TOP TEN WAYS TO IMPROVE TECHNICAL WRITING

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While engineers often claim that they spend more time writing than they do on any other single task, providing constructive criticism of students' reports is the most difficult and thankless task a faculty member may face. Most schools do not have the luxury of having a writing specialist who can help engineering students with their reports, and even if students take a writing course, they need feedback on their technical reports.

What rules of grammar, usage, and writing style should students and faculty focus on? English usage changes with time, and experts do not always agree, but in spite of numerous excellent (and voluminous) style guides,[1-6] editing for correct usage need not be a daunting task. There is a relatively small list of topics that are particularly troublesome, even for well-educated chemical engineering students.

In this paper, ten general suggestions are offered to help improve one's technical writing style. They have been gleaned during the past six years from several hundred drafts of industry reports submitted by over a hundred students at the David H. Koch School of Chemical Engineering Practice at MIT. Practice School students are candidates for the Masters degree, and all have been well educated in some of the best chemical engineering programs, both here and abroad. Reports are submitted by two or three students working as a group on real industrial projects at a company site. All reports are written with an impending deadline, with two reports expected during the typical one-month project duration.

The engineering education literature contains many examples of technical writing as part of the curriculum[7-12] and of writing pedagogy.[13,14] In contrast, this top-ten list is intended to supplement standard usage and style manuals that have more depth. Strunk and White[15] remains a classic for its brevity and good advice, and the ACS *Manual of Style*[16]

is a comprehensive book that is useful to chemical engineers. There are two useful manuals written by chemical engineers.[17-19] No writer should suffer from a lack of reference material. Spell- and grammar-check software should be used as a minimum level of guidance, and style guides are available on the World Wide Web.[20,21]

This paper is intended to focus attention of both instructors and students on the most prevalent writing problems. With apologies to David Letterman, I will present and discuss the top-ten list in reverse order. Each will be illustrated with actual examples of sentences from report drafts.

- 10 -
Select Words with Care

Misuse or overuse of some words occurs frequently enough in technical writing to deserve special mention and ranks tenth on my list of admonitions. There is such a diverse range of examples that it almost defies categorization, but several of the more common ones will be used to illustrate the problem.

It is well known that a spell or grammar checker cannot be relied on as the sole source of misused words. Writing must be proofread with care to make sure you have said what you think you said. Sometimes an inadvertent slip seems so ap-

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propriate that it cannot be distinguished from a deliberate put-on, as in

Original: This would lead to extra liquor sipping cost, which is given in row 4.

Better: This would lead to extra liquor shipping cost, which is given in row 4.

Chemical engineering students frequently use the words *setup/set up, scaleup/scale up,* and *shutdown/shut down* in their reports and misuse is not uncommon. The following example shows that *set up* should be used when a verb phrase is needed:

Original: The apparatus is setup so that any overflow would be collected in the trap.

Better: The apparatus is set up so that any overflow would be collected in the trap.

If the objective of a technical report is to get across a message to the reader, pretentious words have no place.[22] Perhaps no word gets overused as much as *utilize.* It has a well-deserved reputation of pretentiousness and should probably never be used, since *use* is a simpler synonym. Beware of trendy big words (such as *-ize* verbs made from nouns, or nouns made from verbs) that sounds like bureaucratese (another example!) at its worst. Do not try to make your prose impressive—make it understandable.

For the most part, students have a good sense of the proper use of words. Occasional lapses occur, however, on common word pairs. Look out for *there/their, fewer/less, between/among, it's/its, continuously/continually, varying/various,* and *altogether/all together.* It is easy to slip up and use the wrong one.

Finally, technical writing is necessarily replete with acronyms. Some are so common (such as CSTR), that they may not need definition, but it is best to be cautious and consider the reader. If a chance exists that your report will be read by someone without your same perspective (and that includes virtually everyone), define your acronyms the first time they are used, and even more frequently if necessary. Never use so many different acronyms that your reader is forced to divert attention away from what you are saying to mentally decode the terminology.

