



SOFT SKILLS FOR CHEMICAL ENGINEERS

Technical skills are not enough for chemical engineers to be successful in the workplace. Engineers interact with a range of disciplines (e.g., operators, managers, scientists, customers), present findings to management, and manage projects. As a chemical engineer, you will likely find yourself at some point in your career leading team meetings, mentoring junior associates, negotiating with vendors, participating in brainstorming sessions, and summarizing your experiments or trials in reports. These are just a few of the many engineering roles that require so-called soft skills.

The term soft skills refers to nontechnical proficiencies. As the name implies, soft skills are not rigidly defined but often include communication (verbal and written), teamwork and collaboration, leadership, creativity, and adaptability. These skills are not necessarily part of the undergraduate chemical engineering curriculum, but they are required for many jobs — in industry, academia, and government.

CEP covers soft skills for engineers in its Career Corner column. Recent columns have explored working with difficult coworkers (Feb. 2017, p. 13), tips for being productive while working from home (Aug. 2016, p. 14), and brushing up on your interview skills (June 2016, p. 60).

This issue explores two soft topics — creative thinking and writing. As the authors of these articles point out, soft skills can be learned, and improving these skills might not be as difficult as you expect.

In “Get Creative with Process Safety Management,” Paul Baybutt of Primattech discusses the importance of applying creative thinking to process safety. Baybutt explains that creative thinking can be learned. The article identifies potential barriers to thinking creatively, as well as tips on how to stimulate this type of thought. See what characteristics are common in creative thinkers (p. 57), attitudes that kill ideas (p. 59), and dispositions that can foster creative thinking (p. 60).

Writing — a critical skill for communicating your ideas, thoughts, and findings — is the topic of “Become a Better Writer.” In this article, Robert Bly of Marketing to Engineers provides 10 tips to improve your writing. These tips include: be technically accurate, write clearly and conversationally, and put the reader first. Read the full article for more on these and the other seven tips.



GET CREATIVE WITH PROCESS SAFETY MANAGEMENT

PAUL BAYBUTT
PRIMATECH, INC.

Creative thinking is a necessary skill in process safety. While most people are born with the capacity for creative thinking, this skill can be lost through formal education and societal pressures that discourage it. Luckily, creative thinking can be learned.

Creative thinking is an important, albeit often overlooked, skill for many process safety management (PSM) activities, such as conducting process hazard analysis (PHA) studies, incident investigations, and management-of-change (MOC) reviews, writing procedures, and developing emergency response plans. Despite its importance, creative thinking is not necessarily encouraged or cultivated during the formal education process.

Although empirical evidence suggests that some people may be more gifted or predisposed to think creatively, the prevailing view is that we can all learn to think creatively. Many studies have been conducted and published — providing a large resource from which to extract guidance on creative thinking.

This article provides suggestions, guidelines, and strategies gleaned from the literature that can help you employ creative thinking in process safety.

The nature of creative thinking

Creative thinking engages your imagination to generate new ideas or new ways of looking at a situation. It requires divergent, lateral, out-of-the box, and out-of-the rut thinking. Creative thinking involves:

- perceiving layers of detail
- asking many types of questions
- identifying relationships among elements and determining how they fit together
- noticing connections between the current situation of interest and prior knowledge and experience
- developing interpretations based on observations
- reflecting, assessing, and revising.

Creative thinkers ask questions of themselves and others, including:

- What if?
- Why?

- Why not?
- How?
- How else?

What-if questions are particularly important, because they examine (and question) long-held, potentially erroneous, assumptions.

Creative thinkers ask questions such as:

- How else can we view or consider this issue?
- What alternatives might exist?
- Is there anything we haven't yet considered?
- What other ways might there be to do that?
- Where else can we get more information?
- Who else has a suggestion?
- How *can* something happen (rather than *whether* something can happen)?

The kinds of questions we ask are important. Good questions encourage exploration, open our minds to possibilities, enliven curiosity, and excite imaginations. Good questions probe a problem until the heart of the issue is uncovered; they are provocative, thereby eliciting others to think differently, and they are open-ended, allowing more than one answer. In addition, they jumpstart thinking by stimulating and engaging others, generate other productive questions, and produce new answers.

