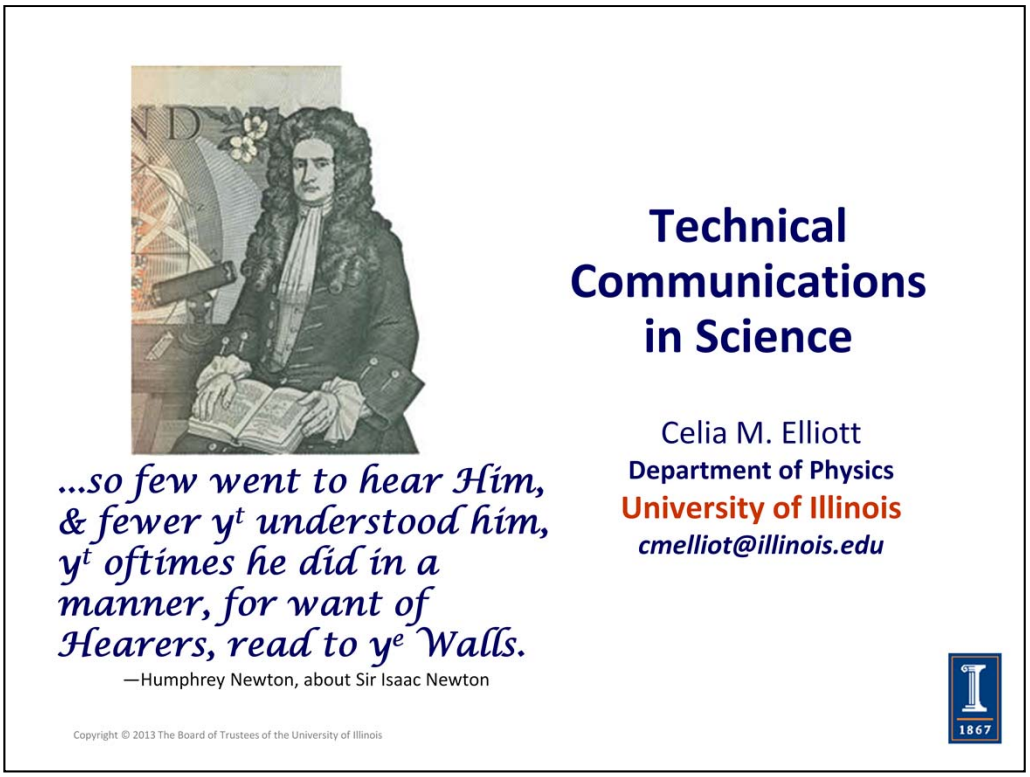


If you're the next Isaac Newton, you could probably get by with "reading to the walls." If you're not, you must learn how to communicate effectively in science if you're going to be successful.

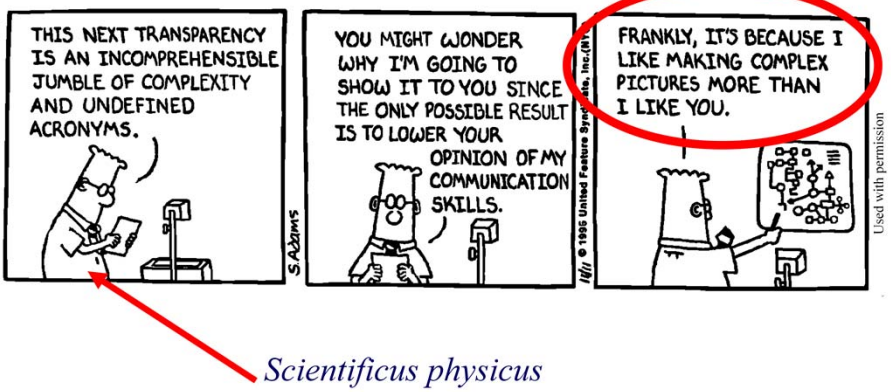
1) I'm a physicist; I do math, not prose...
    a) Increasingly, physicists work in teams; good teamwork depends on good communication skills.
    b) If you want to get promoted, you must have good communication skills; oral and written communication skills become more important than technical skills as you advance, because executives and professors spend most of their time communicating—supervising, delegating, evaluating, clarifying, leading.
2) I'm too busy...
    Good communications skills save time and increase efficiency by eliminating mistakes and misunderstandings.
3) My word processor will correct all my mistakes...
    a) Best spell-checkers can't distinguish between "assess" and "asses."
    b) Grammar checkers don't help with organization, style, or tone.
4) Tech editors will edit my papers...
    a) Communication is not just writing.
    b) Copy editors may correct cosmetic errors in some (increasingly rare) journal papers, but they don't write your internal memos, email, reports, presentation visuals, proposals, lecture notes, or any of the other piles of things you'll be called upon to write.
    c) Must rely on your own skills to communicate your ideas.
5) I'm just not a good writer/speaker...
    a) Good communications skills are not innate, they are learned.
    b) Anyone can improve with education and practice.

