Writing As a Tool for Learning Biology
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# Writing as a tool for learning biology

Few skills are more important to biologists than effective writing (Enke 1978, Moore 1992b, 1993). For example, biotechnology companies rank communication skills (e.g., writing) as the second most important quality in prospective employees; these skills rank only slightly behind relevant work experience, and they rank far ahead of other factors such as chemistry background, a degree from a recognized program, grade-point average, personal recommendations, and highly focused biological expertise (Davis et al. 1989). Improving one's writing skills greatly enhances one's prospects for employment in science (Kelly 1992, Pollack and Godwin 1983) and other professions (Moore 1992a, b).

Inadequate writing can slow or prevent publication of scientific research. According to an editor of *Evolution*, for example, poor writing is almost as frequent a reason for rejecting a manuscript as is flawed experimental design or analysis; nearly 50% of rejected papers are so poorly written that reviewers and editors cannot understand the experimental design, analysis, or interpretation (Endler 1992). My informal survey of editors of other biological journals suggests that this percentage is typical.

A scientist's ability to write about science greatly influences others' opinions of his or her credibility as a scientist (Moore 1992a, 1992b, and references therein). Truth in science is the product of argument and persuasion, which, in turn, are created with language. Because most persuasion occurs through the literature, people who cannot write effectively can seldom do science effectively.

by Randy Moore

In light of the importance of writing in science, it is not surprising that our constituents—the people who pay our salaries and hire our students—expect our students to be able to write well. Unfortunately, most students cannot do so (Healy 1992, Rosato 1992). Only 12% of all employers think that high school graduates write well. For comparison, 22% of employers think that these students understand math well (Landis 1991). The much publicized crisis in math literacy pales when compared to students' inability to write effectively (Kelly 1992).

In addition to the consequences of not being able to communicate well in writing, effective writing is a means of thinking clearly. The first step in writing is discovering ideas. Then the writer uses paper and pencil, or computer screen and keyboard, to think through the ideas, with each sentence written suggesting yet others. By writing about biology, students can deepen their understanding of the subject far more than they do by studying for multiple-choice exams.

Students' inability to write effectively is a great handicap. What has caused this problem? More importantly, what can biologists do to help solve it?

## Grades K–12: Where the problem starts

Throughout their elementary and high school education, students progressively learn to dislike writing (Tables 1 and 2). Writing assignments in most secondary schools are mechanical and trivial; for example, only 3% of these assignments require students to write more than one paragraph (Applebee 1981, Ordovensky 1991). Consequently, we should not be surprised that high school graduates write poorly (Anonymous 1987, Douglas 1993).

Although 59–65% of high school students can do an adequate job of informative writing (i.e., describing what has occurred), only 7–25% of students can do an adequate job of analytical writing (i.e., describing why something has occurred; Anonymous 1987). This statistic is troubling because analytical writing—being able to provide evidence, reason well, and build an argument—is important for a successful career in science and most other professions. In addition, fewer than one-third of students can do an adequate job of persuasive writing (i.e., presenting evidence to support conclusions; Anonymous 1987). This result is disturbing because those students unable to construct an effective argument are handicapped throughout their academic and scientific careers.

Less than 25% of high school students can write adequately on tasks involving skills required for success in business, academia, or other professions (Anonymous 1987, Kelly 1992). This inadequacy helps explain why college students write so poorly and why employers have trouble finding employees who can write well.

According to a survey, secondary school teachers of science, more than teachers of any other subject, use writing to test mastery of a subject rather than as a tool to learn the subject (Applebee 1981). Moreover, most high school students are neither taught nor learn strategies for effective writing, and most teachers assign writing exercises for no purpose other than practicing the students' poor writing. This method of teaching is unfortunate, because students who learn strategies for effective writing write better than do students who lack such strategies (Moore 1992a, b, 1993).

## College: Where the problem worsens

High school graduates write poorly and dislike writing (Anonymous 1987, Dodge 1991). The writing ability of most of these students does not improve appreciably during college. Ironically, English teachers are often a student's biggest obstacle in learning to write well. Many English teachers strongly encourage students to write poorly by giving better grades to complex, indirect, wordy, and inflated writing than to simple, direct, concise, and understandable writing (Hake and Williams 1981 and references therein). By so doing, these teachers encourage what they claim to deplore, and they discourage what they claim to admire. Such experiences also explain why some students emerge from a university worse writers than when they began (Douglas 1993).

