IMPROVING COHERENCE IN TECHNICAL WRITING

G.K. SURAISHKUMAR
Indian Institute of Technology • Bombay, Powai, Mumbai 400 076, India

It is a well-recognized fact that effective technical communication is a skill that graduate/undergraduate students in engineering disciplines need to develop, and many good suggestions have been made[1-6] to improve it. Although good communication involves good skills in writing, speaking, reading, and listening (<www.writing-reading.com> accessed on 3 Feb 2003), we usually concentrate on developing only the speaking (presentation) and writing skills in students. Between the two, it is usually more difficult to develop good writing skills, probably because it requires higher clarity and rigor in the thought processes. Furthermore, there is a general notion that one learns to write well in the same way that one learns to ride a bicycle, to play a musical instrument,[7] or to swim—in an experiential manner.

When graduate students write their first manuscripts, spelling and grammatical aspects are addressed first, either by a person comfortable with the language or by a word processor. A grammatically correct document may not always read well, however. Often, advisers know that the manuscript is not written well, but cannot clearly explain why. They tend to talk about "clarity" and "style" (as distinct from that described in the Chicago or the American Chemical Society style manuals), and further confuse the student. Ultimately, the adviser might say something like, "It's all in there—you just need to communicate it better," and without further direction, ask the student to rewrite the paper.

Students typically rewrite their first manuscript many times, and the writing improves intuitively with each progression. Throughout this process, it is helpful if the student reads well-written scientific literature.[8] When the adviser finally accepts the manuscript, the student knows that the final draft is written better, but is usually not aware of *why* the paper is improved. These same students later become professors/advisers, attesting to the fact that university teaching is probably the only skilled profession for which there is no formal training (<www.ncsu.edu/felder-public/RMF.html> accessed on 3 Feb 2003), and the cycle continues.

This article presents a reasonably structured approach that faculty members can use to improve the writing skills of students. Alternatively, it also provides a direction for the not-so-experienced writers of scientific material to consciously improve their writing skills.

COHERENCE

Good communication, in either written or oral form, results from a solid knowledge of the subject, a clear awareness of the aspects that need to be communicated (and those that need to be left out), clear thinking, and good organization, assuming that the language (grammar, spelling, and pronunciation) are also addressed. For the most appropriate organization, one should be aware of how the reader/listener will perceive the information. In other words, one needs the ability to "tell a story," or the ability to coherently present *relevant* material. In fact, many advisers ask the question, "What is your story?" when they discuss a student's research work. The above requirements are even more critical in written communication because the communicator is not present when the receiver reads the document, unlike an oral presentation when the communicator can draw on nonverbal communication cues to bolster the material.

G.K. Suraishkumar *is currently Associate Professor in the Chemical Engineering Department at Indian Institute of Technology, Bombay. He received his B.Tech from the Indian Institute of Technology, Madras, and his PhD from Drexel University in Philadelphia. His current research interest is in the area of free radical based improvements in the productivity of bioreactors. He can be reached at <gksuresh@che.iitb.ac.in>.*

A fairy tale is a good example of coherent presentation. Children can listen to a fairy tale being read and completely understand the story, even if they are sleepy at the time. If engineering students could embrace the same simplicity and coherence embodied in a fairy tale when they present scientific material, their message would be more easily understood.

This idea led to an exercise for students taking a M.Tech (graduate level) communication skills course at the Indian Institute of Technology, Bombay. They were required to narrate a fairy tale in front of the class. Many of them could not coherently narrate even a simple fairy tale such as Cinderella the first time they tried. One example: "Cinderella is that girl who wore a shoe. The Prince found her with the shoe. She went to the ball in a chariot made from a pumpkin. There was a fairy that helped her. While running away from the ball she lost one of her shoes. Cinderella had a wicked stepmother and two stepsisters...." A chronological organization of information, a crucial requirement for delivery of the tale, was completely absent.

Faculty members quite often find the same type of disorganization in a first draft of a report or manuscript written by a student. The presentation is a recital of mere facts, written in the order of recall without bothering about the relationship between them.