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Use Parallel Construction

Writing is more effective when parallel ideas are presented in parallel fashion. The reader's burden is lessened when the

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wording or words follow a pattern. This pattern can be in verbs, nouns, adjectives, phrases, clauses, and sentences. It can be extended to the organization of paragraphs, or even to sections of a report. It improves the style and can make the reader better understand that the ideas are parallel.

Two obvious situations that call for parallel construction are in enumerated lists and compound expressions joined by correlative conjunctions. Each one of the enumerated section headings of this paper is an imperative admonition starting with a verb and followed by its object. Parallel construction may not always be possible to maintain, but deviations from it can be unnecessarily jarring to the reader. On the other hand, correlative constructions using the conjunction pairs *both...and, either...or, neither...nor,* and *not only...but also* can be misleading or even incorrect if the words following the correlative conjunctions are not parallel to each other. Consider the example below. In the original form, a verb form follows *either,* but a noun phrase follows *or.* The natural correction would be to move *either* so that *based on* applies to either noun phrase. Both noun phrases following the correlative conjunctions are parallel, and it is clear that the values will be assigned in either case.

Original: Values that are either based on engineering terms or financial terms will be assigned to each piece of equipment.

Better: Values that are based on either engineering terms or financial terms will be assigned to each piece of equipment.

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Avoid Passive Voice and First Person

Good prose is direct and forceful. This is no less true in technical writing. It is better to say that the subject *did* something than to say that something *was done* by the subject. Technical writing tends to overuse the passive voice, sometimes with good reason. It is not wrong to use the passive voice, but is should be avoided when possible.

Most technical writing also tends to avoid using the first person. The message conveyed should focus on the technical content without putting undue focus on the authors. Unfortunately, the choice is often between using the first person (or its close equivalent "the author") and using the passive voice. It is not wrong to use the first person, but it should be avoided when possible.

In the following example, the active voice makes the sentence simpler and more direct. In this case, the Microsoft Word

> *Most important, always consider those who will be reading what you have written and try to make it easier for them to grasp your message.*

grammar checker not only identified the passive sentence but also suggested an improvement. Consider whether rewriting each passive sentence would improve the flow of the sentence and still convey the same information. If your sentence is too complicated for the grammar checker to offer an improvement, maybe the sentence should be simplified.

Original: Two methods <u>are being examined by</u> the company for possible implementation.
Better: The company is examining two methods for possible implementation.

Technical writing should usually emphasize your accomplishments, not you yourself. This is the reason for avoiding the first person, as illustrated in the example below. Using other words, such as *the authors, the group,* and *the project team,* may avoid the first person, but they do not avoid placing the emphasis in the wrong place. Use them advisedly, even if it means using the passive voice.

Original: <u>We followed</u> established protocols to carry out the measurements.
Better: Measurements were made following established protocols.

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Use Proper Punctuation

The wide variety of possible punctuation problems justifies its ranking of seventh on the top-ten list of things to watch for. Most writers have a good sense of how to punctuate properly, so a comprehensive summary of the rules seems unnecessary. Only two of the more common rules will be mentioned here.

Technical writing too often uses long and complicated sentence structures. If this is really necessary, good writing practice guides your reader through long sentences by using a comma whenever it is appropriate to pause slightly. The following is a good example of where a comma prevents the words from running together:

Original: The tin-catalyzed racemization rate also <u>decreases resulting</u> in higher quality product.
Better: The tin-catalyzed racemization rate also decreases, resulting in higher quality product.

The single comma should never be used to separate the subject from the predicate of the sentence or the verb from its predicate complement, however. The reader should proceed directly from one to the other with no pause.

A related situation with the use of a colon arises frequently in technical writing. The colon has only one proper use in sentences: it separates a definition, a list, or other explanatory material from the rest of a complete sentence. It should never be used to separate a verb from the rest of the predicate or any other part of speech from its required complement. The original version of the example below uses the list as the direct object of the preposition *into*. The colon should *not* be used there. If you want to use the colon, add *the following* or some other object before the colon. The same rules apply if the explanatory material is set off on the following line, as in an enumerated list or an equation.

