Learning Technical Writing Using the Engineering Method

A Handbook for Groups

Norman Ramsey
Tufts University

August 2014

Preface

You may have difficulty writing, or you may have heard from professors or reviewers that your writing is hard to follow. Or you may have studied writing only in the context of literature, and have trouble translating your skills into a technical setting. Enough students have these difficulties that I have invested significant effort in helping students become comfortable, fluent, clear technical writers.

This booklet explains how to study technical writing in the context of a weekly group. If nothing else, a group will show you that you are not alone in your difficulties. Problems you may have are problems that others also have, and you can find similar problems even in published papers. But we do not emphasize problems; instead we emphasize useful principles and practices—engineering *heuristics*—that you can learn to apply to your own manuscripts.

- I emphasize principles that can be applied successfully by a beginning writer. Especially for students in science and engineering, a principle is easily applicable when there is a simple, experimental way to decide if the written words obey the principle. (For example, I do not try to teach "omit needless words," because I know of no simple way to decide if a word is needless.) In this approach, I have been greatly influenced by Joseph Williams (1995).

- I emphasize practices that have been shown, again by experiment, to lead to productive writing. For example, I explain the difference between "binge writing" and "brief, daily sessions." In this approach, I have been greatly influenced by Robert Boice (2000).

What both approaches have in common is that even a beginner can apply a simple test to see whether he or she is applying a given principle or following a given practice. I hope this "engineering" focus on testable ideas will help you with your writing.

Norman Ramsey
Medford, Mass.

Contents

She, who had, by the age of three hundred,
mastered all the known techniques developed
in tens of thousands of years of painting,
still believed her technique was weak,
and not only always strove to improve it,
but believed, the results of her own hand
to the contrary, that nothing except barest
technique was of any importance whatever.

— Steven Brust, *The Phoenix Guards*

1 Why a group and what might happen

Compared with individual instruction, a writing group is not only more comfortable but also more effective. The focus is not relentlessly on your own writing; you also see other writing at your own level. You have a broader basis from which to evaluate the utility of the principles we teach and decide what does and does not work. The engineering method is all about evaluating and choosing techniques that work in practice on your particular problem. You can apply the engineering method to writing.

A group also helps because if you've just learned a new technique, you can probably apply that technique more easily to someone else's writing than to your own. And when your own writing is the focus, you will learn from the way your work is read by the group. It is invaluable to sit quietly and see where readers do not understand; where they miss the point; and where they feel distracted, bored, or confused. One reader's reaction might be idiosyncratic, but when a whole group of readers reacts the same way, it is easier to accept that the flaw might lie in the text.

The rest of this section gives a short overview of the material you may study in the group, as well as some things you can expect to happen.

1.1 Techniques for study

The primary purpose of this group is to learn good technique, as summarized by the principles and practices in Table 1 on page 8. A *principle* describes some property of a text; I try hard to phrase each principle so that you can easily decide whether a particular text respects it. You can then evaluate the hypothesis that a text which respects the principle produces a better effect in the reader's mind.

The practices focus not on properties of texts but on the means by which texts are produced. A *practice* recommends a behavior that, when followed by the writer, can lead to more fluent and successful production. It is unfortunately quite difficult for a single student to evaluate which practices make a difference, but you may get a chance to read about and discuss some of Robert Boice's (2000) controlled experiments, which I have found quite convincing.

1.2 Expected outcomes

Groups vary, but there are certain things you can expect to happen:

- You can expect your writing to improve, and perhaps to come more easily. Some of the exercises in Section 3.2 are simple enough that you will see results immediately.
- You will learn a few principles, and you will learn to apply those principles, but you will probably find it easier to apply them to others' work—repeatedly—before you can apply them to your own work.
- In a 75-minute meeting, you will be able to discuss a surprisingly small amount of text. Don't be disappointed; a narrow focus (even just a few sentences!) often yields the deepest insights.
- Even when the focus is very narrow, discussions will often be great fun.
- Your first meetings will probably focus on mechanics. But after a month or two, you can expect discussions of mechanics to lead to discussions of ideas. As your group gains experience, you will move more often (and more quickly) towards ideas.
- Most of the time, you will probably prefer texts which respect the principles in Section 3.1. But you may encounter one notable exception: there are texts that readers like, but that completely disregard Williams's advice about subjects and verbs (Principle 3). Such texts tend to be technical *description*, in which it is hard to identify any real actions taking place.
- You will be able to learn a lot about writing in a few hours per week; you should be able to leave each meeting feeling you understand something significant about your own and others' writing.
- In one semester, you will probably find it difficult to learn more than just 2 or 3 principles or practices—and even that much will be hard work. But if you really internalize 2 or 3 useful principles and consistently apply them to your own work, you will be impressed at how much better your writing gets.

2 Mechanics and pragmatics

2.1 Expectations: preparation and meeting

I have found it ideal to meet once a week for around an hour and a half each time. And preparation is imperative; when students begin, they may need an hour or two for exercises and another hour or two for supplemental reading. But by the end of a year's study, almost every student can prepare in under an hour.

Attending the meetings is important; unlike other kinds of knowledge, which can be acquired independently from a text or by listening to a taped lecture, writing can really only be learned by doing and by getting feedback. If you don't show up, you learn nothing, and if you don't comment on others' work, it's unfair for you to benefit from others' reading of your own work.

Meetings about principles Most meetings will focus on principles of clear writing. A meeting focused on a principle will probably be organized around an exercise that you will have completed before the meeting. Each exercise requires analysis, and sometimes revision, of a sample text written by a student author or by a professional. A typical exercise focuses on just a few paragraphs, or at most a section. The exercises might remind you of problem sets, except that because they often call upon you to evaluate events that happen in a reader's mind, not everyone will agree on the answers.

Meetings about practices Some meetings will focus on practices of successful writers. A meeting focused on a practice may be organized as a discussion of some reading. The discussion may resemble discussions in graduate seminars. The most effective discussions analyze how the ideas in a reading might apply to your own writing practices.

There is a better way to organize a meeting about practices, but it requires preparation in advance: keep a notebook that records data about you you tried to use a practice and how it affected your productivity. Analysis of the data will reveal not only what works, but even more important, how to make it work.

Early meetings For the first few meetings, I like to analyze professional papers. Such papers provide a good platform for testing our principles scientifically: Do the writers we like respect our principles? With what effects in the minds of the readers? I will enlist your help by inviting you to bring examples of published papers you like and dislike.

2.2 Commenting on a text

A key part of our approach is to ensure that group members' comments support empirical evaluation of a text. Here are some examples of useful comments:

- "I believe that the most important idea in the paper is the idea of using a finite automaton to model the infinite space of possible signatures."
- "At the end of paragraph A, I was happy, but but the time I got to sentence 3 of paragraph B, where it says that a machine register has a weight that is equal to the number of resources it consumes, I felt that I no longer understood what was going on."
- "I don't understand the distinction between an 'argument' and a 'parameter'."

Each of these examples provides evidence of important events happening in the reader's mind, and two of them tie those events to specific words or locations in the text.

An example of a less useful comment is "the third section is not well written." The comment is about the text, not about what is in the reader's mind, and it is not focused on any particular part of the text.

When your paper is being discussed, we may ask you not to speak. In part, we do this to be sure that any comments are made in response not to you but to the words on the page. In part, we do it to mimic the process of professional reviewing; after all, when you send a paper out for review, you can't enter into a discussion to explain what you really meant. And in part, we do it to give you space to focus your full attention on what your readers are saying, without being distracted by thinking about how to formulate a response. You'll get a chance to talk at the end of the session.

When your text is being discussed, we encourage you to take notes. It is surprisingly difficult to remember what is said; no matter how sympathetic the group and how mature the author, hearing one's work discussed is such an intense experience that it can be hard to hear and remember everything as it is being said. If your group members agree, you may even wish to use a microphone to record discussions, especially if you are getting comments on a paper that you will soon submit.