Some examples of good questions are:

- Why do we consider a safety instrumented system failure as a near miss?
- How can we avoid a runaway reaction?
- To what extent do personal safety and process safety overlap?
- Why not allow senior operators to train new operators?
- What if we invited members of the Local Emergency Planning Committee to participate in our hazard analysis studies?

Overcoming obstacles to creative thinking

Several obstacles often stand in the way of our creative thinking. Overcoming them can allow our creativity to thrive.

Searching for the "right" answer. Formal education systems typically teach students to determine the correct answer. This approach is fine for problems that have only one correct answer. However, most real-world problems have many "right" answers. Unfortunately, if a person believes there is only one correct answer to a problem, they will stop looking as soon as they find one — and might miss a more-promising solution.

One way to encourage people to continue brainstorming is to set a quota on the number of alternatives that must be generated. For example, when investigating process safety incidents, engineers may be tempted to jump to a conclusion about the cause of an incident because of their strong desire to know what went wrong. Setting a quota on

Characteristics of a Creative Thinker

- Thinks imaginatively
- Views issues as challenges
- Engages with challenges
- Open to new ideas
- Believes alternatives exist
- Wonders and speculates about what could or might be
- Looks at issues from different perspectives
- Stimulated by the ideas of others
- Able to defer judgment on an issue
- Displays an open mind
- Exhibits fluency and flexibility of thought
- Uses metaphor, analogy, and visualization to make connections and explores ideas from varied perspectives
- Able to live with ambiguity
- Self-confident
- Able to tolerate a degree of chaos in thinking
- Knows how to ask good questions



the number of possible causes that must be identified can prevent engineers from prematurely settling on an answer. While this approach may generate less-than-promising ideas that are impractical or improbable, its value is that this kind of thinking can be a stepping stone to better ideas.

Assuming limitations that are not there. Sometimes people make invalid assumptions about the constraints on a problem. Then they identify solutions to that problem based on constraints that do not exist. As a result, they may not develop an optimal solution to the problem.

For example, when trying to determine the best way to reduce the risk of a runaway reaction, an engineer may assume that no amount of pressure relief on the vessel will be adequate and, consequently, a reaction-kill system is needed. While the assumption may be valid in many cases, it is possible that the reaction kinetics and heat and mass balances in this particular case invalidate the assumption and make pressure relief viable.

Creative thinkers must always look for assumptions in their thinking, stated or unstated, and challenge them.

Following rules. There is considerable societal pressure to follow rules, including ones that are unwritten. Most educational systems encourage this practice and people feel more comfortable following rules than challenging them.

Creative thinkers must identify and challenge rules. You may find a creative solution by successfully breaking rules or sidestepping obsolete rules. Of course, rule breaking must not be illegal, immoral, or unethical.

I encountered a situation in which following an obsolete rule was causing operational difficulties. Operators were transferring material from one tank to another, allowing the

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material to sit for an hour, and then transferring it back to the original tank. After some investigation, we determined that this unwritten rule originated during a time when different materials were being used in the process, but a change had been made and the transfer operation was no longer needed. If someone had not questioned the rule, this unnecessary and inefficient operation would have continued.

Emotional blocks. Emotional blocks to creative thinking occur when feelings (e.g., anger and fear) inhibit effective problem-solving. Anger can prevent participants of a PHA study team from thinking clearly. The anger must dissipate before creative thinking is possible.

Fear of being wrong or sounding stupid can also inhibit PHA participants from asking questions. An experienced PHA facilitator once told me that he always includes a recently graduated engineer on his study teams because they can be relied on to ask the questions that more-experienced team members might not ask; often, the questions considered “stupid” led to the discovery of serious hazards.

Creative thinkers get out of their comfort zone and are willing to risk failure. Failures should be viewed as learning experiences that are necessary to improve the ability to think creatively. Similarly, creative thinkers are comfortable with errors. Most people are inclined to try to avoid errors. However, such an inclination can impair creative thinking. To err is not wrong in the context of creative thinking. It is acceptable to err intelligently.

