Teach Technical Writing in Two Hours per Week

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October 25, 2006

Preface

Many students at American universities have trouble with technical writing. To help students over this trouble, we often use inefficient methods. These methods, like other aspects of graduate education, sometimes remind me of medieval apprenticeships. For example, I have known smart, capable teachers who were reduced to "teaching a student to write" by taking that student's first paper and rewriting it from start to finish. This booklet describes better methods.

Instead of spending most of my "student time" working on writing—teaching the same material to seniors, graduate students, and postdocs—I now teach writing in a weekly group. The group uses my time more effectively, and it shows students that they are not alone in their difficulties. The problems they have are problems that everyone has, and they see these problems even in published papers. But we do not emphasize problems; instead we emphasize useful principles and practices that students can learn to apply to their 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 beginning student can apply a simple test to see whether he or she is applying a given principle or following a given practice. This focus on testable ideas seems to work especially well for engineering students.

This booklet explains why you and your students might want to have a writing group. More important, it explains what we do in enough detail that I hope you can replicate the experience.

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Contents

1 Why bother?

Faculty have more than enough to do. So why spend time teaching writing? Because your students have to write, and nobody else will teach them.

Is there a problem? A solution? Writing can be a trouble spot for both students and faculty.

- Many students dread writing; many are unhappy with the results but don't know what to do. Others may not be aware of a problem, but they may find it difficult to get their work published or write their dissertations.
- Faculty's efforts to help students write better can consume lots of time and energy.

It is possible both to make the process of writing more pleasant and to improve the product. And if you want your students to write better but you don't want a new full-time job, there is good news:

- Teaching writing to a group, not to individuals, is especially effective.
- It is relatively easy to help students make significant improvements.
- You needn't be an expert in teaching writing.

How can you appeal to scientists or engineers, who may not be interested in writing? My writing groups are geared to *technical* writers.

1. I emphasize an empirical approach. My students and I analyze writing using empirical principles, which can be inculcated by exercises. Students can use the principles to change their writing and then evaluate the results right away: an author can see whether readers grasp the important ideas and whether they enjoy a paper. Readers' reactions help students decide for themselves whether applying the principles (and participating in the group) improves their writing.
2. I leverage students' knowledge about how research is conducted, students' training in careful reasoning, and students' appreciation of scientific or mathematical elegance. I emphasize parallels between research and writing: first thoughts are often off the mark; there are many dead ends; revision is essential to progress; elegance derives from—and often conceals—hard work.
3. In group, we continually return to the connection between writing and thinking. Although we start by looking at words in a row, we inevitably find ourselves discussing deep technical material. Better writing becomes better research.[1]

[1] Instructors benefit too. My contribution to the register-allocation paper I wrote with Mike Smith and Glenn Holloway emerged directly from a writing group's analysis of an earlier paper.

Doesn't study of writing take time away from research? Because students spend so much time and energy in the lab, they can come to view writing as a separate, secondary activity—a simple translation of their research into prose, which happens once the research is done. This misconception is terribly constraining. In my group, I try to teach students that

1. The purpose of technical writing is not to describe events that have happened in the lab but to cause events to happen in readers' minds.

2. Writing is thinking, and the best scientists view writing not as something separate from research but as a critical stage in that research.

3. Writing is a tool for discovery—to learn what we really know about a problem, we can write about it.

New views of writing help students use their writing to focus, refine, enhance—and thus ultimately speed up—their research.

Why a group? A writing group doesn't just make it possible to teach many students at once—it actually provides a better environment for students. The focus is not relentlessly on their own writing. They learn that others share their difficulties. They see lots of writing at their own level, but they also get to scrutinize professional writing. In this way, they can evaluate the utility of the principles they are learning and decide for themselves what works.

A group also helps because it's easier to learn new principles by practicing on other people's writing. Such practice gives students a better chance of applying the same principles to their own writing.

A group helps by *reading* students' work and responding to it. For an author, it is invaluable to see where readers do not understand; miss the point; or feel distracted, bored, or confused. One's advisor's reaction might be idiosyncratic, but when a group of one's peers reacts the same way, it is easier to accept that the flaw might lie in the text.