3 Principles, practices, exercises, and guidelines

This section sets forth what you will actually study: principles, practices, and guidelines for successful writers, together with exercises that will help you master the principles. The principles and practices are listed in Table 1 on page 8. I introduce them with short explanations of the thinking behind them, but neither the principles nor the practices are self-explanatory. Explanations can be found in Williams (1995), in Boice (2000), and also in the exercises.

3.1 Principles and practices for technical writers

Principles A principle is useful only if a beginning writer can test to see if a text obeys it. Here are some examples of principles that are difficult to test for (all real advice from real writers):

- Omit needless words.
- Pay attention to the rhythm of the paragraph.
- Group ideas into sentences in the most logical way.

Here are some principles that are easier to test for:

- The agents and actions that you want to appear most important in the mind of your reader should be used as the subjects and verbs of your sentences.
- The old information in a sentence should appear at the beginning, and the new information should appear at the end.
- Don't use different words to mean the same thing, especially for technical terms. For example, don't use both "stack frame" and "activation record."
- In technical text especially, prefer singular to plural. For example, in the sentence "lexical analyzers translate regular expressions into nondeterministic finite automata," how will you know if a single lexical analyzer translates one expression or many? Singular is clearer.
- To clarify the meaning of mathematical or terminological definitions in which no action is taking place, illustrate the definitions with plentiful examples.

By using testable principles, we stay within the educational culture of science and engineering: for each principle, you can test the hypothesis that applying the principle makes writing clearer.

The principles in Table 1 are organized more or less by scale; in general, earlier principles apply to smaller parts of a manuscript. I have starred principles that I consider especially valuable.

Principles

0. *Correctness.* Write correct English, but know that you have more latitude than your high-school English teachers may have given you.

⋆1. *Consistent names.* Refer to each significant character (algorithm, concept, language) using the same word everywhere. Give a significant new character a proper name.

⋆2. *Singular.* To distinguish one-to-one relationships from n-to-m relationships, refer to each item in the singular, not the plural.

⋆3. *Subjects, verbs, and objects.* Put your important characters in subjects, and join each subject to a verb that expresses a significant action. When applicable, say what object is acted upon.

4. *Definitions.* Mathematical definitions lack significant actions, so clarify them using examples.

⋆5. *Information flow.* In each sentence, move your reader from familiar information to new information.

6. *Emphasis.* For material you want to carry weight or be remembered, use the end of a sentence.

⋆7. *Coherence.* In a coherent passage, choose subjects that refer to a consistent set of related concepts.

⋆8. *Parallel structure.* Order your text so your reader can easily see how related concepts are different and how they are similar.

9. *Abstract.* In an abstract, don't enumerate a list of topics covered; instead, present the essential information found in your paper.

Practices

⋆1. *Write in brief daily sessions.* Ignore the common myth that successful writing requires large, uninterrupted blocks of time—instead, practice writing in brief, daily sessions.

2. *Focus on the process, not the product.* Don't worry about the size or quality of your *output*; instead, reward yourself for the consistency and regularity of your *input*.

3. *Prewrite.* Before you write, think, talk out loud, and jot down notes, diagrams, outlines, and so on.

4. *Use index cards.* Use them to plan a draft or to organize or reorganize a large unit like a section or chapter.

⋆5. *Write a Shitty First Draft*™. Value a first draft not because it's great but because it's there.

6. *Don't worry about page limits.* Write the paper you want, then cut it down to size.

7. *Cut.* Plan a revision session in which your only goal is to cut.

Table 1: Principles and practices of successful writers

Practices It's surprising how many books on writing talk only about the words on the page and not about what the writer is actually doing—how the writer behaves. These books are missing many important questions: Where do you write? When? How often? For how long? With what goals? How do you know when to stop? How do you think about writing? The answers to these questions affect not only your attitudes but also the amount and quality of the text you produce. Some of the research is astonishing (Boice 2000).

I call useful behaviors *practices*. Good practices change your behavior, which in turn can change your attitude, which in turn can change behavior, and so on in a virtuous cycle. Writing practices are personal, and a teacher ought not to prescribe given practices but rather should help you discover which ones are best for you. At one time or another, I have found each of the practices helpful, but my two favorites are to write in brief daily sessions (Practice 1) and to plan and revise using index cards (Practice 4). Use the group to discover your own favorites.

