How to Build Better Engineers
A Practical Approach to the Mechanics of Text

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A good idea remains just that until it can be turned into a product, and the transition from idea to product requires that the engineer produce clear proposals demonstrating the idea's practicality and economic feasibility. Writing is a key element in this process.

"Engineers don't need to know how to write. Why are you making us do this?"

I often hear such comments when I present my mechanical engineering students with writing assignments. I must confess that I shared these beliefs when I was myself an engineering student and a young engineer. However, having spent more than two-thirds of my professional life in industrial research, I am well educated in the realities of the engineering world. Technological skill, I tell my students, is only a part of what an engineer needs to succeed.

In my twenty-five years in the field, I spent at least 50 percent of my time writing and communicating. I wrote internal memos, program proposals, letters, and technical reports and papers. In addition, I was called on to organize and present technical material to program managers and directors to obtain project funding.

My experiences are not unique. When my students and I visit engineering companies, the engineers stress that, of course, engineers must understand the technology and economics of their projections, but these skills are worth very little unless they are paired with the ability to write and communicate. A good idea remains just that until it can be turned into a product, and the transition from idea to product requires that the engineer produce clear proposals demonstrating the idea's practicality and economic feasibility. Writing is a key element in this process. But how do engineers acquire writing skills?

Personally, I learned to write on the job. My education—particularly my undergraduate education—provided little writing instruction or support, and when I returned to the classroom as a professor, I was dismayed to discover that little had changed in this regard. Engineering curricula still rely extensively on the English department to teach writing. The engineering school often requires introductory composition classes, followed by a course on technical writing. While these are useful classes, they do not aim to show students the vital importance of writing skills in their profession and, by themselves, they are not nearly enough to help students develop skills for professional success.

Engineers in training may remain blissfully unaware of this deficiency, but once out in the field, they are soon conscious of this gaping hole in their preparation. In a survey of 1995 graduates from our University of Idaho College of Engineering, 40 percent of the respondents thought that more emphasis should be given to written communication, and 60 percent thought that more emphasis should be given to oral communication and presentation skills.

The engineering profession is also aware of the problem. The Accreditation Board for Engineering and Technology (ABET) now requires engineering programs to "demonstrate that their graduates have an ability to communicate effectively and a recognition of the need for, and an ability to engage in, life-long learning." These requirements are compelling engineering schools to recog-
nize that we need to do more to help our students become better writers.

**Helping Engineers Write**

So just what is wrong with the writing of engineering students? In general, part of their deficiency stems from their inclination to write like engineers, by which I mean to write like the engineering textbooks that serve as their principal models. The following example, with its long, involved sentences filled with qualifiers and clauses, is typical:

> A surface represents the only variety of non-Euclidean manifolds capable of actual visualization, and the origin of the metrical geometry of non-Euclidean manifolds in general is found in the work of the German mathematician Karl Friedrich Gauss (1777-1855), professor of mathematics in the University of Göttingen, in which the metrical geometry of an ordinary surface is developed from the standpoint of its intrinsic properties, whereby is meant properties which require for their specification no elements which lie outside the surface itself.

[A. P. Wills, Vector Analysis with an Introduction to Tensor Analysis, xxix, Prentice-Hall, Inc.]

One may argue that an eighty-word sentence is not at all unusual in a textbook. Engineers need to be precise, and qualification (“where by is meant . . .”) is one way to achieve this precision. The problem is that when student writers pack a sentence in this way, their prose often becomes close to incomprehensible:

> The radial stresses in this problem can be ignored because they are so small compared to the other stresses and any failure they will have already had occurred before the radial stresses would have had a chance to reach the yield point which in this case is possible because the radial stresses are not significant as the width of the cross section near the neutral axis here is not too small and relative to rest of the hook the section is large enough.

I push my undergraduates to break up their sentences. In engineering writing, as in much other writing, two or three sentences can often more effectively do the job than one sentence that is bloated and unclear. Further, again like the writers of engineering textbooks, engineering students assume they are writing for an audience of engineers. But in the real-work world of engineering, this is not necessarily true. The fact is engineers are often writing for project managers and others with little knowledge of the language of engineering.

In order to give students a taste of what it is like to write for an audience that does not share their technical jargon, I ask students to describe how a transistor works, in language accessible to a high school student. Here is one student’s effort.

> Transistors are semiconductor devices that can control the electrical current flowing between two terminals of differing electrical potential based on a voltage applied to a third terminal called a gate. This gate voltage controls the number of free charge carriers available at the junction of two dissimilar semiconducting materials and therefore the current which flows between them.

A good try, but the layperson is left with a bunch of questions. For instance, what are “free charge carriers”? What are “dissimilar semiconducting materials”? Many upper-division electrical engineering students would be hard-pressed to know what this author is saying.

