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Sounder Thinking Through Clearer Writing

A graduate course on scientific writing can, if appropriately designed, strengthen scientific thinking.

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In the linked worlds of experimental science, scientific editing, and science communication many scientists are considering just how serious an effect the bad writing in our journals will have on the future of science.

All are agreed that the articles in our journals—even the journals with the highest standards—are, by and large, poorly written. Some of the worst are produced by the kind of author who consciously pretends to a "scientific scholarly" style. He takes what should be lively, inspiring, and beautiful and, in an attempt to make it seem dignified, chokes it to death with stately abstract nouns; next, in the name of scientific impartiality, he fits it with a complete set of passive constructions to drain away any remaining life's blood or excitement; then he embalms the remains in molasses of polysyllable, wraps the corpse in an impenetrable veil of vogue words, and buries the stiff old mummy with much pomp and circumstance in the most distinguished journal that will take it. Considered either as a piece of scholarly work or as a vehicle of communication, the product is appalling. The question is, Does it matter?

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Does the Standard of Writing Matter?

Some editors believe it does, and either work themselves into the ground or employ large staffs to set the writing right. Others regard the correction of an illogical or pompous sentence as tantamount to remodeling the author's thinking, and consequently none of their business. The majority conclude that, if a paper represents sound work and is reasonably intelligible, no lasting damage is done if it is published complete with all its blemishes. The blemishes may include ungrammatical constructions, confused thought, ambiguity, unjustifiable interpretation, subspecialty jargon, concealed hedging, inadequate description of statistical treatment, or imperfect controls.

I disagree with the majority conclusion. I am amazed by the patience with which my colleagues read these blemished scientific articles. I think that the spirit in which articles are often written, in which the object seems to be to impress the reader rather than express an idea, is all wrong. I think that we should protest vigorously about poor writing in scientific articles when it occurs, and *not* be indulgent about it. And I think we should take steps to ensure that the standard of scientific writing goes up. I feel strongly enough about it to teach a course on the Principles of Scientific Writing for graduate students, in the hope that when they come to contribute to the literature they will do a better job than we, the scientists of today, seem to have done.

Sometimes a skeptic will ask me, "Do you really think it's so important to improve scientific writing? We know it's usually a bit on the pompous side, but once you get used to the conventions you can zip through it pretty easily and get to the author's meaning." Personally, I *don't* find it so easy to zip through the pretentious constructions, and I think that one all too frequently arrives at a meaning that was not intended. But more telling than either of these reasons for concern is this: I have definite and clear-cut evidence that the scientific writing in our journals exerts a corrupting influence on young scientists—on their writing, their reading, and their thinking.

Decline of Writing, Reading, and Thinking

When science students enter graduate school they often write with admirable directness and clarity of purpose, like this:

> In order to determine the molecular size and shape of A and B, I measured their sedimentation and diffusion constants. The results are given in Table 1. They show that A is a roughly spherical molecule of molecular weight 36,000. The molecular weight of B remains uncertain since the sample seems to be impure. This is being further investigated.

Two years later, these same students' writing is verbose, pompous, full of fashionable circumlocutions as well as dangling constructions, and painfully polysyllabic, like this:

> In order to evaluate the possible significance of certain molecular parameters at the subcellular level, and to shed light on the conceivable role of structural configuration in spatial relationships of intracellular macromolecules, an integrated approach [see *1*] to the problem of cell diffusivity has been devised and developed. The results, which are in a preliminary stage, are discussed here in some detail

because of their possible implication in mechanisms of diffusivity in a wider sphere.

The student can no longer write: he pontificates.

What has brought about the change? Clearly, the students have copied these dreary and pretentious phrases from the scientific literature. They have been dutifully studying it, as they are urged to do, and it has warped their style to the point that they can no longer walk to the door without "utilizing a pedestrian relocation," or sip their coffee without "prior elevation of the containing vessel to facilitate imbibition."

Concomitantly, something drastic happens to their powers of reading. As one of the assignments in my course, my students had to write an abstract of a published paper. The paper itself was brief, simple, and well written. I was dismayed to find that at least half of my students misread the paper in three major ways. First, they referred to 20-day-old rats, although the age of the animals was never given—the article described 20-gram rats; second, they talked about specific activity of the cholesterol injected, whereas the specific activity was never stated—the figure they had got hold of was actually the number of millicuries injected per kilogram of rat body weight, and they had misread it as mc/mg; last, and most amazing of all, they gave conclusions *directly opposite* to those indicated both by the data and by the authors of the article they were abstracting!