Falling in love with ideas. Becoming enamored with a particular idea can make you unable to see the merits of alternative ideas as well as the demerits of the coveted idea.

Polarizing mental blocks. Polarizing mental blocks occur when you view matters in terms of opposites —

black/white, either/or, right/wrong, us/them.

Polarizing blocks can be addressed by asking “to what extent is ...?” or by stating “yes, but ...” or “no, but ...” For example, if a PHA team determines a process change that could improve operations may increase safety risks, the management team should not insist that the change be implemented. Rather, an appropriate response by management is: “To what extent is the risk increased and what can we do about it?” or “Yes, but is there something we can do to manage the increased risk?”

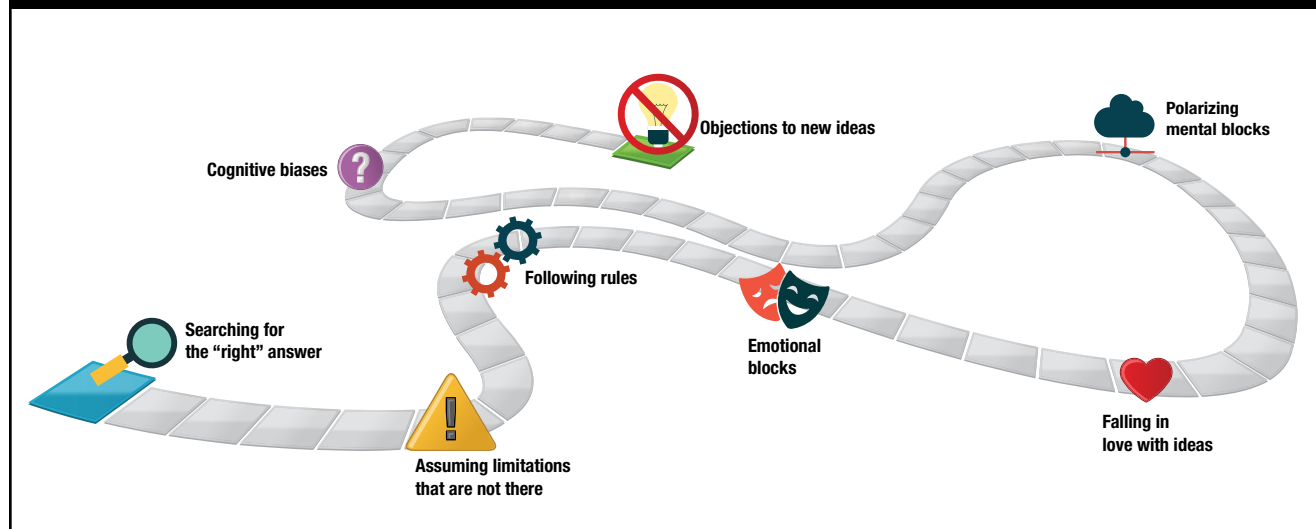
Cognitive biases. Cognitive biases are unconscious, automatic influences on human judgment and decision-making that can interfere with clear thinking and lead to reasoning errors. They occur commonly and can impair creative thinking.

For example, habits of thought involve the unconscious tendency to limit ideas to those that are common, familiar, and habitual. Uncommon or unfamiliar ideas are blocked out. You can address habits of thought by forcing yourself to keep thinking of ideas to address a problem or issue beyond what feels familiar.

A facility in Alaska experienced several separate oil-spill incidents in which the drain valves on storage tanks were inexplicably opened. Investigators considered various explanations, such as mechanical failure and vandalism. However, eventually they discovered that snow freezing caused pieces of ice to form, and the ice fell from the top of the tanks and hit the horizontal handles of the valves. Habitual thinking would not have uncovered this cause.

Many other cognitive biases exist. For example, groupthink occurs when a group makes erroneous decisions because its members value agreement within the group over

OBSTACLES TO CREATIVE THINKING



coming up with an optimal decision. Group members suppress doubt and opinions that go against that of the group, which impairs creative thinking. Also, individual team members may hold assumptions that are so established they do not recognize they exist.