The group has another, less tangible benefit: it can help students feel part of a community of technical writers; it can help make technical writing a subject for discussion inside your department; in short, it can help make writing less isolating and lonely.

2 What I teach and with what ends in mind

Just as the purpose of writing is to cause events to happen in readers' minds, the purpose of teaching is to cause events to happen in students' minds. The events I wish to cause can be grouped under three particular goals:

1. My first goal is to change each student's *technique*—I want students to be able to apply the principles. Most students, if they apply just a few principles consistently, can improve their writing enormously.

2. My second goal is to change each student's *belief*—I want students to believe that paying attention to writing is good for them.

3. My third goal is to change each student's *attitude*—I hope that at least some students will come to enjoy writing.[2]

My long-term goal is that by the time he or she is ready to start a dissertation, each student will be a confident, clear, fluent writer.

Despite these lofty goals, if you observed my classroom, you would see that I focus almost exclusively on technique, and low-level technique at that. I do this because mastering technique will improve students' writing, seeing the improvement will show them the value of technique, and with luck, success will teach them to enjoy it. And eventually, perhaps, good technique will lead to good judgment. In the rest of this section, I describe the technique I have found useful and the outcomes you can expect when teaching it.

2.1 Summary of technique

The scientific method applied to writing

In American universities, writing instruction seems to be grounded in the humanities. Such instruction often leaves science students bewildered, or even thinking that writing instruction is a waste of time. I dare not pit my scholarly authority against that of other writing instructors, so I don't try; instead, I tell students to use the scientific method: to decide what writing techniques are useful, experiment.

I draw an analogy between a piece of writing and a controlled laboratory experiment: there is an independent variable (a text) and a dependent variable (a reader's reaction). After suggesting a particular kind of change in a text, I ask students to evaluate whether the corresponding change in the mind of the reader is an improvement. If so, this is experimental evidence in favor of the change—a persuasive argument for changing one's writing.

Writing instruction by hypothesis testing is a perfect fit for students in the sciences, because science students want claims that can be tested objectively. After all, the whole culture of science is about objective evaluation of claims.

[2] I've been able to write relatively easily since I entered graduate school, but for many years I hated writing—though I enjoyed *having written*. I didn't start to enjoy *writing* until maybe five years after my PhD. I'd like my own students to start sooner.

Principles and practices

The technique I teach is summarized by the principles and practices in Table 1 on page 16. A *principle* describes some property of a text; I try hard to phrase each principle so that a student can easily decide whether a particular text respects it. Each student 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 student to evaluate which practices make a difference, but we do read about and discuss some of Robert Boice's (2000) controlled experiments, which are quite convincing.

2.2 Expected outcomes

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

- Almost all students will improve. Some of the exercises in Section 4.2 are easy enough that students will see results immediately.
- Many students won't improve right away, or even for quite a while. There may be significant delays between the times a student understands a principle, recognizes related flaws in others' work, sees how to correct those flaws by applying the principle, and can apply the principle in his or her own work.
- In a 90-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 a group gains experience, it moves more often (and more quickly) towards ideas.
- Most of the time, you will find that readers prefer texts which respect the principles in Section 4.1. But you will probably 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.
- Your students will be able to learn a lot about writing in two hours per week; students should be able to leave each meeting feeling they understand something significant about their own and others' writing.

- In a semester, you will probably find it difficult to teach any particular student more than just 2 or 3 principles or practices—and even that much will be hard work. But if each student really internalizes 2 or 3 useful principles and consistently applies them to his or her own work, you (and your colleagues) will be impressed at how much better their writing gets.

3 Mechanics and pragmatics

Leading the writing group may be my most improvisational teaching. I cannot tell you how to improvise successfully, but in this section I can give a few suggestions about how to organize your group and how to structure and run each meeting. The first meeting is always special, but after that, plan for two different kinds of meetings: ones focused on principles and ones focused on practices. I describe both kinds, and I also give some suggestions for a syllabus.

Before reading the rest of this section, you may want to glance at Table 1 on page 16.