Show me a physicist who subscribes to these statements, and I'll show you a physicist who cannot get hired, who cannot get his research funded, who cannot get his papers published, and who cannot get promoted.

As a scientist, you will communicate your ideas in all of the following venues:

- Presentations at group meetings, work shops, conferences, and job interviews.
- Publications in journals.
- Teaching and training.
- Grant proposals.
- Reviews of other people's manuscripts and proposals.
- Applications and nominations.
- Evaluations and recommendations.
- Websites and electronic media.

Communication is a two-way process



Scientificus physicus

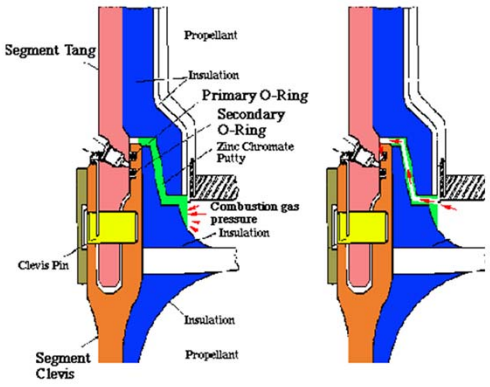
Communication is not broadcasting—it is successful only when the receiver understands the content of a message as the sender intended it.

Eight steps to meaningful communication:

1) You have an idea.
2) You select a medium to transmit the idea.
3) You encode the idea for the medium.
4) You transmit the message.
5) Your audience receives the message.
6) The audience decodes it.
7) The audience transmits a message back to you about what the message means (feedback).
8) You confirm that the message has been understood as you intended.

Some scientific communications (particularly written communications), have no mechanism for Steps 7 and 8. Consequently, writers must be particularly careful that the meaning they seek to convey is encoded precisely and unambiguously and in words that the receiver can understand.