Cognitive biases are difficult to detect and overcome because they occur unconsciously and automatically. The first step in addressing them is to be aware of their existence. In a team environment, awareness permits team members to recognize how cognitive biases may influence others, thus enabling them to address those biases. Team members should always look at situations from various viewpoints. A devil's advocate can be used to challenge the position taken by a team member and help that person recognize the influence of cognitive biases.

Objections to new ideas. Most people tend to be critical when evaluating new ideas, especially ones that may appear impractical. When someone on your team suggests an idea that seems impractical, inquire about the idea in a way that could lead to more-practical ideas.

Consider a process safety incident that involves piping failure. During a PHA, someone recommended that nondestructive testing be performed on all piping in the process. This recommendation was deemed impractical economically. However, through further discussion of the idea, team members came up with an alternative solution. Because the piping failures were caused by external corrosion, visual inspection of all piping could be a sufficient, and practical, solution.

A useful tool is the “creative no” — anyone who objects to an idea must come up with an alternative. When creative thinkers are told their idea won't work or something can't be done in the suggested way, an appropriate response is to ask, “why not?” followed by “what if ...?”

Withhold judgment when generating ideas. Nothing should be done to stop the flow of ideas when people are thinking creatively. Critical evaluation of ideas as they are generated will shut down creative thinking. The ideas can be evaluated after they have all been generated.

Negative attitudes can kill ideas. Such attitudes must be strongly discouraged within a company for creative thinking to flourish. It is important to focus initially on the merits of a new idea rather than its demerits. Creative thinking functions best in a collaborative and collegial environment.

Guidelines for creative thinking

Make time and eliminate distractions. Quiet time, which requires a quiet place, is needed to think, imagine, and reflect.

Think laterally. Lateral thinking focuses on breaking out of the constraints and patterns of entrenched ways of thinking. It is nonsequential and nonselective (unlike vertical thinking, which is sequential and selective). Various

Attitudes that Kill Ideas

- That's not how we do things here
- If it isn't broken, don't fix it
- That sounds ridiculous
- That's impossible
- My mind is made up
- It would cost too much
- Maybe next year
- That's not my/your/his/her/our job
- It would take too much time and/or effort
- What we have (or do) now is good enough
- We tried that before and it didn't work



techniques can be used to stimulate lateral thinking, such as pausing in a deliberate proactive effort to think creatively for a set period of time on a particular aspect of an issue and challenging why something exists as it does or why something is done a certain way.

Pose questions with some ambiguity. When thinking creatively, you will likely ask many questions. Try not to ask questions that are highly specific, as those can stifle your imagination.

Maintain focus on the issue while generating ideas. When thinking creatively about an issue, you may become distracted and digress into thinking about other things. Try to maintain your focus on the issue at hand while remaining open to out-of-the-box ideas.

Don't overlook the value of the hunch. The human mind constantly records, connects, and stores knowledge, experiences, and feelings. The brain can synthesize this information without conscious effort and present it as an idea that emerges from the subconscious — a hunch. Hunches derive from a lifetime of experience and should not be ignored.

Be alert for fringe thoughts. When we try to think creatively, our brains may produce fringe thoughts that seem elusive and on the edge of consciousness. It is worth expending some cognitive effort to pin down the thought and distill it into something relevant.

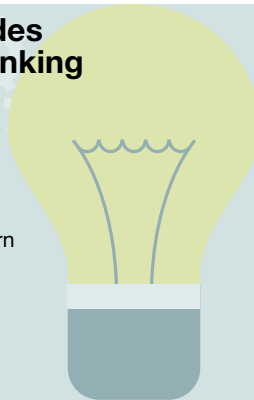
Be alert to kernels of ideas expressed by others. Brainstorming as a team involves people offering up their ideas. You might not believe an offered solution to a problem will work, but there might be an aspect of the proposal that triggers a more-promising alternative. Creative thinking can be jumpstarted in this way.

Look for cross-fertilization of ideas. An idea from one situation may be applicable to another. Therefore, thinking about analogies can be useful when you are trying to think creatively. For example, knowledge of process safety incidents in other companies, even other industries, can help you identify ways to prevent incidents at your company.

