Examining the relationship between content-question scores and report quality, we found that students who received a green light on the content questions were more successful (8/15) than those who received a yellow (6/21) or red light (0/2). These results are consistent with previous reports of improved writing performance by students who possess better knowledge about their topic (Kellogg, 1987, 2001). These data also suggest that almost a quarter of the students who scored poorly on the content questions (receiving a yellow or red light) were able to review their assignments sufficiently well to attain the knowledge necessary to write a successful lab report.

More students wrote high-quality lab reports using the integrated pedagogical approach

We next asked whether our integrated pedagogical approach improved the student success rate of writing a high-quality lab report, as compared to introductory biology courses using the traditional approach of multiple, graded assignments. We based our benchmark for high-quality writing on our own teaching experience: in general, students who wrote one or more introductory biology lab reports, earning a grade of B+ or higher, were ready for the types of assignments required in our upper-level courses.

As a preliminary study, we compared the lab-report success rate of students taught with the integrated approach to that of students taught using the traditional approach (either previous offerings of the same introductory cell biology course taught by the same instructors or concurrent offerings of other introductory biology courses taught by different instructors). When we taught with the integrated approach, typically over half of our students wrote a high-quality lab report (57 ± 20%; n = 3 classes; n = 85 students). By contrast, in courses that used the traditional approach, only about a third of the students demonstrated this level of writing competency on at least one report (33 ± 8%; n = 4 classes; n = 205 students). Although these preliminary data are not controlled for differences among the student participants or the grading instruments used between the study groups (and additional controlled studies are necessary), they suggest that the integrated strategy increases the portion of students able to prepare a high-quality lab report, compared with the traditional approach. This pilot study indicates that the multipronged approach merits a more rigorous examination to confirm its effectiveness.

Many students wrote a high-quality lab report only after multiple attempts

With both approaches, nearly one-third of the students wrote a high-quality report on the first attempt (integrated, 31%; traditional, 32%), and we speculate that these students would be successful writers in either environment. Of more interest are those students who completed two or more lab reports (39/85). Over half of these students wrote a high-quality report on their second or third attempt in courses that used the integrated approach (22/39). By contrast, the overall success rate with the traditional approach (33%) was relatively unchanged from the initial success rate (32%), which indicates that fewer students advanced to become competent writers using the traditional approach.

Students' self-reported motivation was higher in the all-or-nothing grading format

We next explored what might be contributing to the improved success rate with the integrated pedagogical approach. Anecdotal conversations with our students suggested that many were more motivated to give their best effort with the all-or-nothing grading system. We decided to assess this by adapting a self-reporting survey of students' attitudes toward writing (Field-tested Learning Assessment Guide; http://www.flaguide.org/), which our students completed anonymously at the end of the course.

The large majority of questions elicited a similar range of responses in the two groups, suggesting that the students came into both types of courses with similar attitudes about writing. In particular, both groups of students reported a similar understanding of the mechanics and purpose of lab reports and possessed similar attitudes regarding grades and assignments (data not shown).

Several survey questions, however, elicited significantly different responses between the two groups (Table 1). Of particular interest is that the students instructed with the integrated writing approach reported a notably stronger incentive to write well because of the assignment structure. Interestingly, even students in the traditionally graded courses indicated that the all-or-nothing grading system seemed more motivating (although there were a large number of non-responses in the control group, probably from students unfamiliar with the alternative approach; data not shown).

○ Discussion

What motivated more students to write successfully using the integrated format?

Our preliminary data indicated that, using this integrated pedagogical approach, we achieved a higher rate of student success in reaching our threshold for a high-quality lab report and increased the students' motivation, as compared to classes using a traditional approach of multiple, graded assignments. Previous work has indicated that low motivation in a subject is correlated with a lack of achievement, so this association was not surprising (Fass & Schumacher, 1978; Ainley, 2006).

But why were more students motivated to write well using the integrated format? Were they more strongly motivated because of the potential reward of writing fewer papers? Or were they responding to the potential penalty of receiving no credit if they failed to demonstrate writing competency? Ideally, we would focus on the attitudes of those students who failed in their initial attempt and later succeeded; however, because the survey was completed anonymously, we were unable to identify the surveys completed by the successful students. Nevertheless, we can speculate about possible causes. If the students were responding to the positive incentive of the grading system, we would expect the first-attempt success rate in the all-or-nothing system to exceed the same rate in the traditionally structured courses. However, as noted above, we saw similar success rates on the first attempt for both groups of students.

Many students, therefore, seem to be responding more to the potential negative consequences. For such students, the fear of receiving no credit for a major assignment apparently prompts them to prepare subsequent papers more seriously, for example by carefully reading the writing manual or responding to the instructor's comments. It is also possible that we were better able to target our advice to those students who would most benefit from it. Anecdotally, we observed that students were more likely to discuss the previously reviewed lab report with an instructor to learn how they could improve their writing. In addition, their questions were generally more specific and designed to make sure that they had a clear understanding of relevant concepts.

Limitations of This Pilot Study

This preliminary work suggests that our multipronged strategy for developing scientific writing in an introductory biology course improves the student success rate in writing a high-quality lab report and increases students' motivation to write well. However, it is important to note that further research is necessary to confirm our findings. In particular, we note that this pilot study did not take additional measures to ensure inter-rater reliability, though the faculty consulted one another throughout the grading process. In addition, for ethical and curricular reasons, students were not randomly assigned to treatment groups. Nonetheless, our preliminary results suggest that a more careful and complete study of the role of motivation in student performance in the classroom is warranted.

Implementation of the Integrated Approach in Your Classroom

Our multipronged approach rewards students by using an all-or-nothing grading system, provides prompt feedback regarding student comprehension, and provides prioritized feedback on unsuccessful attempts. However, are all of the components of our approach necessary?

With regard to the grading system, one might argue that since students seem to be responding to the potential penalty of no credit on a major assignment, perhaps the positive incentive could be dropped, so that students gain more practice writing lab reports. However, even for those students who don't succeed on their first attempt, we believe that the potential reward of fewer assignments functions as an enticement that encourages students to embrace this novel grading system and ultimately draws them into meaningful writing experiences. The use of rewards to influence learning has been controversial, but there seems to be agreement that rewards can increase motivation for students engaged in undesirable tasks (Frase, 1971; Cameron & Pierce, 1996; Deci et al., 1999; Cameron et al., 2005).

Similarly, we consider the content questions and prioritized feedback to play essential roles in the improved success rates seen with the integrated system. The content questions are a valuable pre-writing experience that prompts students to engage the relevant content prior to drafting a formal report. Just as importantly, evaluation of the responses provides valuable feedback on the student's level of understanding. If it is insufficient, the student can relearn the content before preparing the report or instead choose to forgo that writing opportunity and focus on the next laboratory investigation. This may be a key element in that it provides a clear indication to the students of their understanding of the material before they begin to write, providing the incentive and time to improve understanding before writing the lab report.

Finally, the prioritized-feedback feature of the integrated system plays multiple roles. By focusing only on the most significant issues, it doesn't overwhelm the struggling student with a surfeit of critical comments (Walvoord & Anderson, 1998). Rather, sufficient guidance is provided for students to improve their writing incrementally and methodically.

Halting the review process when the report first fails to meet the quality threshold plays two important roles. First, it prompts the students to give their best efforts early on, since the depth and value of the critique directly reflects the quality of the submission. Second, the prioritized feedback assists the instructor in time management while grading, by limiting the quantity of feedback to that which will be most valuable to the developing writer.

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