The practices in Table 1 are organized more or less by readiness; in general, earlier practices apply to manuscripts in earlier stages of being written. (Indeed, Practices 2, 3, and 4 apply primarily to manuscripts that have not yet begun to be written.) The exception is Practice 1, which applies to work at all stages. I have starred two practices; Practice 1 is singularly important in every stage of manuscript production, and Practice 5 helps students with the most difficult stage: the production of the first draft.

3.2 Exercises

The exercises below comprise most of what we do when I teach writing. Almost every exercise is designed to teach one of the principles in Table 1; an important exception is Exercise G, which although valuable, does not come with an articulated principle. Not all exercises are equally good; among the best are Exercises A, C, and G, which you can profitably do more than once.

The exercises are listed in an order in which it may be useful to do them.

Exercise A: Who does what to whom This exercise is based on Chapter 2 of Williams's *Style: Toward Clarity and Grace*. The big lesson from Chapter 2 is this: if you have certain ideas in your head about what agents and actions are most important, you will communicate those ideas most clearly if you make those agents and actions the subjects and verbs in your sentences. To help you learn how to apply this principle, here is an exercise in three parts.

The first part is about the ideas that form in your head as you read, not about the words on the page. Take the text, and as you read each paragraph, identify

- The important characters in the story
- The actions taken by those characters
- When applicable, the direct objects of those actions

Why include direct objects in Exercise A?

Williams talks only about the agents (characters) and the actions they take, not about the objects acted upon. It may be that using agents and actions as subjects and main verbs is enough to help you construct good sentences. But when you are planning a larger work—say to describe a complex experiment or a system in which hardware, software, and people all play a role—getting a handle on the direct objects is invaluable. It's common, for example, to find a character that is the agent of one action but the direct object of another action (the IDE controls the compiler but the user controls the IDE). It's also common to find relationships in which there may be agency in both directions (the n-gram statistics direct the classifier and the classifier updates the n-gram statistics). Capturing the relationships in table (or even in a directed, labeled graph) is a first step toward explaining them clearly.

Use *your own words* to identify the characters and their actions, not necessarily the words in the text. I recommend using a clean sheet of paper to create a table listing agents (who), actions (does what), and objects acted upon (to whom).

The second part is to go through the text again. Make a distinctive mark on the main subject and verb of each sentence. (I like to underline the subject and double-underline the verb.)

The third part is to compare. How consistent are the important characters and actions with the subjects and verbs used in the text? If you felt good about the text and enjoyed reading it, did you find that the characters and actions were consistent with the subjects and verbs? If you didn't enjoy the text, did you find that the characters and actions were inconsistent with the subjects and verbs?

Exercise B: Diction Sometimes it can be hard to work with agents and actions because the agents or actions are difficult to identify by name. Writing about research in computing can be especially difficult because there are so many new things for which there are no established names. To help with these problems, here are the three parts of Principle 1 (*Consistent names*):[1]

- *Give it a name.* Some writers try to dodge the issue by carefully avoiding naming things. Saying "our language," "the prototype system," or "the algorithm" doesn't do the job. Do your reader a favor and give your language, your system, or your algorithm a name.
- When you are talking about one idea, *always use the same word* or phrase.

[1] All the examples are from papers we have discussed in my group.

For example, don't call your idea "data dispersal" in one place and "revealing secrets" in another.

- When you are talking about different ideas, *never use the same word*. For example, don't use the word "system" to talk about a model, an algorithm, and a software artifact.

The exercise is to scrutinize a manuscript and identify places where names are misused or an important thing is unnamed. Reduce the number of names as needed, and choose effective names for each concept, agent, action, and object.

Exercise C: Old and new information This exercise is based on material from Chapter 3 of Williams's *Style: Toward Clarity and Grace*. The idea is to make text easier to read by considering the flow of information from one sentence to the next sentence within a paragraph. Williams argues that information flows best when old information is at the beginning and new information is at the end.