Now these students are by no means numskulls—they are like the rest of us, busy scientists zipping quickly through the literature to get to the authors' meaning. This is where the habit of guesswork leads.

Worst of all, there is a deterioration in the quality of students' *thinking* as they study the scientific literature. In a survey paper by one of my best students, everything was going along nicely, and everybody's head was clear, until we fell into the mire of this sentence:

> A variety of stimulatory hormones, irrespective of their chemical nature, are characterized by their ability to influence the synthesis of messenger RNA as a prerequisite for the secondary biologic events characteristic of the particular target organ.

"What on earth do you mean by that?" I asked. He blushed, and said, "Actually it's a quotation, I forgot to put in the quotation marks." "Well, but what do you suppose it means, anyway?" He couldn't be absolutely sure. It seemed to clinch his argument, and it *sounded impressive.* And when he told me the name of the journal it came from, my spirits sank. How can we hope to have our students think straight if we can't send them to the most celebrated journal in the country without cautioning them about the woolly thinking they will find there? For I cannot be tolerant, as some people are, and say, "Well, great scientists often write badly." You can't get away from it: execrable writing like this is the product of shoddy thinking, of careless condescension, or of pretentiousness. None of these is good for science.

Bringing about Improvement

These, then, are the negative effects of the scientific literature I have observed in the course of teaching scientific writing. I am glad to say that there are also definite positive findings. The most striking observation is that by teaching writing you can actually strengthen students' ability not only to write but also to read more attentively and to think more logically and rigorously.

It is surely no accident that greater lucidity and accuracy in thinking should result from the study of clarity and precision in writing. For writing necessarily uses *words*, and almost all thinking is done with words. One cannot even decide what to have for dinner, or whether to cross town by bus or taxi, without expressing the alternatives to oneself in words. My experience is, and the point of my whole course is, that the discipline of marshaling words into formal sentences, writing them down, and examining the written statement is bound to clarify thought. Once ideas have been written down, they can be analyzed critically and dispassionately; they can be examined at another time, in another mood, by another expert. Thoughts can therefore be developed, and if they are not precise at the first written formulation, they can be made so at a second attempt.

The power of writing as an aid in thinking is not often appreciated. Everyone knows that someone who writes successfully gets his thoughts completely in order before he publishes. But it is seldom pointed out that the very act of writing can help to clarify thinking. Put down woolly thoughts on paper, and their woolliness is immediately exposed. If students come to realize this, they will write willingly and frequently at all stages of their work, instead of relegating "writing up" to the very end and regarding it as a dreadful chore that has very little to do with their "real" work.

In teaching scientific writing it is not difficult to point out the absurdity of the bombastic phraseology discussed above, and to teach students to simplify their writing and make it direct and vigorous. But these stylistic considerations only scratch the surface of what is really at fault in many scientific articles. I am appalled by the frequent publication of papers that describe most minutely what experiments were done, and how, but with no hint of why, or what they mean. Cast thy data upon the waters, the authors seem to think, and they will come back interpreted.

If this approach to publication is to be successfully thwarted by a course on scientific writing, the course should concentrate primarily on clarifying the students' thoughts about the purpose of a piece of research, the conclusions that can justifiably be drawn, and the significance of those conclusions; matters of style are of subsidiary importance. The course should focus on a method for getting these thoughts fully worked out—the technique of writing them down for critical appraisal. The essence of the approach is: Writing clarifies thought.

Considerations in a Scientific Writing Course

A course on scientific writing is best given, perhaps, within the framework of writing a journal article—for the practical reason that students are familiar with this type of publication and know that they will have to produce journal articles in the course of their work. The most receptive students are those who have done some research and who are therefore psychologically ready to consider how they can best present it in a journal.