There is an important distinction between a fairy tale and a scientific narrative, however—the concept of external and internal times.[9,10] External time refers to the time taken for the actual presentation and internal time refers to the duration of the sequence of events in the presentation. For example, if narrating the Cinderella story takes fifteen minutes, then the external time is fifteen minutes; the internal time is the days or months or years over which the story is set. While external time is relevant for both types of presentations, the internal time is normally absent in a scientific narrative (except, perhaps, in a background/introduction section). Instead of a chronological detailing of internal time, a logical sequence of scientific information (facts, graphs, tables, derived information, discussion, etc.) is present. Students usually develop this ability to present material in a logical sequence through experience.

TOOLS FOR COHERENCE

Students can be encouraged to develop a logical sequence of presentation, as described in a later section. Here we will consider the tools that can be used to improve coherence (see <papyr.com/hypertextbooks/engl_126/book126.htm> accessed 3 Feb 2003) and communication of the material after it is logically sequenced.

To appreciate the use of tools, consider this well-written passage by Bird,[11] which has been slightly adapted:

> In educational circles today we hear a great deal about teaching and research. However, we hear very little about the activity of book-writing, which ought to be included as a third principal activity of a university teacher since it is concerned directly with the production, evaluation, organization, and dissemination of new knowledge.

Good communication, in either written or oral form, results from a solid knowledge of the subject, a clear awareness of the aspects that need to be communicated (and those that need to be left out), clear thinking, and good organization, assuming that the language (grammar, spelling, and pronunciation) are also addressed.

> Therefore, I thought it might be useful to use this lecture to focus attention on the "rites, rewards, and responsibilities" of book authorship. Since I have had the pleasure and good fortune to coauthor several books, perhaps I can offer some appropriate words of encouragement to aspiring writers and even a few helpful suggestions regarding the art of writing. Maybe I can help others avoid some of the mistakes I've made. From time to time I will cite specific personal experiences in order to avoid discussing the problems of authorship in the abstract.
>
> ***What Kind of Books do Chemical Engineers Need?***
>
> A library of professional volumes includes various classes of books: (i) *edited volumes* to present very recent developments by teams of experts; (ii) *research monographs* to catalog and evaluate the research published in the preceding 5-10 years; (iii) *treatises* to give authoritative, encyclopedic coverage to one particular topic; (iv) *textbooks* to set forth the basic ideas in the field in a form suitable for students; (v) *handbooks* to summarize standard results of widespread use; and (vi) *design manuals* to provide up-to-date procedures for practicing engineers. Each of these categories has a different audience, and each requires special organizational talents. Generally speaking, there is a flow of information from (i) toward (vi) in the above listing—that is, from innovative, exploratory, and (sometimes) impractical ideas of the researcher all the way to the time-tested and reliable tools of the practitioner. Along the way many ideas and methods are inevitably discarded, and only the most useful material survives to the arena of industrial practice. But without this constant exploration of new ideas and subsequent filtration, a profession can stagnate and atrophy.

■ **Repetition** is an important tool for improving coherence. In the above example, Bird repeats the word "book(s)" in a few places to build coherence.

■ If repetition becomes boring, **synonymy** can be used; *e.g.*, Bird uses the word "volumes" to avoid a tiresome repetition of the word "books" in the first sentence of the last paragraph. Similarly, **antonymy** (using an opposite word) can improve coherence; *e.g.*, see the use of "impractical ideas" and "reliable tools" in the same sentence in the last paragraph.

■ The **pronoun** is commonly used to improve coherence between sentences; *e.g.,* the pronoun "it" is used to refer to "book-writing" in the first paragraph. Also, **parallelism**, which refers to the use of the same sentence structure in subsequent sentences, improves coherence.

■ A tool that is commonly used by engineers is **enumeration**, which refers to the use of specific markers of sequence to achieve a connection between thoughts. A good example of enumeration appears in the second paragraph in which Bird uses enumeration to link the various classes of books.