Article continues on next page

Dispositions and Attitudes that Foster Creative Thinking

- Patience
- Perseverance
- Curiosity
- Positive frame of mind
- See mistakes as opportunities to learn
- Welcome challenges
- Willing to follow intuition and instinct
- Desire to explore rather than prove
- Desire to consider rather than argue



Shift attention from one aspect of an issue to another.

If you feel blocked when thinking about one aspect of an issue, shifting your attention to a different aspect may be helpful. For example, when exploring how to reduce risks for a process, a PHA team may focus initially on inherently safer technologies, but these approaches may not be viable. Shifting attention to the use of other approaches, such as engineered safeguards, may prove more fruitful.

Look at an issue from other points of view. Adopting a different perspective or considering the issue in a different context can help you generate new ideas. For example, when evaluating a process safety hazard involving a runaway chemical reaction, shift your focus from how to mitigate the runaway reaction to how to prevent it by changing the reaction chemistry.

Be aware that the need to satisfy constraints can spark creativity. Time or other resource limitations can provide a stimulus and force thinking beyond conventional solutions. Of course, such constraints can also impair thinking, so you must exercise care when constraints exist. For instance, in a process hazard analysis, time limitations may constrain brainstorming and impair the results of the analysis.

Allow time for the incubation of ideas. Stepping back from a problem for a while allows you to see the big picture. Ideas can germinate, assumptions can be queried, and more information can be developed.

Pay attention to anomalies. It is easy to overlook some aspects of a situation because they seem minor or you cannot explain them. Careful examination of such anomalies may trigger new ideas that have been overlooked by others.

Don't let the obvious escape your attention. Anything we take for granted may evade our attention. One way to address this matter is to explain a problem or issue to someone who knows nothing about it. This will force you to state the obvious, which may help you identify an idea that you would otherwise have overlooked.

Foster enjoyment of problem-solving. A playful approach to creative thinking lowers people's defenses and

makes them more inclined to experimentation and exploration. It also provides a license to try different approaches without fear of penalty and makes for a more-productive thinking environment.

Recognize that humor facilitates creative thinking.

Humor puts people in a frame of mind conducive to thinking creatively.

Comedians take a different perspective on a topic, often by combining ideas not usually associated with each other, and they play the role of an outside observer looking in. Comedians also question authority and challenge assumptions. These aspects of humor are valuable for thinking creatively.

Recognize that the hand stimulates the brain. Studies have shown that activating basic motor functions can improve mental performance. Consequently, some creative thinkers manipulate a ball or other object when they are thinking.

Employ a devil's advocate. Devil's advocates constructively challenge the thinking of others. They help to put issues in a fresh light and stimulate thinking. Devil's advocates try to think of different interpretations, question what others take for granted, reverse assumptions, and ask the seemingly stupid questions that no one else will ask but that yield good ideas.

Final thoughts

Creative thinking is essential in numerous aspects of process safety, but it is not practiced widely. The approaches described in this article can be used to help put creative thinking into practice.

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Become a Better Writer

ROBERT W. BLY
MARKETING TO ENGINEERS

You may call yourself an engineer, but you're
also a writer. Follow these 10 tips
to improve your writing.

When it comes to accelerating your career success, increasing your chances of getting a job or promotion, and even making more money, technical writing skills are highly valuable. Conversely, weak communications skills can hinder your career progression and even make it difficult for you to get hired. For example, some business units at Rockwell Automation, a Milwaukee-based automation vendor, specifically evaluate candidates' writing ability, reports Susan Schmitt, a senior vice president of human resources (1).

In a survey conducted by the College Board, a nonprofit organization, about half of the companies surveyed said they consider writing ability when promoting employees, and nearly all said they would hold poorly written job application materials against candidates (2). A recent survey by the National Association of Colleges and Employers (NACE) found that the ability to create or edit written reports was one of the top 10 skills employers look for when hiring new college graduates (3). According to an article published by the Institute of Electrical and Electronics Engineers (IEEE),

engineers spend 20–40% of their workday writing, and the higher they move up the corporate ladder, the more writing they do (4).