3.1 Expectations: preparation and meeting

Our goal is to teach technical writing in two hours per week: half an hour of preparation and an hour and a half of meeting. (Experienced students really do prepare in half an hour, but beginning students spend more time both on exercises and on supplementary reading.) 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. A student who doesn't show up learns nothing, and it's unfair for such a student, who seldom comments on others' work, to benefit from others' reading of his or her 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 students 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 students to evaluate events that happen in a reader's mind, not everyone will agree on the answers.

My main goal is that students be able to complete relevant exercises successfully. If they can do the exercises well (and if they can *remember* them in their own writing), they know enough to apply the principles to the drafting and revisions of their own texts.

Meetings about practices Some meetings will focus on practices of successful writers. A meeting focused on a practice will probably 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 students' own writing practices.

3.2 The first meeting

For the first few meetings of a new group, I like to analyze professional papers. Such papers provide an opportunity for tremendous frankness—students can complain bitterly without hurting anyone's feelings. Such papers also 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?

To engage the students in this enterprise, I invite them to bring examples of published papers they like and dislike:

> At our first meeting, I invite you to bring in a sample paper from the professional literature. If in the course of your classwork or your research, you have encountered a paper that you especially liked (or disliked), please bring it tomorrow, and during the term, we'll discuss some of them. I confess that it is often more satisfying to discuss bad papers, because it can be so easy to improve them.

Before the first meeting, I lend each student a copy of Williams,[3] and I ask the students to read the first chapter. With this background in place, here is what I do to launch a new writing group:

- I provide some introductions and explanations: what the group will be about, why we are doing this, and how we will use the principles, practices, and exercises.

- I give out copies of the student's edition of this booklet.

- I talk a bit about Principle 0 (correct English). Most of my students have no difficulty writing correct English, but many of them have had teachers who gave them an unreasonably narrow idea of what is correct. I rarely spend class time on questions of usage, but at the first meeting I come armed with a stack of authorities, and I encourage students to do some browsing and to broaden their ideas of what is acceptable.

  My favorite authorities are Fowler (1968) and Garner (2003). For questions related to punctuation and typesetting, I like *The Chicago Manual of Style* (Chicago 1993). Finally, many computer scientists seem to like Dupré (1998). Although I myself dislike the book, I recommend it anyway.

- I ask each student to talk a bit about papers he or she has brought to the meeting—at minimum, I collect the papers that are especially liked and especially disliked.

After that, my main goal is to talk with students about their impressions of Williams, Chapter 1, and to be sure that they understand the idea of using the experimental method to evaluate a principle:

1. Learn how to decide if a text complies with the principle.

2. Compare a compliant text with a non-compliant text.

[3] My students' work in writing group is above and beyond their usual courseloads. To avoid provoking resentment, I don't require them to buy anything. A few smart ones always wind up buying their own copies.

3. Decide which, as a reader, you like better.

Then, if you find a principle you like, you can go on to advanced work:

4. Transform a non-compliant text into a compliant text.

3.3 How to organize a meeting about a principle

Before the meeting

1. Choose a text and an exercise. Not every text works well for every exercise; if something goes wrong, it is usually because you are trying to do a relatively advanced exercise using a text in which the basics are not right. (You can take "advanced" to mean "later in Williams.") You therefore should make your choice in one of two ways:

   - Have an exercise in mind and choose a text to fit. A good reason to do this is that you are trying to proceed logically through some sort of syllabus.
   - Have a text in mind and choose an exercise to fit. A good reason to do this is that you are trying to give a student feedback on his or her work.

   Beginning students may feel less threatened if they discuss a paper from the literature. My students, who are experienced and who are accustomed to discussing writing, are much more motivated to study and discuss a text written by a member of the group. I therefore try to help students master *Subjects and verbs* (Principle 3) and *Information flow* (Principle 4) as soon as possible. Once they get those principles down, their own texts are usually suitable for a variety of exercises.

2. Prepare the text for distribution. For most exercises, it is useful to label each such paragraph with a letter and to number each sentence within those paragraphs (there's an example in Section 5.1). During discussion, participants can then easily refer to "sentence 2 of paragraph A," for example. If you are doing a long exercise such as Exercise G, it's sufficient just to label each paragraph with a letter.

