To Teach Scientific Writing

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Capsule Summary

A science-writing workshop initiates in graduate students the notion of thinking like a writer and thus the development of a conscious writing process.

Abstract

We describe the principles behind and practical implementation of a science-writing workshop that we conduct annually for graduate students in the geosciences. Our approach rests on two principles. First, good science writing is defined by being clear, and there are well-established and teachable techniques of writing clearly. During the workshop, these techniques are applied to draft research papers submitted by the participants. Second, we articulate the fundamental writing problem of scientists, which is that they do not develop a conscious writing process because they do not think of themselves as writers. The writing process covers every step from the early, unconstrained collection of ideas for a research paper to the final scrutiny ensuring that every sentence, every word, and every piece of punctuation serve its purpose. Our workshop aims at initiating in the students the development of such a conscious writing process. This essay provides a blueprint for conducting science-writing workshops based on the two principles enunciated here.

Introduction

Scientists, in order to practice their profession, must write. Therefore, we expect our graduate students to write. We expect students who may not have written anything at all in English to publish professional-quality papers in peer-reviewed journals. But while we assiduously teach the practice of scientific research, we do not address in a purposeful way the basic writing techniques and principles that would help our students communicate their research—even though, as scientists, we recognize that research and the written communication of it are inextricably braided (e.g., Montgomery 2003, Schultz 2009). Why do we teach the one and largely ignore the other?

One reason, the two of us believe, is that few scientists—and fewer of their graduate students—think of writing technical papers as actual writing or of themselves as writers. Generations of scientists have learned to write papers by imitating their advisors and other senior scientists. But this leaves the inexperienced graduate student without foundation principles to formulate the logic of a research paper and to express that logic in clear, crisp prose. And it leaves the student's advisor, who recognizes that the problem in the student's paper is not the quality of the research but the clarity of the communication, in the unenviable position of being de facto a writing teacher who has learned only from experience. To help students attain clarity is the objective of a science-writing workshop that we conduct annually for the graduate students at the Max Planck Institute for Meteorology (MPI-M).

The workshop originated from a chance meeting in 2006, during which Marotzke brought up the need, as he had perceived it, to teach writing to his students. Murphy suggested the workshop format. He had conducted his own fiction-writing workshop in New York for a decade, but to our knowledge, there were no readily available models of science-writing workshops. A few writing workshops do exist (though not necessarily in the natural sciences; see, for example, Knight 2003 and Gopen 2006), but it is fair to say that writing workshops as part of a graduate science curriculum are the exception, not the rule.

In this essay we describe first how we use the workshop format to expose the students to practical writing techniques. We then argue that our students, in order to think like writers, must develop a conscious writing process, and we outline possible steps toward that development. We close with a few concrete suggestions for establishing a science-writing workshop at other institutions.

The Workshop Conceptual Foundation

First, all writing is a request for the reader's attention. There exists a tacit agreement between writer and reader anytime one sits down to read anything. I, the reader, will give the piece my attention; I agree to follow its logic. I, the writer, will make it easy on my reader; my reader won't have to struggle to follow my logic. If at any point the writer presents his ideas in such muddy language that the reader must do the writer's work for him—figure out, that is, what he just said—then the deal is broken, and the writer can't expect the reader to persevere.

Second, some comforting news: Good science writing does not require writing talent. Science writing is utilitarian literature, designed to be useful or practical rather than attractive; it is purely an intellectual process, in that respect like science itself. Therefore, it can be effectively taught.

Third, the science writer can identify his audience with a degree of accuracy far higher than in other forms of literature. When crafting a paper for, say, the *Journal of Physical Oceanography*, the writer knows that his audience mainly consists of fellow oceanographers. This "clarity of audience" is a luxury for the inexperienced science writer, because knowing his audience allows for direct empathy with it.

Workshop Description

Before the intensive five-day process begins, each student submits a draft paper based on his own research. Each paper is then considered individually, three per day. To begin, Murphy reads aloud the abstract, introduction, and conclusion of each paper. Hearing a paper often spotlights points where the thinking/writing goes awry or devolves into murkiness. Then we turn the discussion over to the class. “Well, is it clear? Do we know precisely what this paper is about and what it is not about? Or were we forced to hack away the verbal undergrowth to get at the writer’s purpose and objective?” This—active student participation devoted to their own papers—is the essence of the workshop approach, and the difference between it and other, more detached means of teaching writing (e.g., Ramsey 2014).