■ A tool that students learn easily is **transition.** Transitions are conjunctions or conjunctive adverbs that link sentences with specific logical relationships. They can be subcategorized according to their meaning (see <papyr.com/hypertextbooks/engl_126/book126.htm> accessed on 3 Feb 2003) as follows:

Identity • Indicates sameness (that is, in other words)

Opposition • Indicates contrast (but, yet, however, nevertheless, still, though, although, whereas, in contrast, rather)

Addition • Indicates continuation (and, too, also, furthermore, moreover, in addition, besides, in the same way, again, another, similarly, a similar, the same)

Cause and effect • (therefore, so, consequently, as a consequence, thus, as a result, hence, it follows that, because, since, for)

Indefinites • Indicates a logical connection of an unspecified type (in fact, indeed, now)

Concession • Indicates a willingness to consider the other side (admittedly, I admit, true, I grant, of course, naturally, some believe, it has been claimed that, once it was believed, there are those who would say)

Exemplification • Indicates a shift from a more general or abstract idea to a more specific or concrete idea (for example, for instance, after all, an illustration of, even, indeed, in fact, it is true, of course, specifically, to be specific, that is, to illustrate, truly)

It is easy to identify the use of transitions in the Bird example. These coherence tools can be used to improve scientific writing. While it is unlikely that Bird was aware of the coherence tools he used while writing, a faculty member should encourage a novice writer to use the tools consciously until a time when they become a subconscious part of the writing process.

STRUCTURED APPROACH FOR COHERENCE

Coherence tools can only help improve something that was initially reasonably well written. The following structured approach is one way by which well-written drafts can be achieved. It is neither a panacea nor the only way, however, since there are innumerable factors that contribute to good writing, including the writer's own personality.

The Preliminaries

1. The writer must have the requisite knowledge/information before beginning to write. This is an absolute prerequisite.
2. If a manuscript is for journal publication, a thesis, or a report, a substantial number of discussion aspects (say, 50%) should be clear to the student before writing begins. The student should be encouraged to analyze scientific material and note the salient points for discussion, with clarity, before writing anything. Many first manuscript drafts are poor in the discussion of data/simulations.
3. The student should be relaxed; (s)he should be encouraged to drink a glass of water or to take a few deep breaths, taking care to exhale more slowly than during inhalation. Then the student should take a few blank sheets, a pencil and an eraser (or a word processor), and sit where (s)he will not be disturbed.

The Questions

Now the student should ask himself/herself the following questions and incorporate the suggestions that follow them. To illustrate, I will present an example of my own thought processes while writing a paper a few years ago.

What is the main idea that I need to communicate?

For example, we had just discovered that induced free radicals could improve the productivity of cells in bioreactors, and we were very excited about it. Therefore, the main idea that we wished to communicate was "induced free radicals can be used as a novel means to improve bioreactor productivity." Considerable thought may be required for first-time writers to recognize the main idea to be communicated, but that is the absolute starting place.

How do I communicate the main idea?

This is fairly simple for engineers/scientists who are normally bound by the required format of a journal, the university, or a funding agency. Typically, we are required to communicate the main idea in various sections, such as Introduction, Materials and Methods, Mathematical Model, Results and Discussion, Conclusions, Nomenclature, References, Appendices, etc. Also, we rarely use anything except a linear presentation of information, which makes this aspect very simple.

Taking one section at a time, ask the question, "What do I want to communicate in this section?"

Jotting It down

Write down the points as they occur to you.

For example, what do I want to communicate in the Introduction of the manuscript on induced free radicals? We were excited about the **novelty** of the strategy—therefore I needed to communicate that. I also wanted to communicate the various **contributions** we have made in this work. In addition, I wanted to tell the readers what **motivated** us to do the work, and since the typical reader of this journal was unlikely to know much about free radicals, I needed to give the **relevant background on free radicals.** Also, to provide focus, I wanted to present the **overall aim and objectives of the work.**

If the information is given in the order above, the readers (who will most probably not be familiar with the work) will find it difficult to understand. But if the same information is presented in a logical sequence, the reader's understanding and the paper's readability would improve significantly.

Ordering

Put yourself in the reader's position and then logically order the aspects written in bold in the above section. One possible list would be

1. Relevant background on free radicals
2. Motivation for the work
3. Novelty of the strategy
4. Overall aim and objectives, along with contributions

Jotting Down: Paragraph Level

Addressing the items in the list above, I first determined what it was that I wanted to communicate to the reader and noted the points down on a piece of paper as I thought of them. They were that: 1) Free radicals can be expected to improve bioreactor productivity; 2) They mediate cell processes such as cancer, apoptosis, etc.; and 3) They are suspected mediators of the effects of temperature, osmolarity, and nutrient levels (important bioreactor variables) on cells.