Engineers are often tapped to write, help write, or work with editors and technical writers to produce reference, product, marketing, and educational materials, including technical articles, press releases, instructions, datasheets, reports, manuals, proposals, emails, newsletters, blog posts, web page content, white papers, books, and presentations.

It is important for engineers to write and edit publications skillfully, quickly, and correctly. Clear, concise, and persuasive prose could prevent a safety incident, make a project proceed more efficiently, convince others of the merits of your ideas, reduce calls to customer support, and improve user satisfaction. In addition, good writing can help establish your reputation as an expert in your field, gain wider acceptance of your company's technology, get your work published, and even generate more leads, inquiries, and sales of your products and services.

"Publish or perish" doesn't just apply to scholars, writ-

ing can help your star rise higher and faster within your organization and in your field. “The reverence people have for the printed word is amazing. Simply because a man [or woman] appears in print, the public assumes that he [or she] has something authoritative to say. This applies on every level,” writes Edward Uhlan in his book *The Rogue Of Publishers’ Row: Confessions Of A Publisher* (5).

The proliferation of personal computers and increasing use of email — which enables us to write more and more often — makes writing an undeniably important skill. When I entered the corporate world as a technical writer in the late 1970s, the only people using typewriters were secretaries. All the technical writers in my department wrote in longhand with a pen and pad, and gave their work to a secretary to be typed up. When I told my boss I needed a typewriter, he thought I was nuts and discouraged me. But I insisted and found a clunky old electric typewriter in storage.

Back then, the average manager or executive did not have a typewriter, so they wrote very little. But now, thanks to computers and email, everyone is a writer. The average engineer spends about one-third of their time writing. If you spend a full third of your day doing something, wouldn’t you want to do it well?

What does it take to get your writing skills to the next

level? Surprisingly, less effort than you may think. In fact, you can significantly improve your writing with minimal time and effort just by putting into practice the 10 tips presented in this article.

#1. Be technically accurate

A U.S. Occupational Safety and Health Administration (OSHA) bulletin explains that the atmosphere we breathe must have 19.6% oxygen content or higher to sustain human life. If OSHA had made a typographical error and typed 9.6% instead of 19.6%, an engineer referring to this document while designing an automated fire suppression system might calibrate the nozzle to dispense an excessive volume of the fire-extinguishing agent. The excess volume of agent could lower the oxygen level in the room far below 19.6%. Although the fire will likely be extinguished, the inhabitants of the closed space may suffocate.

Compare this error to, for example, a Sunday newspaper mistakenly citing the distance between the Sun and Earth as 920 million miles instead of 92 million miles. Embarrassing? Yes. But no one is going to burn to a crisp flying their rocket too close to the sun, even if our rockets could fly that far, because scientists and engineers fortunately do not plan space flights based on popular science articles.

Accuracy in technical writing is more important than in perhaps any other type of writing, because people act on the information. If the content is inaccurate, everything from a product defect or structural weakness in a bridge, to a toxic chemical spill or an explosion, could result.

#2. Write clearly and conversationally

Readers — even those who are highly technical — appreciate documents that are clear and concise. In my nearly four decades as a technical writer, I have never once heard an engineer complain that a document was too easy to read. Use these methods to make your writing a pleasure to read:

- *Omit needless words.* Say what you have to say, but do so in the fewest possible words. Avoid redundant and wordy phrases. For instance, “plan in advance” is redundant, because all planning is done in advance. Simply write “plan.” The expression “RAM memory” is also redundant, because the M in RAM stands for memory.

- *Choose an informal, conversational style.* For instance, instead of “The data provided by direct examination of samples under the lens of the microscope are insufficient for the purpose of making proper identification of the components of the substance,” write “We can’t tell what it is made of by looking at it under a microscope.” The second sentence is written in a more informal, conversational style than the first; it flows more smoothly, is easier to understand, and sounds more natural than the first sentence.



GETTING STARTED

You wouldn’t undertake an engineering or design project without developing a plan, so don’t start writing without a set plan either. No matter the extent of the document, make sure you always:

- identify your audience and their expectations
- know the purpose of the document; refer back to this often while writing so you don’t get off track
- understand the material you will present
- do your research, whether that’s reading the latest articles on your topic in scientific journals, talking to leading scientists in a particular field, or performing experiments
- think about potential visual aids that could help deliver your message
- organize your thoughts and materials
- choose a relevant organizational structure
- budget time to write, review, and edit.