As I have become involved with the Northwest Inland Writing Project at the University of Idaho, I have been working on other ways to help my students explain educational principles in laypersons’ terms. But that has been only one aspect of my involvement with the writing project. Until recently, I treated my students’ writing problems—those of the sort I have noted above, as well as many surface errors such as pronoun reference problems and errors in subject-verb agreement—by noting these deficiencies on their final documents and returning their marked papers to them. I am sure they checked their grades and then filed the papers without reading the comments or using them to improve their writing, because the next assignment would invariably contain the same errors and have the same deficiencies.

Then in the spring of 1997, I attended a writing-across-the-curriculum seminar presented by Elinor Michel, director of the Northwest Inland Writing Project. Faculty from across the university attended this week-long course, which introduced us to a variety of writing techniques. We learned about writing to learn and writing to communicate. We explored the research on writing. We heard the experiences of our peers who had introduced writing in their courses. They described techniques that worked and those that did not. We also began to develop assignments for use in our classes. This initial exposure to teaching writing was followed by a series of meetings during the fall and spring terms to hone assignments and discuss experiences with writing. The follow-up meetings
How to Build Better Engineers

provided the support I needed to implement writing in my engineering courses.

I brought away from the seminar two overarching strategies that have guided my teaching since my involvement with the project. One is the wisdom of what writing teachers call “scaffolding” and the other the power of peer review. As it turns out, both of these approaches connect to the real world of engineering writing.

Scaffolding—the process of moving through a series of ordered steps in developing a piece of writing—comes very close to the practice engineers and other professionals encounter when they generate and submit an article to a technical conference. The engineer-writer submits an abstract that receives comment from the conference organizers or journal editor. He or she writes the article, which is then sent out for peer review, and the reviewers’ comments are incorporated in the final draft. This is “process writing.”

In my classes, I try to replicate this process. Students first submit, along with a formal letter of submission, extended abstracts explaining the scope and nature of their intended articles. Acting as an editor, I review the letters and the abstracts and accept, reject, or request revisions. The formal submission process gives the students experience and skill in drafting both formal letters of transmittal and, in the form of a concise abstract, an outline of the intention of a proposed work. These are vital skills for survival in a workplace.

As many of my undergraduate students have had little experience with writing, technical or otherwise, I introduce them to this process in a nontechnical context. I ask them to write a paper explaining the contributions of a significant inventor. Here is a sample abstract:

Adolphe Sax—Abstract

Adolphe Sax was born on November 6, 1814, in Dinant, Belgium. While he was growing up, he was exposed to his father’s occupation of designing and building woodwind and brass instruments. From this, he learned to build and how to design instruments. This combined with his musical talents led Adolphe to modify and build a large variety of instruments with hundreds of modifications and improvements over current designs. He is also credited with the creation of the saxhorn, the saxtromba, and the saxophone. These improvements and instruments had a long-lasting impact on the design of instruments and are still evident today.

This abstract gives me a pretty good idea of where the student is going in her paper. I would expect, for instance, that this paper would discuss in some detail some of the “hundreds of modifications . . . over current designs” that Sax had introduced. Unfortunately, not every abstract presents such a clear path. When this happens, my responsibility is clear: I ask students to revise their work. Students, in general, seem not particularly used to revising their writing, and they are particularly not used to revising their writing in an engineering class. But by demanding a retooled effort, I believe I am introducing them to real-world engineering writing.

After I accept the abstracts, each student writes a draft of the proposed article and submits it in triplicate to me. These multiple copies allow me to send the work to peer reviewers, that is, to other students; to return a copy to the author with comments; and to verify that revision is taking place during the assignment.

The peer review process gives students an opportunity to participate in a critical review of each other’s work. It challenges students to evaluate the content of the document and the presentation of the material and to assess what they have learned from the document. The students are given specific guidelines to aid them in this process:

Prepare a short (½ to 1 page) review of the submitted article. The review should address the technical content of the article, the writing style, and the manuscript format. Suggested questions to guide your review follow:

a) Technical content: Did the writer provide the necessary information that was described in the abstract submitted for the article? Is the article technically sound?

b) Writing style: Is the writing style consistent with the assigned task of producing a technical article for a non-technical audience? Are the grammar and punctuation correct? Are the sentences clear? Has the author avoided jargon and excessive technical detail?

c) Manuscript format: Has all the necessary information about the author been included? Are the parts of the article clearly delineated? Have the guidelines for preparing the manuscript been followed?

Alas, I have found that written guidelines do not, by themselves, provide enough support to ensure a complete review process. The students tend to use the review questions as a template rather than as a
stimulus to look deeply into the text they are reviewing, as the following example demonstrates.