Many biology teachers do not require students to write anything. They prefer instead to use "objective" (e.g., true-false or multiple-choice) exams. Although such exams are more easily graded, thereby freeing the teacher for other activities, the instructors are ignoring the power of writing as a tool for thinking about, understanding, and communicating ideas in biology. In addition, a lack of writing assignments and exams sends two strong messages to students. The first is that writing is irrelevant to biology. The second message is that, despite claims to the contrary, writing is not part of a general education, not important for a successful career, and not related to learning.

When biologists do assign written work they often try to focus on content rather than style and, in doing so, they choose to overlook what they consider to be trivial errors in students' writing (Moore 1992a). However, the types of errors ignored often turn out to be important to persons having the power to affect students' lives, such as their potential employers and supervisors (Hairston 1981, Mackay 1992, Moore 1992a).

Furthermore, when biologists do pay attention to writing, many of them stress—and even insist upon—a writing style that they believe is unique to their discipline. They say, "This is how biologists write." Such instruction about so-called scientific writing usually encourages the excessive use of passive voice, jargon, and wordiness, all of which impede communication and further diminish the quality of students' writing, thinking, and learning (Moore 1992a, b). Moreover, even if such a style is commonly used by biologists, teaching it to college students is questionable because only a minority of them (only 27% of biology majors) are likely to get jobs that are closely related to biology (Graham and Cockriel 1990).

Most well-meaning biologists who do assign a variety of writing tasks do not teach students how to use writing as a tool for learning. Even scientific writing courses are based on misconceptions (Moore 1992b). Consequently, most writing assignments do little more than force students to practice, even perfect, their poor writing (Moore 1993).

Students often want to write well, but they do not know how and become frustrated. Consequently, most students dislike writing and do not use writing to learn biology (Moore 1993).

**Table 1.** Students' attitudes about writing (Educational Testing Service 1988). Values given are percentage of students reporting the statement true or answering the question with yes.

| Statements about writing | Grades 4 | 8 | 11 |
|---|---|---|---|
| I like to write. | 57.0 | 41.2 | 39.4 |
| I am a good writer. | 57.8 | 42.1 | 40.7 |
| People like what I write. | 53.2 | 36.5 | 36.7 |
| I write on my own outside of school. | 48.2 | 35.4 | 28.8 |
| I don't like to write things that will be graded. | 36.0 | 31.7 | 30.4 |
| Did you like writing the last thing you wrote for school? | 67.4 | 57.5 | 53.6 |

## Writing-across-the-curriculum

To improve students' abilities to write and think, many colleges and universities have implemented writing-across-the-curriculum, a program that incorporates writing into courses other than freshman composition. This program's popularity results from claims that people inevitably learn about a subject as they write about it; that is, that the process of writing leads to truths (Berthoff 1982, Griffin 1983, Raimes 1980).

Although writing-across-the-curriculum programs require students to write essays and papers, they seldom teach students how to write effectively. Moreover, there is little quantitative evidence that the claims of the program's supporters apply to learning biology. Indeed, anecdotal evidence of the success of writing-across-the-curriculum in science is matched by anecdotal evidence of its failure (Braine 1990, Liss and Hanson 1993, Morgan 1987, Sorenson 1991, Young 1985). For example, Liss and Hanson (1993) report that biology students did not benefit from writing assignments, despite the fact that students were given general feedback as to the nature of their writing errors. Others claim that journal writing—a common ingredient of writing-across-the-curriculum programs—does not appreciably improve science students' writing skills or their understanding of the subject (Hoff 1992, Labianca and Reeves 1985, Linden and Whimbey 1990). Merely writing about sciences does not necessarily ensure that students learn science, learn to write more effectively, learn to use writing as a tool to learn, or appreciate the importance of writing for success as a professional (Moore 1993).

## How biologists can improve students' writing

Although most biologists do little to help students learn to write effectively, we nevertheless bemoan their poor, ineffective writing. Amidst our complaining, we pass students

through our courses, hoping they will somehow outgrow their poor writing. Most students do not.