Original: These mechanisms can be classified <u>into</u>: solid-solid interactions, liquid necking, adhesive and cohesive forces, and chemical reactions.
Better: These mechanisms can be classified into solid-solid interactions, liquid necking, adhesive and cohesive forces, and chemical reactions.
Or: These mechanisms can be classified into the following: solid-solid interactions, liquid necking, adhesive and cohesive forces, and chemical reaction.

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Ensure Agreement in Number

Subjects and verbs must agree in both number and person. Similarly, pronouns must agree with their noun antecedents. Since most technical writing is done in the third person, person agreement is not usually a problem. Number agreement, however, can sometimes be a problem, especially in two common instances: recognizing the number of certain nouns and recalling the true subject of a more complicated sentence. The latter problem appears frequently enough in student reports to justify this admonition as sixth most important.

A common mistake is to give the verb the number of the closest noun rather than the true subject of the sentence. The subject in the example below is *measurements,* not *extraction,* and the verb should thus be plural. Intervening phrases or clauses, especially when they end with a noun, can draw the writer's attention away from the true subject.

Original: The temperature measurements for the lab-scale extraction <u>was</u> compared with the simulation described above for validation.
Better: The temperature measurements for the lab-scale extraction were compared with the simulation described above for validation.

It is well known that words such as *kinetics, economics,* and *physics* are singular in spite of the final *s. Data* can be more troublesome. Classically plural, as the counterpart of the currently unused *datum,* data has acquired a collective use as well, requiring a singular verb. A good key to the difference is whether *data points are* or *data set is* can be substituted. If you can substitute either one, your sentence is prob-

ably too vague to be useful. My suggestion is to be as helpful to the reader as possible and avoid ambiguity. Think first that the word *data* is plural and use *data set* if you really want it used in the collective sense.

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Place Modifiers with Care

Modifiers should always be placed as close to what they modify as possible. No ambiguity about what word the modifier belongs to should exist. The classic examples of inadvertent absurdities introduced by misplaced modifiers are easy to catch, and the more subtle ones are fodder for technical editors. Technical writing spawns more modifying words and phrases than is consistent with clarity. The more modifiers introduced into a sentence, the more likely that some ambiguity will arise. Grammar-check software can be used to alert you to too many modifiers in your sentences. If the sentence cannot be recast to avoid some of them, at least check to make sure they are modifying what you wanted them to modify so the reader will face no ambiguity.

The next example illustrates that the simple placement of a modifier can drastically alter the sense of a sentence. In the original wording, one might picture Erickson submerged in a caustic solution making the diffusion measurement, instead of the reaction occurring in the caustic tank. Place the modifying phrase after the word *reaction* rather than as an introductory phrase.

> *Original:* In the caustic retention tank, Erickson (1995) has already confirmed that the neutralization reaction is diffusion controlled.
> *Better:* Erickson (1995) has already confirmed that the neutralization reaction in the caustic retention tank is diffusion controlled.

When a phrase has no word that it can logically modify, it is called "dangling." The following is a good example. The opening participial phrase should modify the person doing the comparison. Placement of the phrase suggests that the subject of the sentence would be the agent, but neither *it* nor the *cooking system* could possibly be what the phrase modifies. By the time the long modifying phrase was completed, the writer had forgotten that the agent should be the subject of the sentence.

> *Original:* Comparing the characteristics of the steam tunnel and those of the RotaTherm, as claimed by Gold Peg and its distributors, it appears that the RotaTherm steam fusion continuous cooking system would be more advantageous.
> *Better:* Comparing the characteristics of the steam tunnel and those of the RotaTherm, as claimed by Gold Peg and its distributors, we concluded that the RotaTherm steam fusion continuous cooking system would be more advantageous.

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Use a Hyphen Only When Needed

Technical writing is plagued with jargon, and authors need to learn how to use it consistently. Too often words are coined ad hoc, using standard prefixes in combination with technical words to form a new word with a precise meaning understood by the reader. When to hyphenate such a prefix is clearly not well defined, if one is to judge by the number of times that *non-linear* appears in respected publications. A good dictionary should always be the accepted arbiter, but even the best ones will not cover all the technical terms clever students choose to use. This problem frequently puzzles students.