Explaining the *Challenger* disaster



Report of the Presidential Commission on Space Shuttle Challenger Accident, 1986

© Marilynn K. Yee, NYT Pictures

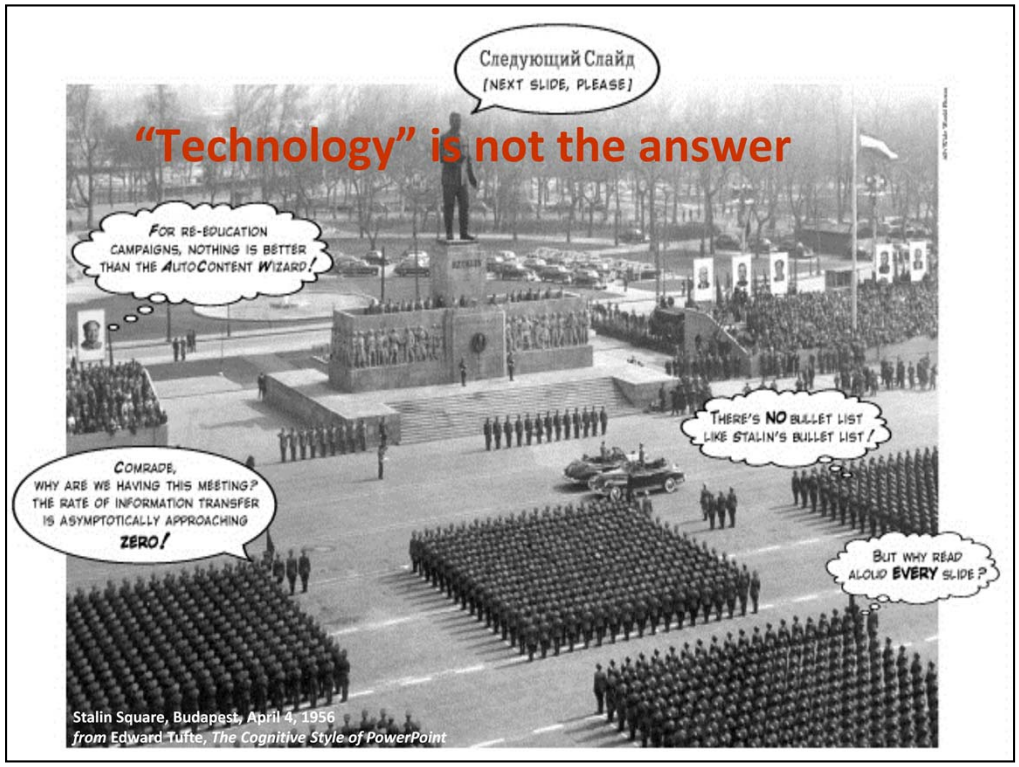
An enormous gulf divides “talking” or “writing” and effective communication.

On the left is NASA’s explanation for the Challenger accident. On the right is Richard Feynman’s admittedly flawed experiment that galvanized the American public.

“I took this stuff I got out of your [O-ring] seal and I put it in ice water, and I discovered that when you put some pressure on it for a while and then undo it, it doesn't stretch back. It stays the same dimension. In other words, for a few seconds at least, and more seconds than that, there is no resilience in this particular material when it is at a temperature of 32 degrees. I believe that has some significance for our problem.”

“What Do You Care What Other People Think?” Further Adventures of a Curious Character, Richard P. Feynman, as told to Ralph Leighton (W.W. Norton and Company, New York, 1988), pp. 151–153.

You must provide explanations that are understandable and meaningful to your audience if you’re going to succeed as a science communicator.



Good science papers and presentations are defined by the quality, relevance, timeliness, and integrity of the content—not the flashiness of the delivery.

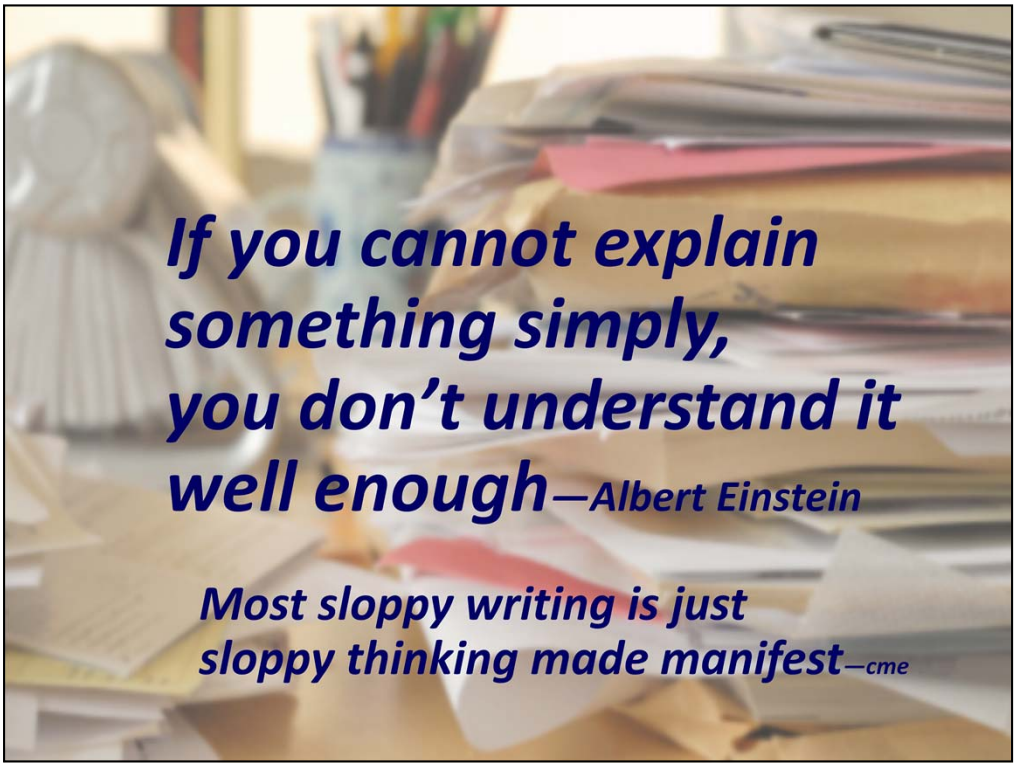
But—"interesting" trumps "boring" every time.