Guided instruction can significantly enhance students' abilities to learn biology and write effectively (Moore 1993). This instruction assigns more reading of well-written work on biology, and it focuses on how to write effectively, instead of merely correctly.

**Incorporating more reading into courses.** The declining abilities of students to write effectively correlates with their reduced interest in reading. Indeed, from 1968 to 1990, the number of students who checked out even one book or journal from their high school library dropped by 40%, and the number who had done any outside reading for any course declined by almost 25% (Dodge 1991). Moreover, typical college-bound seniors—even those in advanced placement courses—read fewer than ten pages per day (Ribadeneira 1992), an amount significantly less than that of only two years ago (Anonymous 1992, Foertsch 1992). Similarly, more than 30% do not read for fun (Anonymous 1992, Foertsch 1992). Some students are not asked to read even one book during their senior year of high school (Ribadeneira 1992).

Students who are better readers are usually better writers. Therefore, it is disturbing that most students read so little, both in and out of school. Students will probably not learn to write better until they read more.

An excellent way to improve both the students' writing and their understanding of biology is to incorporate more reading in courses. Just as a child with a hearing defect has problems learning to speak, so too does a student who does not read have problems in writing.

Unfortunately, most biology teachers restrict their reading assignments to textbooks, many of which are little more than compilations of facts and definitions. Because these textbooks are meant to be studied rather than read, it is hardly surprising that most students find them boring. Moreover, few textbooks show how science or scientists work, how scientific knowledge has been interpreted by great thinkers, how people use biology, and how current knowledge depends on giants of biology's past (Carter and Mayer 1988).

**Table 2.** Students' attitudes about the importance of writing (Educational Testing Service 1988). Values given are percentage of students reporting the statements true.

| Statements about writing | Grades 4 | 8 | 11 |
|---|---|---|---|
| Writing is important. | 78.6 | 72.6 | 69.2 |
| Writing helps me learn about myself. | 53.6 | 44.6 | 49.5 |
| Writing helps me study. | 74.0 | 71.5 | 65.9 |
| Writing helps me come up with new ideas. | 69.6 | 61.7 | 59.9 |
| Writing helps me think more clearly. | 56.1 | 44.0 | 51.2 |
| Writing helps me understand my own feelings. | 54.4 | 43.3 | 48.4 |
| Writing can help me get a good job. | 46.0 | 50.7 | 57.3 |
| Writing helps me show people I know something. | 68.4 | 61.5 | 62.5 |
| People who write well have a better chance of getting good jobs. | 53.8 | 45.7 | 56.1 |
| People who write well are more influential. | 51.0 | 47.4 | 56.4 |

Many popular books describe biology and biologists better than do textbooks. Thus, we can improve students' writing skills and understanding of biology by insisting that they read books that classical and modern biologists wrote for the general public. To help biologists choose books for use in the classroom, Carter and Mayer (1988) published a list of 22 books that "every biologist should read." Topping this list was James Watson's controversial *The Double Helix*; subsequent entries included Charles Darwin's influential *The Origin of Species*, Lewis Thomas' entertaining *Lives of a Cell*, Rachel Carson's emotional *Silent Spring*, Thomas Kuhn's philosophical *The Structure of Scientific Revolutions*, and Paul Ehrlich's prophetic *The Population Bomb*. We should tell students not to be afraid to model their writing after that of their favorite writers. After all, Bach and Picasso used models, and biology students will benefit by studying the works of great biologists.

**Teaching effective instead of correct writing.** Many biologists equate effective writing with correct writing—that is, writing that breaks none of the sacrosanct commandments that the biologists remember from their composition classes (e.g., "Never split an infinitive."). To appreciate the failure of this approach, quickly read the essays in the box and then consider your impressions of the quality of each writer as a biologist.

Both of these essays use the same technical words and present the same information in the same order. Both essays are also correct—they differ only in their use of language. Smith's essay is more informative and easier to read because it uses familiar words, avoids inflated phrases, and uses shorter, more forceful sentences. Conversely, Brown's essay is harder to read because it contains big words, long sentences, and complex constructions.