The general rule is that particles such as *bi, by, co, de, non, pre, re, un,* etc., that are not words by themselves should not be hyphenated when added as a prefix to a word. (Modern usage is different from that in older literature when new compound words were hyphenated until they became accepted in the vocabulary.) Also, no hyphen is called for when a number of longer prefixes are used, and the ACS *Manual of Style* gives a long list of them, including *anti, poly, post, counter, super, over, under, infra, pseudo,* etc. Consider the following example.

> *Original:* Agitate the device for a pre-determined period.
> *Better:* Agitate the device for a predetermined period.

Two exceptions to the above rule should be noted. First, use a hyphen when omitting it might cause confusion to the reader. Any time ambiguity in meaning or pronunciation might result, a hyphen should be used. Think, for example, of the interpretation of "post-aging" if a hyphen is not used. Also, always use a hyphen when the modified word requires a capital letter (for example, *non-Newtonian*). Second, consider using a hyphen whenever the prefix introduces a double vowel into the word. A hyphen is not needed in well-known words, such as *cooperative,* however. For example, I would consider *preexponential* a common enough term in chemical engineering to permit dropping the hyphen, but others would still require it.

Compound modifiers (words used together to modify a noun) should be hyphenated. Application of this rule is straightforward in many cases, but in others it is not. In the example below, *small-scale* is a modifier of *batch vessel.* Note, however, that *batch* is also a modifier of *vessel.* It is not hyphenated with *small-scale.* In this case, *batch vessel* seems more natural as the noun expression being modified.

> *Original:* Experiments were performed in a small scale batch vessel, with samples taken periodically for rheology measurements.
> *Better:* Experiments were performed in a small-scale batch vessel, with samples taken periodically for rheology measurements.

Common technical terms that have a meaning together

should not be hyphenated, however, even when used as a modifier or descriptor. The hyphen tends to take away from the common meaning of the expression *mass transfer* in the example that follows.

Original: The capping experiments so far have been useful for obtaining estimates of mass-transfer parameters.

Better: The capping experiments so far have been useful for obtaining estimates of mass transfer parameters.

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Go "Which" Hunting

This is a classic admonition from Strunk and White[15] that White apparently added to the original version.[23] How often it is ignored is perhaps surprising and is what makes it the third most frequent writing problem I've encountered. Too frequently it appears that the rules of usage are not known rather than being consciously subverted.

That is a relative pronoun used to introduce a restrictive clause, one that is necessary for the definition of the antecedent that it should immediately follow. If the clause is removed, the sentence will not convey its full meaning or the same meaning. Such a restrictive clause should not be set off from the antecedent by commas.

Which is a pronoun used to introduce a nonrestrictive clause, one that is incidental to the definition of the antecedent that it should immediately follow. Such a nonrestrictive clause can be omitted without destroying the sense of the rest of the sentence, and it should be set off from the rest of the sentence by commas. In the example that follows, the sentence ending at "parameters" would be incomplete—the following clause is restrictive to the nature of parameters being described. The clause should be introduced by *that* rather than *which*. The grammar check in Microsoft Word will catch the incorrect use in the original sentence.

Original: a_i and b_i are parameters <u>which</u> can be determined by flux measurement.

Better: a_i and b_i are parameters that can be determined by flux measurement.

Unfortunately, some good writers will use *which* in place of *that* to introduce a restrictive clause. It has had an accepted literary use for effect,[24] although the advantage is more often than not difficult to see. Whether such use was purposeful or inadvertent is impossible to determine. For modern technical writing, it is probably best to avoid such use and to go *which* hunting as White advises.

Which clauses may also be used to modify the sense of the entire main clause of the sentence. This use is hardly necessary, however, and a simple rewording can avoid it. The reader is spared the possible ambiguity of trying to discover the noun that the *which* clause modifies. In technical writing this use should probably also be avoided. The following example,

although not incorrect as originally written, shows that changing the *which* clause to a participial phrase avoids possible confusion about whether the *which* clause actually modified the natural antecedent *solution*.

Original: CO_2 was observed bubbling out of solution, <u>which</u> would result in a higher pH.

Better: CO_2 was observed bubbling out of solution, resulting in a higher pH.