To learn how to apply this principle, here is an exercise in two parts.

- The first part is to go through the text and mark the old and new information in each sentence. I usually mark with a dotted underline for old information and a solid underline for new information, but you should mark using a system that works for you.
- The second part is to identify one or two sentences that you would like to revise based on information flow, and to suggest a revision for each.

Exercise D: Important information You may have difficulty identifying old and new information in Exercise C. A useful simplification is simply to mark the *most important* (new) information in each sentence. Discussion can proceed based on how many sentences place the most important information at the end—or how sentences might be revised by moving the most important information to the end.

Exercise E: Coherent subjects This exercise is also based on material from Chapter 3 of Williams's *Style: Toward Clarity and Grace*. The idea is to make a paragraph feel more coherent by considering the string of topics within the paragraph (Williams 1995, page 56).

To learn how to apply this principle, here is an exercise in two parts.

- Go through a paragraph and underline the first five or six words of each sentence.
- Study the topics for coherence. First, eliminate every outlier that simply refers to information from the end of the preceding sentence. Do the remaining topics seem to form a coherent sequence? If not, please *suggest* a sequence of topics you like better, then *revise* each sentence as needed to move the suggested topic to the beginning of the sentence.

Exercise F: Quick start Underline the first seven or eight words of each sentence. If the underlined portion does not contain an agent as subject and an action as verb, that sentence is a candidate for revision.

Exercise G: Structure of a section This exercise can help you with the structure of a section in a conference or journal paper or with the structure of a chapter in a thesis. The preparation is simple: each member of the writing group reads each paragraph of the section or chapter and answers two questions.

1. What is the purpose of this paragraph?
2. How well does it fulfill its purpose?

The first question is more important than the second. The hard part is distinguishing the *purpose* of a paragraph from the *content* of that paragraph. Roughly speaking, content is what a paragraph is about, while purpose usually has to do with causing an event to happen in a reader's mind. The group meeting needs a skilled moderator who can keep the group focused on purpose.

The fun comes in the meeting. *The author is not allowed to say anything.* Instead, the text has to speak for itself. The writing-group moderator will help the group form its collective impressions of the paragraphs. You can expect a lot from this exercise.

- It can be eye-opening for the author to learn how others read the text.
- It can let the author know how successful the section is in general.
- It can identify several kinds of structural problems:
  - Paragraphs that try to serve two or three purposes at once
  - Paragraphs the purpose of which is not obvious
  - Introductory material at the end of the section
  - Paragraphs serving the same purpose that are widely separated in the text
  - Redundant paragraphs

  There's generally no need to try to identify such problems in advance; these identifications emerge naturally from the discussion.

We've used this exercise successfully with sections of 10–20 paragraphs.

After doing this exercise, it may be helpful to use a deck of index cards to reorganize the section (Practice 4).

Exercise H: Parallel structure Much of scientific writing is about making comparisons. When two or more complex things are compared, a reader can follow more easily if the comparison uses parallel structure. Because more than one parallel structure is possible, part of the writer's job is to identify an effective one.

The exercise proceeds as follows:

1. Begin with a piece of scientific writing in which two or more alternatives are compared.

2. Break each alternative down into its atomic elements. (The choice of what elements are considered atomic is up to the author.)

3. For each atomic element in each alternative, consider how it relates to elements in other alternatives. There are three possibilities.

   - Elements are parallel because they are the same in multiple alternatives. For example, both XEmacs and GNU Emacs are free software released under the Gnu Public License.
   - Elements are parallel because although they are not the same, they are directly comparable; e.g., you have to choose among them. For example, XEmacs draws the screen by using the Xt toolkit, whereas GNU Emacs uses the X protocol directly and can work without a toolkit.
   - Elements in one alternative have no parallel in another alternative. For example, GNU Emacs is controlled by Richard Stallman, who is a well-known, controversial figure. No person of similar characteristics is associated with XEmacs.

4. Finally, and most difficult, choose a single structure that can be used to describe each of the alternatives, such that parallel elements appear in corresponding places in each description.

Identifying parallel and non-parallel elements can be done outside of group, but choosing a good parallel structure is best done during the group meeting.