3. Send the text and exercise to the students, with instructions that they spend about 30 minutes on it. Distribute the labeled paper at least 48 hours in advance—one cannot have a productive discussion of a paper that students have only skimmed.

During the meeting I structure the meeting around the exercise.

- I typically work my way around the room, asking each student about one sentence or one paragraph, depending on the scope of the exercise. After each student's answer, I ask for other students' opinions. I often write all suggestions on the board.

- I listen carefully to help students avoid any pitfalls that I associate with the exercise. (Section 4.2 discusses potential pitfalls.) I continually ask students to distinguish a text's objective, measurable properties from their feelings about that text, then to correlate them.

- I carefully listen to and shape the students' comments about the text. When the text is written by a student author, handling comments is especially important; an analysis appears below.

- If the group feels that revisions are called for, I will sometimes ask for suggestions. Depending on context, I may stop the process after general suggestions, or we may write new sentences.

A meeting focused on an exercise feels something like a problem session that one might conduct for a class in math or physics.

3.4 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.

One of the leader's most important roles is to help develop vague comments into something useful. Students need a vocabulary with which to discuss elements of their papers and to analyze texts that are poorly received. They need ideas for creating alternatives. It's often helpful for the leader to ask readers to put themselves in the author's mind: What did the author think was most important? What effect was the author hoping to achieve in the reader's mind?

When the author is a member of the group, comments must be handled especially carefully. When a student's paper is being discussed, we may ask him or her not to speak. In part, we do this to be sure that any comments are made in response not to the author but to the words on the page. In part, we do it to mimic the process of professional reviewing; after all, when an author sends a paper out for review, the author can't enter into a discussion to explain what he or she really meant. And in part, we do it to give the author space to focus his or her full attention on what the readers are saying, without being distracted by thinking about how to formulate a response. (It also helps that the readers can focus on the text without being distracted by the author.) After the discussion, we always invite the author to respond. Be sure to leave time for this response—the participants can learn a lot from hearing what the author intended.

When a text is being discussed, we encourage the author to take notes. It is surprisingly difficult to remember what is said; no matter how sympathetic the group and how mature the author, there is something intense and sensitive about having one's work discussed. The intensity of the experience can make it hard to hear and remember everything as it is being said. We have even used a microphone to record discussions, especially when discussing a draft that is nearly ready to be submitted.

3.5 How to organize a meeting about a practice

In a meeting focused on practices, my main goals are that students become aware of their own writing practices, and that each student may identify a new practice that he or she might wish to try—or an old practice that might be best abandoned. Because the external supporting readings are not as crisp, and because my own material is less well developed, these meetings are less structured and more difficult to conduct.

Before the meeting

1. Choose a reading. I usually choose a chapter from Boice (2000). I have also sometimes used Becker (1986) or Beck (2003). Your university writing center may also have some suggestions.

   The chapters from Boice are short but dense; in a 90-minute meeting, don't try to cover more than one.

2. Distribute the reading.

3. Prepare a few questions to guide discussion during the meeting. (A sample of the kinds of questions I have used can be found in Section 5.3.)

During the meeting I generally arrange the meeting as a discussion, and I conduct the discussion using the same teaching methods that I use in my advanced graduate seminars. For these kinds of classes, Bruffee (1999) recommends small-group discussion of prepared questions, followed by a plenary meeting of the entire class. Although I do not share Bruffee's obsession with the social construction of knowledge, I have found his teaching methods effective.

3.6 How to plan a syllabus

A short syllabus If you and your students want just to try out a writing group and see if it does anything for you, you might be able to do something interesting in two meetings.

- The first meeting, which is described at length on page 8, should focus on the empirical method.
- For the second meeting, I recommend Exercise A. In my experience, this exercise is the most likely to show students how discussions of writing can lead to discussions of research ideas.

A long syllabus It's not productive to try to plan a rigid syllabus in advance. If students haven't mastered basic principles, there's no point in teaching advanced ones. And it's well known that under pressure, writers typically forget the new things they've learned, making it useful to go back to basics. So instead if a syllabus, the most I can give you are some ideas about what to do when.