These are the kinds of question that should be considered:

"In the work to be described, what was the question asked and what are the answers obtained?" These must be clearly placed before the reader. Students, with their recent results in mind, can often tell you what their *answers* are, but they are not always so sure

of what the *question* was. Here is the first opportunity to test the hypothesis that writing clarifies thought. When they write down the questions asked and the answers obtained, students frequently come to see that the answers they have are to questions different from what they had thought. Fortunately, the questions to which they do have the answers are usually valid and important, but the difference from the previous state of affairs is that each student is now able to define the true subject of the paper he is about to write. He will not confuse his readers, or himself, with a paper that does not match its title; on the contrary, he can now commit a fitting title to paper and keep closely to the subject it defines through all the subsequent steps, without wandering off into irrelevancies. In addition, he often perceives what the questions are that he would now *like* to ask, and begins to design experiments to answer them. Writing has clarified thought.

The next questions are, "What was the purpose of the work, and what is the significance of the conclusions?" Purpose and significance should always be stated for the reader. At this point, surprisingly, a storm of protest arises. "The work is descriptive!" the students cry. "The reader who is knowledgeable in the field will grasp the purpose, and draw his own conclusions." They seem to think that in research you don't need to have a clear purpose, or to state the conclusions drawn from your frantic activity; that the technique of Science is to mix A and B, inject C into rats, heat it up, precipitate it, centrifuge it, analyze it—and hope against hope that the results will throw light on some "problem" that has not even been defined. And it's not only raw students who think this: examination of the literature reveals that the attitude is widespread. When, however, the students are made to put the problem *in writing* they see why they did the experiments—and why, perhaps, others would have been more to the point. Their probing into the unknown becomes less haphazard, because it is more disciplined.

Any supervisor of research tries to apply this kind of training, of course. All I would like to do is to systematize the training, and to get writing accepted as a regular part of the apparatus for self-criticism.

Other considerations in a course on scientific writing (*2*) include methods for separating main issues from side issues and side issues from irrelevancies; the function of publication; methods of search; the nature of scientific proof—essentially, in one guise or another, most of the aspects of scientific method. Lastly, toward the end of such a course, students can be taught to recognize and avoid the sort of clumsy and barbaric sentence constructions with which our literature is strewn. All these points should be made in the name of three things that the budding scientist is bound to have respect for: logic, clarity of thought, and precision.

The process of educating scientists is becoming increasingly complex. The student has to learn more and more facts, study exceedingly complex theories that are out of date before he can master them, and become adept at using more and more machines. We seldom make him, or even let him, write—which is the only way for him to find out if his thoughts are clear or muddled. Surely, the object of a university training is not so much the acquisition of knowledge as the development of the power to think. I believe we can strengthen scientific thinking by teaching scientific writing. If this is so, the teaching of scientific writing should not be, as it is at present, almost entirely neglected, but should be accorded a place at the very heart of a science curriculum.

Much attention is currently being paid to the streamlining and automation of information retrieval and the possible use of computers not merely to compile bibliographies but to enable scientists seated at widely separated consoles to engage in "dialogues." In view of all this it seems, perhaps, slightly old-fashioned to be concerned with precise formulation of thought in written language, composed without haste and considered with care. Yet I am convinced that unless we do concern ourselves with it, unless we do train our students to use the technique of writing to clarify thinking, communication between scientists will degenerate into chaos and scientific thinking will decay into a haze of fruitless intuitive feeling.

Summary

Bad scientific writing involves more than stylistic inelegance: it is often the outward and visible form of an inward confusion of thought. The scientific literature at its present standard distorts rather than forms the graduate student's view of scientific knowledge and thought, and corrupts his ability to write, to read, and to think.

Strong educational measures are needed to effect reform. I advocate a course on scientific writing as an essential feature in every scientist's training. Such a course delves deep into the philosophy and method of science if it deals with logic, precision, and clarity; on how these qualities can be achieved in writing; and on how such achievement strengthens the corresponding faculties in thinking.

References and Notes

1. Whenever an "integrated approach" is mentioned (why anyone should use a disintegrated approach passes all comprehension), the reader should steel himself for other tidbits of Fashionable Foundationese: "constellation of ideas," "sophisticated balance of experimentation and ideational material," "man-machine interface."
2. Council of Biology Editors' Committee on Graduate Training in Scientific Writing, "Manual on the Teaching of Scientific Writing," in preparation.