These differences in writing style strongly affect biologists: almost 70% of the 1580 scientists who read these essays judged Smith's essay to be more interesting, stimulating, credible, and impressive than Brown's essay (Bardell 1978, Turk 1978, Turk and Kirkman 1989, Wales 1979). Readers also judged Smith to be more dynamic, helpful, and intelligent than Brown. Moreover, when asked to judge Smith's and Brown's competence—specifically, which biologist seemed to have a better-organized mind—almost 80% chose Smith. The message here is as unmistakable as it is important: although both essays are correct, only Smith's is effective.

## Teaching writing as a tool to learn biology

A well-designed course can greatly enhance students' ability to use writing as a tool to learn biology (Moore 1993). Such a course might begin with a discussion of what is effective writing and why is it important?

## Brown's essay

In the first experiment of the series using mice it was discovered that total removal of the adrenal glands effects reduction of aggressiveness and that aggressiveness in adrenalectomized mice is restorable to the level of intact mice by treatment with corticosterone. These results point to the indispensability of the adrenals for the full expression of aggression. Nevertheless, since adrenalectomy is followed by an increase in the release of adrenocorticotrophic hormone (ACTH), and since ACTH has been reported to decrease the aggressiveness of intact mice, it is possible that the effects of adrenalectomy on aggressiveness are a function of the concurrent increased levels of ACTH. However, high levels of ACTH, in addition to causing increases in glucocorticoids (which possibly account for the depression of aggression in intact mice by ACTH), also result in decreased androgen levels. In view of the fact that animals with low androgen levels are characterized by decreased aggressiveness the possibility exists that adrenalectomy, rather than affecting aggression directly, has the effect of reducing aggressiveness by producing an ACTH-mediated condition of decreased androgen levels.

## Smith's essay

The first experiment in our series with mice showed that the total removal of the adrenal glands reduces aggressiveness. Moreover, when treated with corticosterone, mice that had their adrenals taken out become as aggressive as intact animals again. These findings suggest that the adrenals are necessary for animals to show full aggressiveness.

But removal of the adrenals raises the level of adrenocorticotrophic hormone (ACTH), and ACTH lowers the aggressiveness of intact mice. Thus the reduction of aggressiveness after this operation might be due to the higher levels of ACTH which accompany it.

However, high levels of ACTH cause the levels of glucocorticoids to rise, and the levels of androgen to fall. Since animals with lower levels of androgen are less aggressive, it is possible that removal of the adrenals reduces aggressiveness only indirectly: by raising the levels of ACTH it causes androgen levels to drop.

Students are much more likely to learn about writing if they see its relevance and importance to their careers.

The instructor should then advise students on the best way to prepare a first draft of a paper. He or she should demonstrate techniques that can help students get their ideas onto paper and show the students that writing is a powerful tool for discovering information as well as for organizing and communicating it.

Next the course should focus on revising a manuscript as a means of rethinking the ideas presented. In this effort, the students should concentrate on writing to communicate. The ability to revise a paper is critical to producing an effective work. Revisions are not merely corrections of mistakes; rather, they underlie the writer's ability to meet readers' expectations. In the process, skillful revisions produce clear, precise, coherent, and concise writing.

Students should also consider how to write for different audiences. Biologists address a wide variety of audiences, including peers, students, funding agencies, and the general public. Each audience requires a different approach to writing. The use of supporting features—such as photographs, line-art, and statistical tests—that are appropriate to a given audience can greatly improve a paper and promote learning about biology.

All of these topics focus on an understanding of writing rather than a memorization of rules. Such an understanding helps students not only to know what is wrong with their writing, but also shows them the choices available for improving their writing and enhancing their learning.

I have previously published more detailed suggestions for organizing and teaching a course that instructs teachers and students how to use writing to learn biology (e.g., handling the paperwork, the importance of effective assignments, grading, and informal and collaborative writing; Moore 1992b, 1994). Such a course can enhance students' understanding of biology and their ability to write effectively (Moore 1993).

## Conclusions

Writing is important for success in any profession, especially biology. Therefore, we must teach students to write effectively. If we fail at this task, we handicap our students, fail the people who pay our salaries and hire our students, and ignore the needs of our profession.

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