- If you meet once a week for an academic year (about thirty meetings), that's enough to get students exposed to all of the principles and practices on page 16, and to get them real experience with a significant fraction (maybe two-thirds of the principles and one-third of the practices). To expect mastery would be unrealistic; if your students master two or three principles and maybe a practice, be very happy.
- During the course of a semester (or year), plan for your students to follow three arcs: from small scale to large scale, from technique to ideas, and from discomfort to comfort.
- The principles on page 16 are organized from small scale to large scale, but this is not the right order in which to learn to apply them. Instead, follow the order in Williams. In particular, plan explicit exercises on *Subjects and verbs* (Principle 3, Exercise A and possibly also B), *Information flow* (Principle 4, Exercises C and D), *Coherence* (Principle 6, Exercises E and F), and *Abstract* (Principle 8, Exercise K), in that order. Plan at least two or three meetings for *Subjects and verbs* and *Information flow*, one or two meetings for *Coherence*, and two meetings for *Abstract*.
- *Structure of a section* (Exercise G) is an exercise in search of a principle, but it is nevertheless worth doing at least twice. This exercise can really help a student organize a chapter in a thesis or a difficult section in a paper. Postpone the exercise until your students have a good chance of writing reasonably coherent paragraphs with well-chosen subjects and verbs.
- *Parallel structure* (Principle 7, Exercise H) is a bit tricky. If you're lucky, you'll get a student's text in which you can plan to discuss parallel structure. Watch for an opportunity.

- *Consistent names* (Principle 1, Exercise B) and *Singular* (Principle 2, Exercise I) are best covered opportunistically on the fly, as they arise in some text.

- I can't give you much guidance about practices—which practices are helpful depends on the needs and even the personalities of your students. All the practices are valuable, but the one that is really essential, because it runs so counter to established myths and practices in our field, is *Write in brief daily sessions* (Practice 1). The experimental data are all there in Boice's research.

  Many students have trouble getting started; for them you may want to discuss *Prewrite* (Practice 3) and *Write a Shitty First Draft* (Practice 5). Our undergraduate students are often very worried about whether their initial work is good enough (thank you, Harvard); for them, we discuss *Focus on the process, not the product* (Practice 2). Beck's (2003) article on perfectionism can be interesting reading.

  In my own writing, my most valuable weapons are brief daily sessions (Practice 1) and index cards (Practice 4).

4 Principles, practices, exercises, and guidelines

This section sets forth what I actually teach: principles, practices, and guidelines for successful writers, together with exercises that will help students master the principles. The principles and practices are listed in Table 1 on page 16. 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.

4.1 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.

By using testable principles, we stay within the educational culture of science: for each principle, students 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.

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

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 and verbs.* Put your important characters in subjects, and join each subject to a verb that expresses a significant action.

⋆4. *Information flow.* In each sentence, move your reader from familiar information to new information.

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

⋆6. *Coherence.* In a coherent passage, choose subjects that refer to a consistent set of related concepts.

⋆7. *Parallel structure.* Order your text so your reader can easily see how related concepts are different and how they are similar.

8. *Abstract.* In an abstract, don't enumerate a list of topics covered; instead, convey 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.* Don't be afraid to think before you write, or even jot down notes, diagrams, 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

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 are all about changing students' behavior, which in turn can change their attitudes, which in turn can change behavior, and so on in a virtuous cycle. Writing practices are highly personal, and the role of the writing group is not to prescribe given practices but to help students discover which ones are best for them. 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 help each student discover which practices work best for him or her.

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 Practice 1 because of its singular importance and Practice 5 because my students consistently have great difficulty writing first drafts.

4.2 Exercises

The exercises below comprise most of what we do in my writing groups. 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 repeatedly.

The exercises are listed in an order in which it may be useful to do them. Most have been tested thoroughly; those not so tested are clearly identified.

Exercise A: Agents and actions 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

Use *your own words* to identify the characters and their actions, not necessarily the words in the text. You will probably find it easiest to take notes in the margin or on another sheet of paper.