Attached is a copy of the reviewed article. Using the guidelines stated in the memorandum, I evaluated the paper and found that it met the guidelines. The article was technically sound with the information that it presented. The specific inventions in the abstract were explained in the article. Some other important inventions of Watt were included in the article that were not specifically mentioned in the abstract. The writing style guidelines were also satisfied. The article presented a technical topic in a way such that a non-technical person would have little trouble understanding the information presented. A lack of jargon helped with this understanding. I found no grammar, spelling or punctuation errors in the article. This article appeared to be in the proper manuscript format. All focus changes are clearly marked in the article so that the reader can easily find the information needed... The only improvement that could be made would be to add a little more to the workings of his inventions. A brief explanation of the sun and planet gear would be interesting to many readers.

This student reviewer has followed the formula of the guidelines by simply rewriting the guidelines with minor comments. However, some students did provide better feedback while still following the formula, as this example shows:

The attached paper is an excellent submission... The paper excels in accomplishing the goal of communicating the importance of technology to a nontechnical audience. The technical content and writing style are perfectly written. Minor comments for improvement are specified for the manuscript format.

Technical Content—The paper artfully explains important subjects from the abstract. Especially interesting are explanations of how the microscope was improved, why Royal Society was written, and how innovations influenced science.

Writing Style—The writer has a superb ability to explain complex concepts in simple terms. An example is the excellent description of how the understanding of the fertilization process evolved.

Manuscript Format—Highlights include an interesting title and subheadings that facilitate reading and understanding. Recommended improvements include compliance with the American Society of Mechanical Engineers standards for top, bottom, and side margins and the longest line for the title.

In conclusion, this paper is excellent and represents a standard that other engineers should strive to achieve.

While this reviewer offers primarily positive feedback, he does support his praise with specific examples, which demonstrates that he has carefully read the article.

However, I've received enough reviews of the former kind that I realize students need more preparation if writers are to receive truly useful peer reviews. I plan to expand the guidelines for review, incorporate an in-class activity in which students review and discuss a technical writing and develop a rubric for it.

As the assignment continues, I ask the peer reviewers to submit their reviews in triplicate. I review the reviews and give comments to the reviewers to help them look critically at their colleagues' work. Authors cannot respond when a reviewer makes a general comment like "there is a problem in this paper." They can respond to a specific comment like "the facts presented in this paper are contrary to accepted interpretations." I remind reviewers to balance their criticism of content and style, respect the author, and recognize that style differs from writer to writer.

The authors receive blind copies of the reviews with a request to revise their submissions, incorporating the peer reviewers' responses. They are also given the opportunity to present reasoned rebuttals for not making suggested changes. They submit the final drafts of their articles in triplicate for editorial approval.

The revisions show the results of peer review and the sense of ownership that the students take in improving their writing. As editor, I check the articles for clarity and accuracy, revision or rebuttal, and conformance to format. I return the manuscripts to the authors once more for final revision and submission of camera-ready copies, then assemble the finished pieces into a bound booklet, which I give to the students for inclusion in a personal portfolio of their work.

Rather than tell the students in advance that their work will be compiled into a booklet, I present it to them as a reward for their effort in producing good writing. Production of the booklet gives me an opportunity... continued on page 40
Beyond Rhetoric

continued from page 31

appropriate. I use old essays that received an A. I explain to my students that A papers are rarely under four pages typewritten and often up to eight pages, because of the level of detail required to persuade me of A quality. If students are to explain the content learned over an entire semester or year and include detailed examples in a persuasive format, they will need to elaborate. It's possible to do this in fewer pages, but that means very tight, clever writing—something that takes as much time as writing more.

I've found that students are usually accurate and honest when giving themselves a grade. Their assessments almost always come close to mine. Students who put a lot of time into their writing do so on this essay as well, so they ask for a good grade and, as a rule, get it. Students who don't put the time in write shorter essays with less information and often get grades that reflect their previous work. But they usually recognize it and ask for a B or C.

I began using this assignment without much thought. It was a quick solution to the annoying end-of-the-term required exam. As I have reflected on the process, I've begun to see the great benefits of an assignment that elegantly combines reflection, persuasion, review, craft and detail, and the course evaluation. At first, the essay was an isolated task at the end of the year, but now I see that it can be an integrated, important part of my practice. Now I will talk more about this final project at the beginning of the year, allowing more time for planning and peer conferencing, and creating a rubric with the students for more consistent grading.

Settling down to read these exams, I realize the personal mental health benefits for me. It's a great way to combat end-of-the-year fatigue, and it helps me understand what students have found important and memorable about the class, even as, on this last day, they learn a few more things about the process of writing.

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How to Build Better Engineers

continued from page 35

to demonstrate the need for uniformity in format and for adhering to schedules and page limits.

The entire exercise is a lot of work for the students—and of course for me—but this process provides a valuable lesson that can help students understand the kinds of writing skills and processes they will be called upon to use in the corporate or educational world after graduation. This kind of preparation gives them a jump-start on their future.

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