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## How to Write a Good Scientific Paper: Style

Chris Mack



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“Have something to say, and say it as clearly as you can. That is the only secret of style.”

—Matthew Arnold

Deserved or not, scientists and engineers have a reputation as bad writers. An average person reading a science journal paper will likely come away numb within a few sentences. Much of that is due to the complexity of the subject and a writing style that assumes a readership of knowledgeable peers. But some of that reputation is deserved, as many writers in our field either don't value clear and concise prose, or don't know how to achieve it.

If you feel that you are not as good a writer as you want to be, what can be done? Specifically, how can you improve your writing for a scientific journal paper? Style is a layered concept, and learning to improve your style means mastering words and grammar first, clear and accurate sentences next, then paragraphs that communicate complex thoughts well, and finally an organized whole that contributes to the accumulated knowledge of science.<sup>1</sup> If that sounds like a big task, it's because it is.

Much of the job of learning to write well is independent of genre (at least in the case of nonfiction writing). But some aspects of writing a good scientific paper are unique to the scientific style. Thus, I'll begin by talking about good writing in general and end with the scientific style in particular.

### 1 Some Books on Style

There are numerous books that purport to help their readers become better writers. Many focus on usage and grammar, sometimes with a strong emphasis on rules that do not matter. (While not universally shared, I have a specific viewpoint on grammar: “correctness” matters only if it improves or speeds up the comprehension of the reader.) Other books deal with style at a higher level. Here are my favorites.

By far the most well-known writing self-help book is Strunk and White's *The Elements of Style*. Begun as William Strunk's course notes at Cornell about 100 years ago, they were edited and expanded by E.B. White and published nearly 60 years ago. For better or worse, Strunk and White has formed the

basis of most high school English composition courses in America for the last 50 years. When I read it, I can't help hearing the voice of my 12th grade English teacher, spitting out emphatic commandments that took me many years of writing to learn to ignore.

Some of the advice in Strunk and White is accepted writing wisdom: Omit needless words; make definite assertions; be specific, definite, and concrete; avoid fancy words. But much found in this little book, especially concerning usage and grammar, is outdated, idiosyncratic, or just wrong. Still it is worth reading if for no other reason than many people frequently refer to it. And it is well written, sometimes even charming.

If there was only one book that an inexperienced to moderately good writer would read, I recommend Joseph Williams' college textbook *Style: Lessons in Clarity and Grace*. Williams not only tells you to omit needless words, he helps you understand how to do it. There is very little emphasis on usage or grammar; he stresses how to craft a clear sentence and how to best string several sentences together. There is little advice in Williams' book that I consciously ignore.

For the moderately good writer hoping to get better, I suggest William Zinsser's classic *On Writing Well*. While it contains much of the same advice as Williams' *Style*, Zinsser speaks more broadly to the nonfiction writing project and what makes good writing very good, or even great. Zinsser provides less actionable advice than Williams but more inspiration.

My new favorite writing guide is Steven Pinker's *The Sense of Style*. This book is nearly a perfect balance between usage and grammar instruction and writing as craft. A linguist, cognitive scientist, and well-regarded author, Pinker is not afraid to reference brain imaging results to support his views. He describes not only what can go wrong when we write but why. This book is now my go-to guide to settle those questions of grammar and usage that sometimes escalate to a religious fervor.

A book no one should read is Henry Fowler's *A Dictionary of Modern English Usage*, the darling of grammar scolds who regularly declaim the falling standards of American literacy. Its long list of arbitrary and unjustified rules and its prescriptive approach to usage do more harm than good.

These books are sure to help any writer become better. But by far the best way to become a good writer is to become a good reader. Like children learning language, we learn writing best by imitating good writers. Either consciously or unconsciously, copying the style and approach found in the very best scientific papers is the surest way to write good scientific papers yourself. Only by reading good writing and paying attention to what you like can you develop an ear for what sounds good, or not, in your own writing.

Which brings us to the scientific style. The style used in peer-reviewed science and engineering journals is unique to that genre, with its own expectations and quality criteria. Thus, the advice given in the more general writing guides must sometimes be modified (and occasionally abandoned) when writing in the scientific style.

### 2 The Scientific Style

There are many writing styles: plain, practical, classic, romantic, contemplative, oratorical, and others. According

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to Thomas and Turner,<sup>2</sup> a writing style is defined by the stand taken on five issues:

- **Truth:** What is the writer's philosophical stand on truth and how it can be known and communicated?
- **Presentation:** What does the writer (and reader) value in the mode of presentation?
- **Scene:** What is the model for transmitting the writer's thoughts to the reader?
- **Cast:** Who is the intended reader? What does the writer assume about the reader?
- **Thought and Language:** What is the relationship between the writer's thoughts and the language that is chosen to express them?

Every different style differs in some way among these five qualities. Thus, to explain the scientific style, let's look at each one in detail.

### 3 Truth

The scientific style assumes a universal and objective reality that exists independent of the writer or reader. There is a truth concerning this reality, but it is not manifest. It takes hard work to get close to this truth, and in the end we can only comment on the accuracy of our scientific models, not their correctness in some absolute sense. Because truth is independent of both writer and reader, it is accessible by anyone willing to put forth the effort to understand it. The writer assumes no privileged access to truth, and if a reader had performed the same work and thought about it in the same way, they could have come to the same conclusions. Scientific knowledge is not invented or created, it is discovered. Then, after it is discovered, it is verified by other scientists.

### 4 Presentation

In many styles of writing, clarity and grace, vividness and vigor, rise to the top of the values cherished by both writer and reader. But in the scientific style, the most valued attributes are accuracy, precision, clarity, concision, and grace (in that order).