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 make comparisons. 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?

For the instructor: *My experience with this exercise varies widely, but at its best, this is by far the most interesting of the exercises. Discussion of agents and actions can produce deep insight into research. The exercise can lead to significant revisions in the text, including revisions that cross paragraphs.*

The big pitfall in this exercise is to use the exact words found in the text as one's description of agents or actions. Coming up with descriptions in one's own words often requires real intellectual effort, but the effort can be repaid by a better understanding of the material.

Other notes:

- *A question that sometimes comes up here is whether two different words are used to mean the same thing. Less often, a single word may be used with two different meanings. I usually suggest rewording to avoid such problems (Exercise B).*
- *As part of this exercise, when some agents and actions are on the board, it can be quite helpful to get the group to work out what entities are truly distinct and how they relate to one another.*

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*):[4]

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

[4] All the examples are from papers we have discussed.

- 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.

For the instructor: *Beginners, especially undergraduates, consistently have trouble with diction. And even an experienced writer can forget to name the new baby.*

I've never devoted a meeting to this exercise; instead, I handle the principle when it comes up in a student's paper. But depending on the text, a class that intends to do Agents and actions *(Exercise A) may well wind up doing this exercise instead.*

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.

For the instructor: *I'm always surprised at how much trouble students have with this exercise. The difficulty seems to be in identifying what information is old and what information is new. If your students also have trouble, you may want to try the next exercise instead.*

Exercise D: Important information Students sometimes 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.

For the instructor: *I've had mixed results with this exercise. In the professional literature, we have read some truly impressive paragraphs, which stuck to one or two coherent subjects without seeming boring or repetitive. On the other hand, when we try to do the trick ourselves, it can require complete disassembly and reassembly of several paragraphs, which in turn requires real insight into the author's intentions. When it works, it's great, but I haven't yet figured out when it can be done without destroying the paragraph. In other words, I have had a hard time figuring out in advance whether a text will work well with this exercise.*

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.

For the instructor: *Williams suggests this exercise, but I have not actually used it.*

Exercise G: Structure of a section This exercise can help an author 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. During the meeting, you will find you must continually 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. We've had good experiences with 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).

For the instructor: *This exercise can be very helpful to the student who has a draft that may be submitted within a few weeks. As noted above, you'll have to lean hard on people to force them to distinguish* contents *from* purpose.

A paper suggested with this exercise in mind may also be suited to Parallel structure *(Exercise H). Prefer Exercise H; you can do* Structure of a section *with any paper, and opportunities to teach parallel structure should not be overlooked.*

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.

For the instructor: *Parallel structure is a very powerful technique, and in technical writing it comes up often. When applied to a few pages of a student's manuscript, the exercise can be extremely effective. When your students have drafts, watch for an opportunity to teach parallel structure. You may also try to help them use parallel structure to discover whether their comparisons are fully thought out.*

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).

For the instructor: *I've never found it worthwhile to spend a whole meeting on this exercise. Instead, when the opportunity presents itself, I hammer away at the principle.*

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 one's own work, we suggest practicing cutting on someone else's work. We plan 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.

For the instructor: *It is very difficult to cut one's own work. Unless a member of the group has a paper that needs cutting to meet a length limit, it may be better to practice these techniques on a published paper. It should not be hard to find a journal paper that could be improved by vigorous cutting.*

I haven't actually used this exercise.

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.

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 conveyed in the abstract. Highlight, make a list, or do whatever works for you.

- In group, we will attempt to prepare abstracts at two of the more common lengths: 200 words and 50 words. As time permits we 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 $1\frac{1}{2}$-hour 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 your students can apply these techniques successfully.

For the instructor: *Abstract writing is a niche skill but an important one. If you have the luxury of many meetings, you may well wish to teach it. If you wait until late in the year, you'll be able to see if your students can successfully apply other principles (like information flow) to the writing of the abstract itself.*

4.3 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?

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?