Only during the first day do we need to prompt the students. Sincere participation soon becomes organic, based on mutual benefit—the students are here to help each other write better scientific papers by identifying where and how each paper succeeds, where and how it does not. And the students find the lesson compelling when eight people all say that they lost the logical strain somewhere around paragraph three of the introduction.

Time and again when encountering unclear, often downright opaque, sentences we have asked the student, “What did you mean to say? Say it now, verbally.” Almost every time they responded with a simple, clear statement of what they meant. Something happened, then, some disconnection between the idea and its expression in written language. The students know what they are talking about, but not *how* to manipulate the language such to express. This brings us to some basic, eminently teachable techniques fundamental to thinking like a writer about their own prose (see “Toward Clarity” sidebar).

Toward Clarity

How syntax alone can help attain clarity is well known in principle (e.g., Williams 1990, Gopen and Swan 1990), but most of our workshop participants are unaware of the techniques that use a reader’s “syntactical expectation”. To address a frequently occurring problem, we have therefore found it useful to ask the writer of a convoluted sentence to identify its subject, verb, and object—if the subject is separated from its verb by twenty-five modifying or qualifying words, the sentence will probably not hold together. Furthermore, we alert the students to the natural stress positions in an English sentence—the beginning, where the topic of the sentence is established, and the end, where the new information is presented.

Of course sentence clarity is not the end goal; sentences need to develop into paragraphs. A paragraph is a group of sentences addressing a single topic, and each paragraph has a topic sentence that alerts the reader to the paragraph’s content. So herein lies another test for clarity. Can the students identify the topic sentence in each paragraph? And does the sequence of topic sentences—and hence of paragraphs—sustain the paper’s “through-line,” the intellectual string that holds the paper together? This is *structure*. In addressing structure, we have found Williams’s (1990) classification—clarity, cohesion, and coherence—to be particularly useful. “Clarity” refers to individual sentences, “cohesion” to the logical connection between sentences in a paragraph, and “coherence” to the paragraph-by-paragraph connections, or the through-line.

By disassembling their sentences and paragraphs, the students begin to think like writers.

Language and Usage

Infelicities of language—dangling modifiers, bad agreement, wrong words, or run-on sentences—inevitably crop up from time to time. When a recurrent problem arises, we stop to explain. But we also refer the students to manuals to look it up for themselves (e.g., Strunk and White 1992, University of Chicago 2003). Furthermore, we emphasize that science writers, regardless of their native tongue, need to read—and analyze—other kinds of English texts as the best means of learning the flexibilities and possibilities of English.

We have learned that discussions of English usage, even though they are sometimes a matter of copy-editing and not of writing itself, serve as a psychological aid to the students. Inexperienced writers like rules, clear do's and don'ts, because in rules there is a measure of security. While the process of successful scientific writing is impossible to cast into a few undisputed rules, usage matters can seem like a relief in their concreteness. However, while addressing the rules, we try to place them in that context of communication with the intended audience.

And What About the Science?

It is understood that the writing exists to serve the science and that we are not teaching writing generally—we are teaching *science* writing. And it sometimes takes a scientist to recognize that the lack of clarity in a paper may be attributable not solely to muddy language, but to a gap in the research that the student may be unaware of or has tried, if unconsciously, to obfuscate. Therefore, we conduct the workshop side by side. And if Marotzke spots a problem in the scientific reasoning, we stop to discuss it.

Usually, however, the science is far more solid than the communication of it. And being aware of the solidity of his research has on several occasions led the author of an unclear paper to wonder if the group might not find it clearer if it knew more about his specialized branch of research. To address this fallacy, we composed an introductory paragraph that is thoroughly nonsensical but structurally sound (see "Jabberwocky" sidebar).