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Use Direct and Concise Statements

The second most common problem with writing styles is verbosity. Writing concisely is an art that needs to be practiced. If there is a direct way to say something, use it. If there is a shorter way to say something, use it. Of the many ways verbosity appears in student reports, two have been selected here for illustration.

An introductory phrase or clause can be useful in making a transition from, or connection to, previous sentences and to orient the reader to the main clause that follows. A common writing problem is the use of such a phrase to indirectly say what the sentence is about when a more direct and concise approach would suffice. Consider the following example in which the introductory prepositional phrase was meant to help the reader know what was being compared. The shorter sentence is more direct and less awkward, however, and conveys the sense just as well.

Original: <u>Between water content and temperature, the latter</u> had the stronger effect on the viscosity.

Better: The temperature had a stronger effect on the viscosity than water did.

A common example of verbosity is to use a phrase in place of a single word. Many phrases have become clichés and should not be used at all. Others should be used with discretion. In the following example, *due to the fact that* is used when a simple *because* would be appropriate. Other phrases you should look out for include *the reason is because, it is because, considered to be, by means of, in order to,* and *for the case where.* Other phrases, such as *in terms of, as is understood, result of, is that of, kind of, the fact that,* and *type of* might best be eliminated entirely.

Original: This was <u>due to the fact that</u> more water condensation from the vapor was required to vaporize the additional hexane.

Better: This occurred because more water condensation from the vapor was required to vaporize the additional hexane.

- 1 -
Use Specific and Precise Language

By far the most common weakness I have found is a fail-

ure to be specific enough. This may arise because of uncertain knowledge of new material or because of the material's relevance, but it shows in a number of ways. In many cases, specific information is easy to include; in others it may not be, but the wording should not be vague or imprecise.

Of the many different types of nonspecific writing, three have been singled out for illustration here. The first type is related to weak words that include *such as, like, including, for example, various, diverse, certain,* and *some.* They do have a definite place in writing, but too frequently they appear to weaken the strength of an otherwise specific statement. In the next example, no other property was of interest in the study, and the use of *such as* added an element of vagueness that was totally unnecessary. Look for examples in your own writing and ask yourself if the specific cases would not serve your purpose better. Reserve the use of *such as* for places where you truly need to give illustrative examples from a much larger set.

> *Original:* A fundamental study was conducted to obtain fundamental data <u>such as</u> isosteric heat of adsorption.
> *Better:* A fundamental study was conducted to obtain the isosteric heat of adsorption.

The second type of shortcoming is a failure to use specific numbers when possible. When conveying technical results in a report, specific numerical values should be used whenever possible. The next example shows that amounts with nonspecific adjectives of degree should be replaced by specific values when possible. Although the original statement may not be wrong, the more specific the reporting, the better the result usually is. Watch out for similar modifiers, such as *majority, most, high, low, large, small,* and even *some,* and other expressions such as *around about, approximately,* and *the order of magnitude,* to see if they can be removed by using specific numerical values. Reserve the use of such words for situations in which the numerical values are not precise, but in which you want to convey some sense of magnitude.

> *Original:* A representative crude oil composition containing <u>high amounts</u> of tocopherol was used as the feed for these processes.
> *Better:* A representative crude oil composition containing 2% tocopherol was used as the feed for these processes.

The third type of nonspecific writing deals with the presentation of results. Too frequently, students feel that it is sufficient to present their results in a table or graph without explanation. Although this is sometimes enough, more often it is not. Only in rare cases will the readers be able to pick out the gist of the results and draw the same conclusion that the author did. It is the responsibility of the writer to point out what the results showed and how conclusions were drawn from them. Do not force the readers to interrupt their train of thought in the report to study the details of the results. Chances are, their focus will be different from your own.

CONCLUSION

Writing technical reports or assessing someone else's writing should not be an overwhelming task. The top ten suggestions made here can be used to good advantage in focusing on the most common problems in technical writing. Practice in recognizing when and how writing can be improved will go a long way toward making you a better technical writer. Most important, always consider those who will be reading what you have written and try to make it easier for them to grasp your message.

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