Logical Ordering: Paragraph Level

If I had written the points down in the order listed above, an intelligent lay-person (the common reader) would have found my message difficult to understand. Therefore, putting myself in the reader's position showed me that I needed to reorder the points for better understanding. One possibility was: 1) Free radicals are known to mediate a number of cell processes, including apoptosis and cancer (citing references); 2) Free radicals are suspected of being mediators of the effects of temperature, osmolarity, and nutrient levels on cells (citing references), which are also important bioreactor environment variables; and 3) Free radicals can be expected to play a significant role in determining bioreactor productivity. Note that in the process, I also improved the accuracy of the information.

Linking Sentences: Paragraph Level

Next, the sentences should be linked to improve coherence, using the various linking tools mentioned earlier:

> Free radicals are known to mediate a number of significant cell processes, including apoptosis and cancer (Feig and Loeb, 1994; Feig, et al., 1994: Okuno, et al., 1998; Reid and Loeb, 1993). **Further**, free radicals are suspected of being mediators of the effects of temperature, osmolarity, and nutrient levels on cells (Nagarathnamma, et al., 1997; Osbourn, et al., 1990), which are also important bioreactor environment variables. **Therefore**, free radicals can be expected to play a significant role in determining bioreactor productivity.

Note that in addition to the transition tools indicated in bold, I also used repetition when I framed the paragraph.

Now, the first paragraph, which communicated (and not merely presented) the background, was ready.

Second Paragraph

Similarly (jotting down thoughts, ordering sentences, and linking them) motivation could be communicated in the following paragraph:

> Xanthan gum is secreted by *Xanthomonas campestris* when it attacks plants (Chamnongpol, et al., 1995). The extent of xanthan gum secretion (mucoidy) is directly related to the pathogenicity of the organism on plants, which it attacks (Throne, et al., 1987; Weiss, et al., 1994). Pathogenicity is related to the induced oxy free radicals (Sutherland, 1991). **From an industrial viewpoint,** *Xanthomonas campestris* is employed for commercial bioproduction of xanthan gum, which has wide applications in food, pharmaceuticals, oil, and other industries (Lee, 1996). If the relationship between free radical induction and gum production is better understood, free radical induction may be employed as a means to improve xanthan gum productivity. **In addition,** a better understanding will help to improve cultivation strategies where oxygen is provided in situ through the liquid-phase oxygen supply strategy (Sriram, et al., 1998).

When the two "completed" paragraphs are read one after the other, the reader will notice an abrupt jump in ideas between them. The paragraphs do not seem to be linked. The first talks about free radicals and the second talks about xanthan gum. The reader, who is subconsciously expecting a link, will experience discomfort when (s)he does not find one, and this leads to a loss in communication.

Linking Paragraphs

In the example above, the relationship between free radicals and xanthan gum, especially from a production viewpoint, was unknown in the literature at that time, and therefore known information could not be used to link the two paragraphs. Given this constraint, how could the ideas be linked?

The third sentence in the second paragraph talks about free radicals and could thus be used as a connecting sentence. Bringing this sentence to the beginning of the paragraph and

suitably modifying it serves the purpose of linking both paragraphs.

> Free radicals are known to mediate a number of significant cell processes, including apoptosis and cancer (Feig and Loeb, 1994; Feig, et al., 1994: Okuno, et al., 1998; Reid and Loeb, 1993). **Further**, free radicals are suspected of being mediators of the effects of temperature, osmolarity, and nutrient levels on cells (Nagarathnamma, et al., 1997; Osbourn, et al., 1990), which are also important bioreactor environment variables. **Therefore**, free radicals can be expected to play a significant role in determining bioreactor productivity.
>
> **Oxy free radicals and oxidative stress are important aspects of plant defense mechanisms against invading microorganisms (Chamnongpol, et al., 1995; Sutherland, 1991) such as *Xanthomonas campestris,* a plant pathogenic bacterium.** Xanthan gum is secreted by *Xanthomonas campestris* **during its attack, and** the extent of xanthan gum secretion (mucoidy) is directly related to the pathogenicity (Throne, et al., 1987; Weiss, et al., 1994). From an industrial viewpoint, *Xanthomonas campestris* is employed for commercial bioproduction of xanthan gum, which has wide applications in food, pharmaceuticals, oil, and other industries (Lee, 1996). If the relationship between free radical induction and gum production is better understood, free radical induction may be employed as a means to improve xanthan gum productivity. In addition, a better understanding will help to improve cultivation strategies where oxygen is provided in situ through the liquid-phase oxygen supply strategy (Sriram, et al., 1998).