If you want to go deeper into sentence structure, Williams's Chapters 8 and 9 show many examples of how large sentences can be structured, including using parallel structure. But be warned that I found these chapters more advanced and more difficult to learn from than the earlier chapters.

Exercise I: Singularity A common fault in computer-science writing is to use plural everywhere. In technical text especially, prefer singular to plural. For example, in the sentence "lexical analyzers translate regular expressions into nondeterministic finite automata," how will you know if a single lexical analyzer translates one expression or many? Singular is clearer.

The exercise is to tackle several paragraphs and eliminate as many plurals as possible (without changing the meaning of the text).

Exercise J: Cutting Many professional papers are limited to a fixed number of pages. To produce a paper within the limit, it is sometimes necessary to write a longer paper and then cut. Because it is so difficult to cut your own work, we suggest practicing cutting on someone else's work. It might be useful to experiment with cutting a section to $\frac{3}{4}$ or even $\frac{1}{2}$ of its original length.

Start this exercise with a section in which each paragraph has been labeled with its purpose, as in Exercise G. Use this information to decide how many jobs the section does within the paper as a whole. Based on this decision, cut in one of two ways:

- If the section does multiple jobs, perhaps one or more of those jobs can be eliminated. In this case, identify the paragraphs doing the work, and cut those paragraphs.

- Perhaps the section does only one job, or perhaps each of the jobs it does is essential. In this case, assign a *relative value* of each paragraph; an easy measure of value would be the ABC scale. Now cut the C paragraphs, followed by as many of the B paragraphs as needed to reach your length goals.

Make these kinds of cuts, repeating if necessary, until the text is at or just under the target length. Now re-examine and rewrite the section to be sure that it is still coherent, that transitions make sense, and so on. If this rewriting pushes you over the length limit, go back and cut again.

When cutting a technical paper, it is tempting to keep all the "real content" and to remove motivation and examples. Resist this temptation.

Exercise K: Writing the abstract Writing a scientific abstract is a specialized art. To practice this art, follow the advice given by Landes (1966): make sure the abstract includes the *essential information* presented in the paper (Depending on whether you have significant experience reading and analyzing technical papers, your teacher may wish to begin instead with Exercise L.)

To prepare for the exercise, the group leader should take a technical paper and remove the abstract. Since this is one of the few exercises for which group members will have to read an entire paper, it helps if the paper is well written, easy, and of interest to most members of the group.

The exercise has two parts:

- To prepare for writing group, read the paper and mark those points that you think constitute the "essential information" that should be presented in the abstract. Highlight, make a list, or do whatever works for you.

- In group, attempt to prepare abstracts at two of the more common lengths: 200 words and 50 words. As time permits you may also try 300 or 100 words. If you are motivated to write an abstract ahead of time, by all means do so.

If you are pressed for time and cannot read the whole paper, you may do almost as well by abstracting what you find in the introduction and conclusion.

Our experience is that an interesting paper usually requires two sessions: In the first session, we agree on what constitutes the essential information in the paper. In the second session, we write abstracts. Because the actual writing requires that we choose suitable subjects and verbs and manage the flow of information well, it helps to do this exercise after you can apply these techniques successfully.

Exercise L: Reading the abstract Finding the essential information in a paper requires real intellectual work, and if you don't already have practice doing this kind of work, it may be that your teacher won't have time to teach it. A reasonable substitute for Exercise K is to read some abstracts instead.

Choose a handful of abstracts. For easy reference, number each sentence of each abstract. The exercise is as follows:

- For each numbered sentence, say whether the sentence actually *presents* information or whether it merely *promises* information.
- Find the abstract that the group likes best, and the one that the group likes least. Is there any relationship between what the group likes and an abstract's ratio of promises to presentation?

3.3 Supplementary guidelines

We have developed some useful guidelines that we do not yet know how to turn into crisp principles or exercises.