Eye candy and animations will not salvage weak content. At the same time, you must provide content in a way that engages the audience, gets them thinking about what you're saying, and helps them remember what you've said.

Edward R. Tufte, "The Cognitive Style of PowerPoint" (Graphics Press LLC, Cheshire, CT, undated).

For a classic example of PowerPoint gone horribly wrong, see http://norvig.com/Gettysburg/.

And for a brilliant PPT presentation, see http://www.slideshare.net/thecroaker/death-by-powerpoint.



Because we think in words, the act of expressing observation in language—of distilling amorphous thoughts into words—is a powerful tool for clarifying your thinking.

The scholastic enterprise works!
Translating your thoughts into words so that you can communicate them to someone else forces you
- to question your assumptions.
- to look for holes.
- to fill in gaps in your thinking.

"The act of composition disciplines the mind; writing is one way to go about thinking, and the practice and habit of writing not only drain the mind, but supply it too." Strunk and White, The Elements of Style, 3rd ed., p. 70.

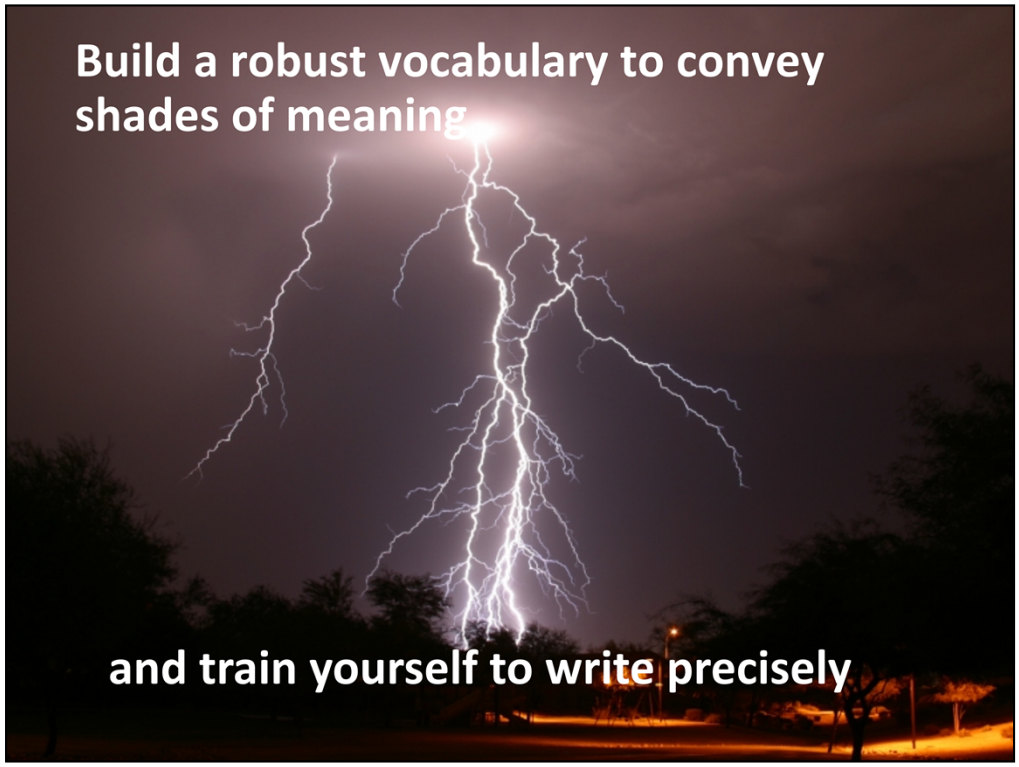
"It's also through writing that we learn to articulate our thoughts clearly; our critical thinking is strengthened and clarified by our expression of it in writing." J.L. Craig, "Writing strategies for graduate students," Proc. ASEE Ann. Conf. & Exposition (Nashville, TN, ASEE, 2005).