Jabberwocky initial paragraph that is structurally sound…

The exploration of magical creatures was revolutionized two hundred years ago by the discovery of stochastic troll concentrate (STC) in doming isopycnals (Grimm and Grimm 1812). The availability of STC has enabled researchers to deploy snow-white sensors in the houses of dwarfs (e.g., Andersen 1835). However, the data do not permit the unambiguous identification of snow-whites unless additional constraints are used (Donner and Blitzen 2005). Here we show how to distinguish snow-whites from cinderellas by using all available data from snow-white sensors together with the well-established constraint that two plus two equals five.

…and its later-invented translation into (almost) real science.

The exploration of sea-level change was revolutionized twenty years ago by the launch of the high-precision TOPEX/Poseidon satellite altimeter (e.g., Lee and Cazenave 2001). The availability of high-precision altimetry has enabled researchers to study global patterns of ocean surface dynamic variability (e.g., Wunsch and Stammer 1995). However, the data do not permit the unambiguous identification of steric sea-level change unless additional constraints are used (Munk 2003). Here we show how to distinguish steric from eustatic sea-level change by using all available data from altimeters together with the well-established constraint that steric sea-level change does not change the mass of the ocean.

Toward a Conscious Writing Process

Lack of clarity arises from an unsound *structure*. It's not usage, not grammar, not the sort of language problems one might expect from a high percentage of non-native English speakers. Sometimes the sentences are grammatically correct yet unclear, and sometimes the sentences themselves are clear but the paper is not, because the tissue connecting sentences and paragraphs is fuzzy in its form and function. The resulting unsound structure inhibits the paper's logical progression from point to point.

Our experience has shown that the workshop discussion can effectively reveal the structural flaws in the paper under consideration and point toward improving it. But the lessons learned are not readily transferred to the paper this student writer is going to write *next*, because of—and this is the fundamental writing problem of scientists—*the absence of a conscious writing process*. Our students usually are too inexperienced to have developed a conscious process, or even to have considered the need for one. But the absence of a process leads to the students *imitating* papers instead of thinking like a writer.

We suggest that our students begin by jotting down random ideas, never mind how or if they logically connect, never mind complete sentences (this jotting down may well happen alongside the research itself, long before the paper writing proper appears to have started; see also Schultz 2009). The objective—at the outset—is to clear one's mind of all external constraints. The next step might be to cull the less important ideas from the most important, leading to a written outline or some other hierarchical structure of ideas. (In the geosciences, it is usually helpful to add key graphics to the outline.) At some point that "outline" must be turned into complete sentences, but one should not rush into sentence writing before being able to articulate what the paper is about and why this research contributes something new to the field. We stress that there are two distinct parts to actually writing the sentences: *what* they say and *how* they say it. Inexperienced writers should not try to do both at once; the sentence content should precede the mode of expression.

Once a complete draft exists, the task is to re-write it, and herein lies another challenge (Williams 1990 provides help here). Almost universally, students submit what they honestly believe are finished papers—they *look* like finished papers, all formatted and ready for their intended journals—but very few actually *are* finished. Inexperienced writers almost always stop the process before it is complete. “Well then,” several students asked, “how do we know when it’s finished?” It’s finished when the writer has analyzed and accounted for every sentence, every word, indeed every piece of punctuation, and determined that everything has been said in the clearest, most economical terms possible.

Some Practical Matters

The timeframe should be brief but intensive. We are fortunate at the MPI-M to have a full week, during which we address three submitted papers each day—total immersion. Everyone is tired by Thursday morning; someone referred to the workshop as “writing boot camp.”

There should be no observers, visitors, or guests. We have been asked repeatedly either by faculty to sit in because they wanted to pick up some of the lessons, or by students because we had reached the enrolment limit of twelve. In each case we declined, because the presence of any observer is likely to undercut the “we’re-in-this-together” atmosphere—an observer becomes privy to the critique of my paper without being subject to critique himself.

Submitted papers should be nearly complete. Over the years, we have become increasingly strict on the level of maturity we require of the submitted papers. A short research prospectus, for instance, lacks the level of purpose and formal structure to reveal the unity of science and its communication. And a finalized master’s thesis does not provide the student with the tangible benefit we seek to offer simply because it is old work, not a step toward improving new work aiming at future publication.

