Writing for Non-scientists about Physics[1]

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Physicists should communicate their knowledge to the general public because, as the American Association for the Advancement of Science puts it, "without a scientifically literate population, the outlook for a better world is not promising." This article discusses what I've learned about writing for non-scientists from working on my physics textbook for non-science college students,[2] as well as from my hometown newspaper column and other writings.[3] Lessons learned include tips for writing effective prose, do's and dont's when writing for non-scientists, choice of subject matter, being relevant to the needs of non-scientists, unifying one's book by using general themes, and the process of organizing and writing a textbook. Many of these lessons should be helpful in all scientific writing regardless of the target audience.

Although most of our scientific communication is directed at other scientists or science students, it would behoove us to devote more attention to the housewives, parents, workers, school students, school teachers, business people, artists, journalists, politicians, future presidents, and others who will determine the future of the planet. Unfortunately, other professional priorities such as research often get in the way of this more general kind of communication.[4] But we ignore non-scientists at our peril. As Carl Sagan put it in *The Demon-Haunted World:*

> We've arranged a global civilization in which most crucial elements …profoundly depend on science and technology. We have also arranged things so that almost no one understands science and technology. This is a prescription for disaster. We might get away with it for a while, but sooner or later this combustible mixture of ignorance and power is going to blow up in our faces.[5]

General principles

Keep your writing for non-scientists conceptual (non-algebraic) and as non-technical as possible. Equations can create disinterest and, worse, fear. Non-scientists generally have little need to solve traditional math-based physics problems. Do not assume that non-scientists know the meaning of such technical words as *force*, *momentum*, *energy*, *radiation*, *wave*, etc. Use technical jargon only when needed, and explain the concept behind a word before introducing the word. For example, instead of beginning a discussion of force with a definition, discuss the general notion of pushes and pulls, give some examples, and then introduce the word.

Citizens must be "numerate" in order to understand issues such as energy resources or overpopulation, so don't be afraid to use numbers when they are relevant. Use mathematical tools such as powers of ten, probabilities, and proportionalities carefully and with clear explanations. Citizens need to understand graphs; don't be afraid to use them, but be sure to clearly explain them. Briefly, while citizens don't need to use algebra, they do need to become numerate.

Make your writing relevant to readers' interests. These interests are different for different readers, but I find that physics-related social issues are relevant and interesting to most non-scientists. Such topics include global warming, atmospheric ozone depletion, nuclear weapons issues, nuclear power, energy resources, transportation technology, geological ages, age of Earth, age of the universe, the search for extraterrestrial intelligence, the scientific process, and why the pseudosciences (e.g. creationism) are non-scientific. Many people are fascinated by modern physics, including topics such as special relativity, $E=mc^2$ (probably the only equation you should mention), general relativity, curved space, cosmology (which requires some concepts from general relativity), the big bang, quantum physics, quantum uncertainty, quantum entanglement, quantum measurement, nuclear physics, high energy physics, the standard model, the LHC, quantum fields, neutrinos, quarks, and the string hypothesis. Many people are interested in the classical physics phenomena that they can experience directly in the world around them, especially if you relate this to their own experience or illustrate by means of common examples such as television tubes, radio, household electrical circuits, automobiles, airplanes, heat engines, sound, falling objects, light bulbs, and water waves.

Op-ed pieces or letters to the editor of your local newspaper are great ways for you to communicate with non-scientists. I was lucky enough to obtain a regular biweekly op-ed column in our regional (northwest Arkansas) newspaper. Write a couple of sample columns and present them to your local newspaper with an offer to write a column on a regular basis. Don't expect much or any compensation. Write about such science-related topics as I've listed above, giving them a local twist whenever possible. As a sampler, here are a few topics I've written about for my regional newspaper: Are Americans scientifically literate? Coal and our energy future. In praise of reason. Whither Fayetteville High School? Arkansas energy resources: lignite. The real cost of gasoline. Winning the climate race. The LHC: going boldly where none have gone before. Let's talk about religion. Transportation and cowboy mythology. The search for Earth-like planets.

For columns, letters to the editor, and articles, choose one central theme and stick to it. Be sure the theme, or purpose, is clear to the reader, probably by beginning and ending with it. A book should have a central theme also, with perhaps some secondary themes. As an example, the theme of my physics textbook is implied by its title: *Physics: Concepts & Connections*, i.e., conceptual physics including its connections to so-

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ciety and philosophy. There are four subthemes: The scientific process; what's different about modern physics; energy; and the social context of physics.

For those who are considering writing a book, especially if it's a textbook: It will probably turn out to be a bigger, longer task than you had planned. Begin planning by being clear to yourself about the book's purpose, the particular niche it will occupy among all the other books. Develop a rough outline, knowing that you can always change it, and fill in some of the details. Write a few sample chapters. It's often best not to begin your writing with Chapter 1. I began writing my textbook with Chapters 6 and 7, because these are the chapters about energy and this is the book's central physics concept.