5 Sample materials from my group

5.1 A text for applying principles

Here are two paragraphs from a beginning student's draft, marked up for use in an exercise. Such a text might be suitable for Exercises A, C, D, E, or F. I believe I chose this particular text for Exercise A.

Paragraph A

1 One solution to this problem and related problems associated with
the impact of large trades is the use of so-called "upstairs markets"
in which broker/dealers shop around large orders to others without
2 revealing the details of the transaction to the public. Market makers
conduct large transactions by mutual agreement, often at a discount
to the prevailing market price, without having to use the more obvi-
3 ous "downstairs markets." Both upstairs and downstairs markets
suffer from the problem of "front-running," in which someone who
knows about an upcoming order is able to execute a trade that takes
4 advantage of that knowledge. Sometimes, this is illegal, when the
front-running is based on inside information; in other cases, it is
merely parasitic, when one trader recognizes the habits of another
trader or sees an incoming large order and is able to act quickly to
5 place a trade before it hits the marketplace. Quite recently, im-
portant market businesses have been investigated and charged with
violations of SEC regulations due to illegal front-running practices.

Paragraph B

1 In upstairs markets, trading large blocks of stock can take more time
and is more prone to negotiation; fewer participants are able to eval-
2 uate the transactions. This ultimately may lead to less competitive
3 prices for those buying or selling. Our solution to this problem is the
use of a homomorphic encryption scheme, similar to that described
by Paillier (1999), to preserve the secrecy of the details of investors'
limit orders while proving that the market is operating according to
4 its published rules. For each order, we encrypt the price and the
5 quantity and place them in an open marketplace. When two orders
"meet," i.e., a buy and sell order have compatible price (buyer's
bid $\geq$ seller's ask), the market notifies the traders and the orders
6 are removed from the marketplace. An appropriate clearinghouse
completes the transaction.

5.2 Papers from the literature

You can pick almost any paper and learn something useful. But if you want a recommendation from me, here are two:

- Xavier Leroy's 1994 POPL paper "Manifest types, modules, and separate compilation" beautifully illustrates many of the principles.
- I hesitate to say this in public, but if you want good ideas badly described, try David Parnas's classic paper "On the Criteria for Decomposing Systems into Modules."

5.3 Discussion questions for writing practices

This section contains some discussion questions I have used in meetings focused on practices of successful writers.

Mindful ways of writing The source for these questions is Boice (2000), Introduction to Part II: *Writing in Mindful Ways*, and Chapter 9: *Wait*.

1. On pages 103–105, Boice enumerates eight reasons why people have difficulty with writing. Which of these are yours? What others are missed? What, at present, is the greatest impediment to your writing?
2. On pages 111–112, Boice enumerates six practices of successful writers. He then restates these practices as bullet points. Do you apply any of these practices in your own work? If there are practices you do *not* apply, which one do you find most appealing?

   (This question may be difficult because the practices are not so easy to understand.)
3. What role do your emotions play in your ability to write?
4. I find the advice in Chapter 9 (*Wait*) to be among the most difficult to understand of all of Boice's book. Can you restate it in your own words? It may help to state the advice negatively: that is, what is it that Boice suggests you *stop* doing?

The questions above are more than enough for a 90-minute session. But here are some more:

5. Do you have a "writing site?" If so, what do you do when you first arrive at your writing site?

   Do you have distinctive tools or materials? Do these help? Do you think they would help?
6. Does your writing suffer from "prolonged procrastination followed by rushed beginnings under deadlines?"
7. How might you apply "precommitment" and visualization to your own writing?

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.)

Bruffee, Kenneth A. 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.

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 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.

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.

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 every week: João Dias, Paul Govereau, David Hiniker, Andrei Lapets, Clayton Myers, Reuben Olinsky, Daniel Peng, and Kevin Redwine. Not one of them complained.

Afterword

This booklet has been a long time coming. I would love to explain the material in more depth and (of course) craft the writing to a higher degree of clarity. But the best is the enemy of the good, and I have chosen to get the booklet out the door. Although there are some significant gaps—I would especially like to write an explanation of each of the practices in Table 1—I believe that the booklet will be useful for its principles, practices, and exercises. If you find it so (or not), please drop me a line.