Writing and speaking are practice-based skills; you learn how to do them by doing them.

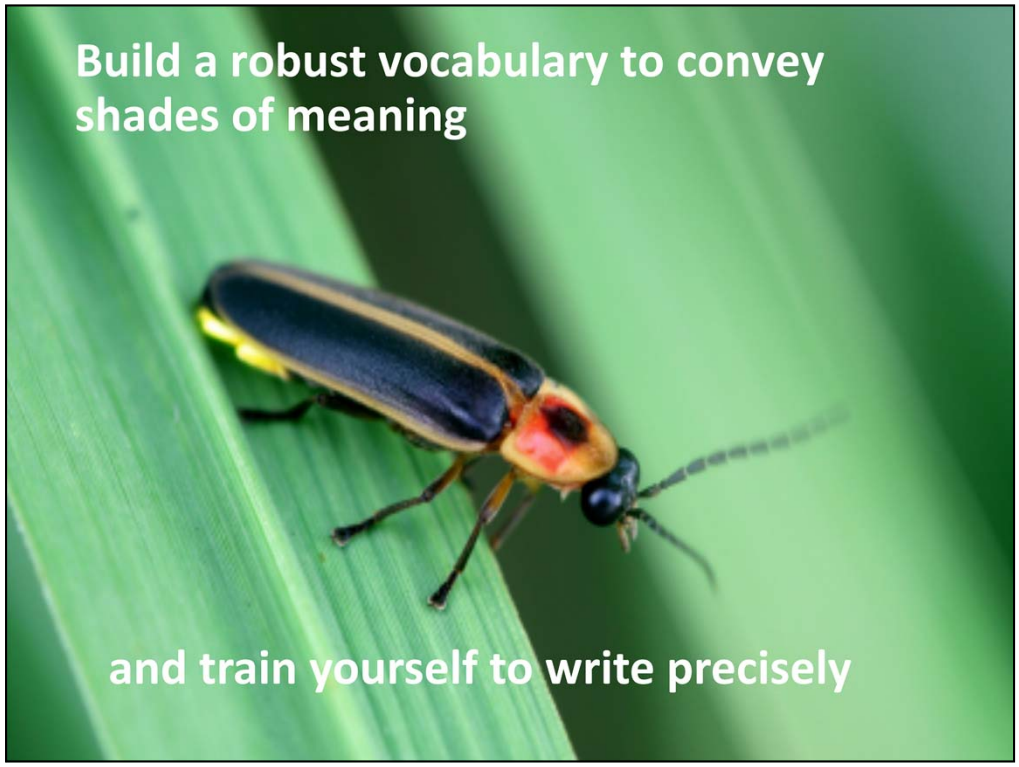
There's no substitute for practice.

Some common problems in students' writing include the following:

- Inappropriate scope or emphasis. Just because you spent 90 percent of your time doing task A doesn't mean that you should devote 90 percent of your writing or presentation to it.
- Lack of logical organization and cohesion. Failure to include transitions. Organizing narratives chronologically instead of thematically.
- Wordiness.
- Use of imprecise or ambiguous language.
- Failure to adhere to scientific writing conventions.
- Inappropriate use of graphics or presentation of data.
- "Mechanical" errors—in grammar, usage, spelling, punctuation.
- **Underestimating the time needed to write, revise, and proof.**



"The difference between the right word and almost the right word is the difference between "lightning" and "lightning bug."—Mark Twain



Use standard nomenclature and notation.