Writing tips

Buy a copy of the brief classic about good writing, *The Elements of Style,* byWilliam Strunk and E. B. White (Pearson Education, Upper Saddle River, NJ, 4th ed., 1999). You might want to take some of its advice with a grain of salt, but it's still the best general book on writing, although my reading about this topic is fairly limited. I also recommend *The Craft of Scientific Writing,* by Michael Alley (Springer-Verlag, New York, 3rd ed., 1996). Both books are full of examples of what to do and not do.

The basic rule of good writing is to help your struggling reader figure out what you are trying to say. Especially in the sciences, give the reader all the help you can by being direct, clear, and concise. The specific rules and guidelines for writing are all geared toward this end.

Do read, aloud or perhaps silently, each sentence, slowly, listening to how it sounds. Is it graceful or clumsy? Honest or pretentious? Concise or wordy? Take whatever time you need to find the right word, every time. If you can't think of the right word, leave a temporary bracket and move on. Don't beat around the bush; say what you have to say as forthrightly as possible. Be wary of long or complex sentences; consider breaking them into simpler sentences.

Be wary of all modifiers (adjectives and adverbs), deleting them unless they add something significant. As an example, the word "very" is almost always superfluous. A violin sonata might be "ravishingly" beautiful, but to say it is "very" beautiful is boring and detracts from the main point, namely that it is beautiful. The heart of good writing is strong subjects and verbs. Non-essential modifiers clutter things up.

Be concise. Shorter is usually better.

Much of the good advice about writing can be summarized as: "Avoid Flabby Prose." Let's discuss some of the specifics.

An often-stated but often-violated principle is: Use the active, not the passive, voice. Replace "A scanning tunneling microscope was used to determine the atoms' positions" and "The atoms' positions were determined by a scanning tunneling microscope" with "A scanning tunneling microscope determined the atoms' positions." The active voice (where the subject does the acting rather than being acted upon) is usually stronger, clearer, and more concise.

Verbs are the lively, active elements of sentences. Don't turn them into nouns. Instead of "perform a study," write "study." Instead of "add heat to the system," write "heat the system." Instead of "make measurements of," write "measure." I've always thought that physicists could eliminate lots of misconceptions by replacing the canonical "A exerts a force on B" with "A forces B," because force is an action, not a thing. But perhaps this is too radical. I do suggest that we eliminate another set of misconceptions by never using "heat" as a noun. You "heat the soup," you don't "add heat to the soup." You can't add heat any more than you can add work. Heat, like work, is an action, not a thing. What is added to the soup is thermal energy, or internal energy, which are nouns.

Try to replace forms of "to be" with strong, specific verbs. Thus, replace "is used to detect" with "detects," replace "was beginning" with "began," replace "is capable of" with "can."

It's OK to use "I." According to Michael Alley, "Much passive voice arises in scientific writing because we scientists cling to the misconception that we can't use the first person ('I' or 'we'). But Einstein, Feynman, Darwin, and many others used the first person." So avoid such flabby phrases as "It was determined that…."

Replace longer more pretentious words with simpler equivalents. Examples: Replace "activate" or "initialize" with "start," replace "consequently" with "so," replace "contiguous" with "adjacent," replace "subsequently" with "then."

Eliminate what Alley calls "writing zeroes" that provide no information. Examples of writing zeroes include "It is interesting to note that," "As a matter of fact," "I might add," and "The fact that."

Cut the fat. This saves the reader's time, saves paper, and more importantly it invigorates your writing. For an extreme example, replace the bloated "Following the observance of this occurrence, it was determined that …" with the fat-free "We then determined …."

Eliminate redundancies. In each of the following phrases, eliminate the word or words in parentheses: (already) existing, (alternative) choices, at (the) present (time), (point in) time, (first) began, start (out).

I'll leave you with advice from Winston Churchill: "Short words are the best and old words when short are the best of all." Also this from Ernest Hemingway: "Cut the B.S." (but Hemingway didn't use the euphemism).

References

1. This article is based on an invited talk presented April 2008 at the American Physical Society meeting in St. Louis.
2. Art Hobson, *Physics: Concepts & Connections*, 5th ed. (Pearson/Addison-Wesley, San Francisco, 2010).
3. Newspaper columns and other publications are available at physics.uark.edu/hobson/.
4. Art Hobson, "Guest editorial: Science literacy and backward priorities," *Phys. Teach.* **44**, 488–489 (Nov. 2006).
5. Carl Sagan, *The Demon-Haunted World: Science as a Candle in the Dark* (Random House, New York, 1995), p. 26.

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