In a similar fashion, I could proceed to compose other paragraphs, linking them to produce a coherent document.

Summarizing the steps for improving coherence, the most important factor is that the student needs to be knowledgeable in the area and aware of the aspects that need to be communicated. Then the student needs to

- *Write down the points that (s)he needs to communicate in each section, as they come to mind.*
- *Order them logically*
- *Improve coherence (by using tools)*
- *Link paragraphs*
- *Link sections/chapters, when needed*

EFFECTIVENESS OF THE STRUCTURED APPROACH

The structured approach was presented to students taking a communication skills course at IIT Bombay. In addition, they were given exercises to practice writing (and presentation). Their writing (and presentation skills) improved significantly, and they ultimately expressed gratitude that such a course was offered to them. Some students who were comfortable with the language were initially skeptical about the utility of the course, but they learned that effective communication does not necessarily arise from an ability to write correct grammar. At the end, these students also felt they significantly benefited from the course.

Many faculty members (15 out of 28) expressed appreciation for, and satisfaction with, the improvement in communication that they observed in the M.Tech seminar course, where students worked on a research area and presented a critical evaluation of the literature through both a written and an oral presentation. After being asked for their input, six other faculty members said the course was useful. No negative comments were received from the faculty or the students, with the exception of certain individual preferences on presentation style.

To summarize, through clear thinking and better organization of information that is based on a sensitivity to the reader's needs, better writing can be achieved. Very often, bad writing results from muddled thinking or an inability to perceive the reader's needs. Further, writing is a skill—as is swimming. One cannot expect a person who does not know how to swim to learn from a set of verbal/written instructions alone—a lot of practice is required. Similarly, good writing requires a lot of practice. The structured approach given in this article cannot obviate that requirement, but it can provide direction for practice.

ACKNOWLEDGMENT

I thank my colleagues, Professors Preeti Aghalayam, Hemant Nanavati, Kartic Khilar, and Santosh Noronha, as well as my graduate student, Susmita Sahoo, for their input.

REFERENCES

1. Woods, D.R., R.M. Felder, A. Rugarcia, and J.E. Stice, "The Future of Engineering Education: Part 3. Developing Critical Skills," *Chem. Eng. Ed.,* **34,** 108 (2000)
2. Nirdosh, I., "Making Successful Oral Presentations: A Guide," *Chem. Eng. Ed.,* **31**, 52 (1997)
3. Newell, J.A., D.K. Ludlow, and S.P.K. Sternberg, "Development of Oral and Written Communication Skills Across an Integrated Laboratory Sequence," *Chem. Eng. Ed.,* **31**, 116 (1997)
4. Prausnitz, M.R., and M.J. Bradley, "Effective Communication for Professional Engineering Beyond Problem Sets and Lab Reports," *Chem. Eng. Ed.,* **34**, 234 (2000)
5. Sureshkumar, G.K., and K.C. Khilar, "On Improving 'Thought With Hands'," *Chem. Eng. Ed.,* **36**, 292 (2002)
6. Bendrich, G., "Just a Communications Course? Or Training for Life after the University," *Chem. Eng. Ed.,* **32**, 84 (1998)
7. Van Ness, H.C., and M.M. Abbott, "Technical Prose: English or Techlish?" *Chem. Eng. Ed.,* **11**, 154 (1977)
8. Haile, J.M., "Easy Writing Makes Hard Reading," *Chem. Eng. Ed.,* **28**, 278 (1994)
9. Chatman, S., *Coming to Terms: The Rhetoric of Narrative in Fiction and Film,* Cornell University Press, Ithaca, NY (1990)
10. Abbott, H.P., *The Cambridge Introduction to Narrative,* Cambridge University Press, Cambridge, UK (2002)
11. Bird, R.B., "Book Writing and Chemical Engineering Education: Rites, Rewards, and Responsibilities," *Chem. Eng. Ed.,* **17**, 184 (1983)
12. ManjulaRao, Y., and G.K. Suraishkumar, "Improvement in Bioreactor Productivities Using Free Radicals: HOCl-Induced Overproduction of Xanthan Gum from *Xanthomonas campestris* and Its Mechanism," *Biotechnol. Bioeng.,* **72,** 62 (2001) ❐