Guideline 1: Explaining a technical concept Science and engineering often involve explaining new concepts. To help decide if the explanation of a new concept is adequate, here are some questions:

- Have I enumerated all the properties of the thing?
- Have I said whether the thing is completely characterized by those properties?
- Does each property have a name?
- If mathematical, does each property have a symbol?
- Have I said what *kind* of value each property is? (Integer, real number, string, symbolic expression, list, tree, graph, etc etc)
- Have I explained relationships that hold among the properties? Who or what guarantees that these relationships hold?
- If I have definitions in which no actions are taking place, have I illustrated each defined thing with examples?

Guideline 2: Checklist for technical exposition Here are some ideas, questions, and techniques we have found helpful when planning, organizing, and assessing a paper as a whole. Some of these ideas apply only to computer science.

- Have you identified the target audience?
- Have you told your reader what you expect? For example, should he or she just understand high-level ideas, or is it important to get all the details? What should a reader take away? For example, should your reader be led to draw a conclusion? Acquire a new skill?
- Do you have examples? They are helpful, and they should
  - Be plentiful
  - Use parallel structure
  - Be connected to each other when possible

  An ideal, when possible, is to use a single running example that appears in each section of the manuscript. (It may be supplemented by additional examples.)
- Is every general, abstract declaration illustrated by an example? For example, is a declaration such as "A constructor is used at compile time to build an abstraction" illustrated by an example such as "for example, a compiler might use the constructor `gbind` to build an environment that binds `main` to a procedure."?

Computer scientists often create artifacts that are too complex to be easily described. Here are some notes for presenting complicated technical abstractions:

- You may well have a nest of interrelated concepts for which there is no obvious order of presentation. To come up with an order, you may have to tell lies, i.e., make simplifications for pedagogical purposes. Such simplifications should be announced. For example, you could claim for pedagogical purposes that a variable stands for a number, not a location.

  Another technique is to mention a concept without defining it. For example, you might say "Let's assume that l is a location on the stack, without going into the details, which are in Section 12."

  Checklist: Is every concept mentioned before it is used? Are most concepts defined before use?
- Types help. Do you give the type of every operation?
- Do you explain the name of each variable? Do you explain what each Greek letter may stand for? For example, do you explain that ρ stands for an environment?

- When presenting abstract data types, we are aware of two styles. Hoare's style talks about the abstraction represented by a type and explains the concrete operations by their effects on the abstraction. For example, Hoare might explain an environment by using the abstraction of a set of bindings, and he might explain lookup by finding a binding with a given left-hand side.

  Algebraic or equational style (owing much to Goguen and Guttag) gives equations that relate concrete operations on the type. Equations can usually be turned into a term-rewriting system that can specify results returned by observers. For example, algebraic style might rewrite a lookup operation into the value looked up (by substituting equals for equals at every step).

  Checklist: Do you know what style you are using? Are your definitions and examples all consistent with that style? Do you wish to use both styles? If so, have you explained the redundancy to your reader?

References

Martha Beck. 2003 (July). Ready... Aim... Oh, well.... *Oprah* magazine.

> This short article suggests ways of overcoming (or working around) one's perfectionism. It may be useful for writers who have trouble producing.

Howard S. Becker. 1986. One right way. Chapter 3 of *Writing for Social Scientists: How to Start and Finish Your Thesis, Book, or Article*, Chicago Guides to Writing, Editing, and Publishing. University Of Chicago Press.

> This chapter debunks a few myths and contains helpful advice about writing practices.

Robert Boice. 2000. *Advice for New Faculty Members.* Allyn & Bacon.

> This book is full of priceless data and practical suggestions about what sorts of behaviors characterize writers who are successful, productive, and take pleasure in their work. Unfortunately, I find much of the material poorly presented or difficult to understand. It nevertheless repays careful reading. (Boice's older title, *Professors as Writers*, is well reviewed, but I have not read it.)

Joan Bolker. 1998. *Writing your dissertation in fifteen minutes a day: A guide to starting, revising, and finishing your doctoral thesis.* Macmillan.