Time should be reserved for rewrites. We devote Friday to rewrites. This unavoidably works to the disadvantage of those whose papers were considered on Thursday. But the lessons derived from installing, while they are still fresh, the principles we have discussed through the week are worth the schedule adjustment—and the twelve-student limit to enrolment. The aim of the rewrites is not to return with perfection, but to achieve a marked improvement in a very efficient manner. We usually ask them to rewrite what they consider the most demanding piece of writing—the introduction.

Some books should be made known to the students. We point the students to three books, one on English usage (Strunk and White 1992), one that stresses the connection between science and writing and thus is helpful in creating the first draft (Montgomery 2003), and one on the techniques of rewriting (Williams 1990). Not a single student had ever heard of these books before we introduced them. It did not occur to them to "research" science-writing techniques because they did not think of what they are doing as writing.

A faculty member should attend each session. It need not be the same faculty member for the entire week, as in the MPI-M workshop. Murphy now also conducts the workshop at the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS), where a different faculty member, usually *not* the advisor of the student whose paper is under consideration, sits in on each session. Results have been excellent.

A professional writer/teacher should lead the workshop. This is the difficult part for most science institutions. Many native English-speaking teachers of writing are not professional writers, and so lack personal experience in the subject they teach. This is particularly important with respect to the writing *process*. And many native English-speaking writers have not considered the pedagogy of writing, because they do not teach. This narrows the field, requiring a concerted search by the science institution interested in this method, the best, we think, for teaching writing at the gradual and postdoctoral level.

Conclusions

The workshop demonstrates to the students the efficacy of learning to think like a writer. The experienced writer reflexively analyzes his work from the standpoint of language, but the inexperienced writer must be taught, mechanically at first, to do so. These writing techniques, demonstrated in the light of their own papers, come as revelations to our students, and the successful ones realize that here is the route to clarity—and to the reduction of stress around the act of writing.

To effect a sustained change in students' attitude toward their writing, the workshop needs to initiate in each participant the development of a conscious writing process. This process covers every step from the early, unconstrained collection of ideas for a research paper to the final scrutiny ensuring that every sentence, every word, and every piece of punctuation serve its purpose.

But of course for a writing workshop to exist, the science institution must first see the need, starting with the recognition that science writing is in fact writing, just more specialized and more pointedly directed at a particular audience with a specific, utilitarian purpose for reading. The need is clear, as is the strategy to address it.

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References:

Andersen, 1835: Fictitious reference.

Donner and Blitzen, 2005: Fictitious reference.

Gopen, G. D., 2006, cited 2012: A tribute to Joseph Williams on the occasion of his being presented with the Golden Pen Award by the Legal Writing Institute. [Available online at http://www.law2.byu.edu/law_library/jlwi/archives/2006/gop.pdf.]

Gopen, G. D., and J. A. Swan, 1990: The Science of Scientific Writing. *American Scientist*, **78,** 550-558.

Grimm and Grimm, 1812: Fictitious reference.

Knight, J., 2003: Clear as mud. *Nature*, **422,** 376-378.

Fu, L.-L., and A. Cazenave, Eds., 2001: *Satellite Altimetry and Earth Sciences: a Handbook of Techniques and Applications*. Vol. 69, Academic Press, San Diego, 462 pp.

Montgomery, S. L., 2003: *The Chicago Guide to Communicating Science.* The University of Chicago Press, Chicago, 228 pp.

Munk, W., 2003: Ocean freshening, sea level rising. *Science*, **300**, 2041-2043.

Ramsey, N., 2014, cited 2014: Learning technical writing using the Engineering Method. [Available online at http://www.cs.tufts.edu/~nr/pubs/learn.pdf.]

Schultz, D. M., 2009: *Eloquent Science.* American Meteorological Society, Boston, 412 pp.

Strunk, W. I., and E. B. White, 1979, revised 1992: *The Elements of Style*. Macmillan, New York, 92 pp.

University of Chicago, 2010: *The Chicago Manual of Style (16th ed.).* University of Chicago Press, Chicago, 1056 pp.

Williams, J. M., 1990: *Style: Toward Clarity and Grace.* University of Chicago Press, Chicago, 208 pp.

Wunsch, C., and D. Stammer, 1995: The global frequency-wavenumber spectrum of oceanic variability estimated from TOPEX/POSEIDON altimetric measurements. *J. Geophys. Res.*, **100,** 24,895-824,910.