Explain.

Specify.

Quantify.

The precision of your description should reflect the precision of your experiment.

Words in English often have a connotation (a subtle shade of meaning) that goes beyond a dictionary definition. For example, a dictionary gives the following words as synonyms for one another, but they're not interchangeable: feasible, suitable, capable, reasonable, likely.

In science, some words have a specific meaning depending on the context, e.g., "displacement":

- to a physicist—the effect that the wavelength at which a black body radiates the most energy is inversely proportional to its absolute temperature
- to a mechanical engineer—the volume moved by the stroke of a piston
- to a seismologist—slippage along a geological fault
- to a marine engineer—the weight of the water displaced by a vessel floating in it
- to a pharmacist—percolation
- to a botanist—abnormality in the position or form of a leaf or organ
- to a psychologist—a defense mechanism in which an emotion is transferred to another, more acceptable object

Here's a famous paper that has a writing flaw...can you spot it?

"Evidence of a positively charged electron was found in cosmic ray tracks produced in a vertical Wilson chamber. Of 1300 photographs, 15 were found to contain this unexplained particle. Analysis of the tracks indicates a particle of positive charge, having a magnitude comparable to that of an electron."

Carl D. Anderson, "The Positive Electron," *Phys. Rev.* **43**, 491–494 (1933).

This paragraph was taken from a paper published in 1933, announcing the discovery of the positron, for which Carl Anderson shared the 1936 Nobel Prize in Physics.

Now, admittedly, Carl Anderson won a Nobel Prize and I didn't. But I still think this paragraph could (should) have been written more carefully.

Can you spot the problem?

"Evidence of a positively charged electron was found in cosmic ray tracks produced in a vertical Wilson chamber. **Of 1300 photographs, 15 were found to contain this unexplained particle.** Analysis of the tracks indicates a particle of positive charge, having a magnitude comparable to that of an electron."

Carl D. Anderson, "The Positive Electron," *Phys. Rev.* **43**, 491–494 (1933).

"Of 1300 photographs, 15 were found to contain this unexplained particle."

The "photographs" did not ***contain*** any "particles" (other than in the sense that they were made of matter).

Tracks recorded on the photographic film could not be explained by the behavior of any known particles.

There is a huge gap between saying "I have a photograph of some weird-looking tracks" and "I have a photograph of Sasquatch."

Write precisely!

Audiences will be listening to you when they're sleep deprived or jet lagged.

They'll get up early in the morning to read your paper, or stay up late at night.

They have hundreds of other things competing for their attention.

They probably have no way to give you direct feedback. How will you know your message has been received and understood?*

They ***will*** make note of your deficiencies and hold them against you if you confuse them or waste their time.

*By writing it as clearly and carefully and unambiguously as you can.

They require having an adequate vocabulary and a sensitivity to words' nuances.
They require practice and iteration.
They require constructive criticism from experts and peers.
Train yourself to recognize excellence and emulate it.
Seize every opportunity that presents itself to improve your skills.
Your investment in improving them *will* affect your future success.

Practice may not make "perfect," but it definitely makes "better."

For good advice and further reading:

W. Strunk and E.B. White, *The Elements of Style*, 3rd ed. (Allyn & Bacon, Boston, 1979).

V. Booth, *Communicating in Science*, 2nd ed. (CUP, Cambridge, 1993).

H.B. Michaelson, *How to Write and Publish Engineering Papers and Reports,* 3rd ed. (Oryx Press, Phoenix, 1990).

S.L. Montgomery, *The Chicago Guide to Communicating Science* (University of Chicago Press, Chicago, 2003).

Michael Alley, *The Craft of Scientific Writing*, 3rd ed. (Springer, New York, 1996).

E. Tufte, *The Visual Display of Quantitative Information*, 2nd ed. (Graphics Press, Cheshire, CT, 2003).