> Bolker explains many of the same writing behaviors and habits that Boice (2000) does, but in a form specialized for doctoral students. As you might guess from the title, Bolker, like Boice, advocates for brief, daily sessions. If you find Boice difficult to read—full of jargon and written from a strange social-science point of view—then you might want to try Bolker. If you can translate her prescriptions from the doctoral setting to your own setting, or if you happen to be writing your doctoral dissertation right now, you will probably value her recommendations.

Kenneth A Bruffee. 1999. *Collaborative Learning: Higher Education, Interdependence, and the Authority of Knowledge.* Second edition. Johns Hopkins University Press.

> This book is somewhat controversial for its views of how people learn and what higher education really means, but I have found it invaluable for its suggestions about how to teach discussion classes.

Chicago Editorial Staff. 1993. *The Chicago Manual of Style: The Essential Guide for Writers, Editors, and Publishers*. University of Chicago Press, fourteenth edition.

I find this edition more readable than the fifteenth. The fifteenth edition does have a lot more information about citing electronic sources.

Lyn Dupré. 1998. *BUGS in Writing, a Guide to Debugging Your Prose*. Addison Wesley Professional, revised edition.

Though I can't fathom why, many computer scientists love this book. I much prefer Fowler (1968) or Garner (2003).

H. W. Fowler. 1968. *A Dictionary of Modern English Usage*. Oxford University Press, second edition. Revised by Sir Ernest Gowers.

Fowler's masterpiece is the original on which many later guides are modeled. Avoid the evil, permissive third edition.

Bryan A. Garner. 2003. *Garner's Modern American Usage*. Oxford University Press, second edition.

In my view, Garner has the best claim to be a legitimate successor to Fowler.

Billy Vaugh Koen. 1985. *Definition of the Engineering Method*. American Society for Engineering Education, Washington, DC.

Koen has written extensively on "the engineering method," which he identifies with the use of *heuristics*. All the principles and practices I teach are heuristics.

Kenneth K. Landes. 1966 (September). A scrutiny of the abstract. *Bulletin of the American Association of Petroleum Geologists*, 50(9):1992–1993. Accompanied by The Royal Society's "Guide for Preparation and Publication of Abstracts.".

Writing an abstract is an important but specialized skill. This one-page article explains what good and bad abstracts look like. Don't miss the author's lament about his science.

Joseph M. Williams. 1981. The phenomenology of error. *College Composition and Communication*, pages 152–168.

This brilliant paper supports my contention in Principle 0 that you don't have to pay much attention to the rules your high school English teachers taught you. If you've been browbeaten about rules, this paper will give you the ammunition you need to fight back—especially if you make it all the way to the end.

Joseph M. Williams. 1995. *Style: Toward Clarity and Grace*. University of Chicago Press.

> Repeatly described as a "master teacher" of writing, Williams has written widely on the topic. Of his works, this volume is among the most accessible and reasonably priced. And it's better than some of the later books written in collaboration, especially the posthumous ones.

Acknowledgments

For ideas, suggestions, and contributions to an early draft of this document, I'm very grateful to Kim Cooper. Among other tricks, Kim taught me to ask students for papers they had read and disliked. I also thank the Harvard Writing Project for supporting this work with a Gordon Gray Faculty Grant for Writing Pedagogy, and Dean Venkatesh Narayanamurti for additional financial support.

Marva Barnett introduced me to Bob Boice, and Christian Lindig introduced me to Joseph Williams. Without them, I wouldn't have anything to teach.

I learned Principle 2 (*Singular*) from an anonymous referee, to whom I shall be grateful until the day I retire.

In their Course Design Institute of January 2014, the Tufts Center for the Enhancement of Learning and Teaching gave me a number of intellectual tools which I have used to clarify my goals and to sharpen the exercises.

Finally, I am extremely grateful to the many students who made it possible for me to go from a bunch of vague ideas to a teaching method that works—and whose writing convinced my colleagues that I wasn't wasting everyone's time. I can't name them all, but I want to thank by name each of the research students who agreed that, as a condition of working with me, they would attend writing group once a week: João Dias, Paul Govereau, David Hiniker, Andrei Lapets, Clayton Myers, Reuben Olinsky, Daniel Peng, and Kevin Redwine. Not one of them complained.