Accuracy means that all new knowledge claims are justified and verifiable. The point of a research paper is to claim new knowledge. Claiming too little gives question to the value of the paper; claiming too much gives question to the competence or integrity of the author. There are two ways to claim too much in a paper: claims in opposition to the facts and claims unsupported by the facts. Further, any claim that cannot be verified given the information provided in the paper is as good as unsupported. So that neither too much nor too little is claimed, the language of a scientific statement must be carefully chosen. Qualifications are essential to accuracy, defining the scope of what is being claimed. Hedges are never desired but almost always necessary. The chances that your paper will be the last word on its subject are extremely small.

Precision means that the meaning taken away by the reader matches the meaning intended by the writer. Lack of precision is best blamed on the writer, even if the reader is at fault. Clarity means that the work is easily and quickly

understood. Rereading a passage multiple times to get its meaning is a sure sign that clarity is missing. Clarity requires precision only if the author's thoughts are clear. Precision does not require clarity but is aided by it. When writing is both precise and clear, the reader easily and quickly comprehends the intended meaning. Jargon that is common to the reader can increase clarity, but using fat words to impress will invariably have the opposite effect.

We value concise writing because we value time. If a paper could have been written in half the words, then it is half as useful as it could have been. The "omit needless words" advice can now be put into practice for the scientific style. If you think a word is not needed, take it out and ask if accuracy, precision, or clarity were harmed. If not, leave it out.

Grace is rarely achieved in science writing, but it is achievable. In other styles of writing, grace is often gained at the expense of accuracy, making definitive statements that are more vivid and compelling but not as accurate without the appropriate qualifications or hedges. In the scientific style, we are willing to sacrifice elegance, beauty, and charm for accuracy and precision. Still, when I run across a paper that achieves the goals of accuracy, precision, clarity, and concision but also manages something like grace, I come away inspired and grateful.

### 5 Scene

The imagined scene for communicating between author and reader is a presentation at a scientific meeting. The audience is there because they are interested in your topic, and they will save their questions till the end. Your job is to teach your audience what you learned in the course of your investigations. This scene calls for a formal and professional tone, lacking in colloquialisms and personal anecdotes. But don't write with words you would never say. Reading sentences aloud helps to ensure that your writing matches this scene.

### 6 Cast

Your readers are like the audience of your imagined symposium talk. They are interested in your topic and generally familiar with the field, though not necessarily with the details. They are enthusiastic graduate students and experienced veterans. They include anyone who might reasonably pick up and browse a copy of the journal you hope to publish in. They are sometimes experts in the specific niche that your work occupies, but usually not. They are intelligent and willing to put the effort into understanding what you have to say, but only if you make it worth their while. Writer and reader are peers.

### 7 Thought and Language

There are no thoughts in the writer's head that cannot be adequately expressed and understood with the right choice of words. Language (including the language of mathematics) is fully up to the task of representing even the most complex concepts with accuracy and precision. The author may claim to be the first to arrive at a new thought, but once properly expressed that thought can be grasped by anyone. Einstein's theories of special and general relativity were shockingly original, a testament to his genius. But once

expressed they could be verified by any competent and diligent scientist.

The scientific style denies intangibles, mysteries, and unique personal experiences. Feelings and fancies have no place here. Often significant effort is made to define terms and agree on their meaning, including the establishment of standard-setting bodies to create a universally accepted nomenclature. Sloppy use of words is considered a sign of sloppy thinking.

### 8 Writing in the Scientific Style

The purpose of a research paper is to present some new result, explain its significance, and place it coherently within the existing body of knowledge. The scientific style, described by its stand on the issues of truth, presentation, scene, cast, and thought and language, creates a unique way of writing that is mostly unfamiliar to the nonscientist. Many common “rules” of good writing (don’t use the passive voice, avoid complex noun phrases, make the action involve people) generally don’t apply to the scientific style.

For example, the scientific stance on truth makes the scientist replaceable; anybody could have done the same experiments/derivations/simulations. To emphasize this important philosophy, scientists attempt to remove themselves from the discussion. Instead of saying “We then performed an experiment,” which puts the authors front and center, we regularly use the passive voice: “An experiment was performed.” My former English teacher would have screamed if she saw that sentence, but only because she did not appreciate the scientific style.

That does not mean first person pronouns are forbidden. While anyone could have performed that experiment, it is the authors who are proposing a new approach, encouraging a new direction, or suggesting a new design. In these cases the authors are not replaceable and their voices are allowed to come through. Using “I” or “we” in the introduction and conclusions is common, but not in the experimental or results sections.

The scientific style also tends to pack complexity into its nouns (and noun phrases) rather than into the structure of a sentence. Consider this sentence with only simple words:

“Jane saw Bob on the hill with the telescope.”

The embedded clauses create ambiguity, and it is ambiguity, not complexity, that the scientific style shuns. Science writing frequently employs complex noun phrases in sentences with simple structures:

“Sidewall sensing in a CD-AFM involves continuous lateral dithering of the tip.”

But it is the mark of a good writer that more complex structures are pulled off without loss of precision and clarity.

Unfortunately, some writers inflate their language in an attempt to sound more professional or profound. Which of these two sentences do you think is clearer?

“In Figure 2, the x- and y-axes represent the cavity diameter and the filling ratio, respectively.”

“In Figure 2, the filling ratio is plotted as a function of the cavity diameter.”

A writer should try to teach the readers, not impress them. The easiest way to do that is to draft the passage using the words that come most naturally, then revise, rewrite, and revise again with accuracy, precision, and clarity in mind. Sleep on it, let someone else read it, then revise it again. Writing is mostly the act of rewriting, and it is work.

There are many more things to say about style, but I’ll let a better writer than me have the final word:

“We are all apprentices in a craft where no one ever becomes a master.”

—Ernest Hemingway

**Chris Mack**  
Editor-in-Chief

### References

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