If the document will be long, such as a report on a new equipment installation, consider creating a structured outline as part of your plan.

- *Use the active voice.* The active voice expresses an action directly, as opposed to the passive voice, which expresses an action indirectly. Instead of writing, “Control of the bearing-oil supply is provided by the shutoff valves,” write “Shutoff valves control the bearing-oil supply.” The sentence that employs the active voice directly attributes the verb to the noun performing the action, which makes the sentence more clear.

- *Select an easy-to-follow organizational scheme.* The way you organize the information in your writing should logically fit your content. Organizing your material in chronological order or by stating the problem first followed by the solution is often best for a case study. Alphabetical order makes sense for a booklet on vitamins (e.g., vitamin A, B1, B12, C, and so on) or an employee directory. Use sequential order for work instructions and process descriptions to make each step easy to follow and reference.

#3. Put the reader first

The difference between mediocre writers and good writers is that mediocre writers start with the subject, while good or excellent writers start with the reader. We often begin writing by thinking about what interests us first — which, for engineers, is often the process, machine, experiment, or technology — rather than our readers. But all professional writers, as well as all engineers and scientists who are good writers, put the reader first.

The more you tell your readers about what they want or need to know about your topic — how it relates to their problems, concerns, goals, project, job, or company — the more interested they will be. To do that, you must understand three things about your readers: who they are, how much they already know about your topic, and how they would benefit from knowing more about it.

Let’s say you are writing an article about when, where, why, and how to use motionless mixers for laminar flow applications in chemical plants. You of course know what motionless mixers are, how they work, their applications, and the advantages of using them, so your natural tendency is to assume everyone else does too. But they don’t. Many chemical engineers graduate without having seen a static mixer in operation. Even ChEs who have worked in industry may not have seen a static mixer in operation. Your article should educate both the experienced and inexperienced reader.

Answer these questions about your reader before you sit down to write an article, report, or paper on a specialized or technical subject:

- Are my readers chemical engineers, engineers or scientists in other fields, technical managers, nontechnical senior executives, or even laypeople?
- What do they already know about my topic?

The difference between mediocre writers and good writers is that mediocre writers start with the subject, while good writers start with the reader.

- What do they want and need to know about my subject?
- How important is my topic to them and their work?
- How will they use the information in my article in their work?
- What do I want them to believe, think, or do after reading my article?
- How can the methods I describe make or save money, increase yield, improve product quality, or deliver other desirable results?

#4. Write in the second person

Writing in the second person means addressing the reader as “you.” Doing so directly addresses the reader, thereby putting them first (as suggested in tip #3).

Using “you” engages the reader in a way that using the third person (*i.e.*, he, she, it, etc.) does not. Instead of writing in the third person, “Chlorine flow may be easily regulated by the operator through use of the control panel,” write in the second person, “You can easily regulate chlorine flow using the control panel.” The second sentence is more engaging, because it speaks to the reader directly.

Successful advertising writers — those who write primarily to persuade — will tell you that “you” is one of the two most persuasive words in the English language. People care about themselves first, and your products, technology, application, or project second. Therefore, when you write “you,” you are talking about the subject that matters most to them and it gets their attention.

(As an aside, the other most-persuasive word is “free.” If you put up a landing page on your company website for downloading your latest white paper, make the headline “Free White Paper on Managing Large Data Centers” instead of “White Paper on Managing Large Data Centers.” Adding “free” to the headline has been proven in numerous tests, in which response rates are precisely measured, to increase conversion rates.)

#5. Motivate the reader with benefits

Motivate the reader? Use benefits? That’s for advertising executives on Madison Avenue trying to sell soap, right? Don’t engineers simply inform and instruct, not persuade?

Quite the opposite is true. People are busy, and sometimes you need to sell them on an idea you want them to believe, an action you want them to take, or even a document you want them to read. Consider these introductory paragraphs of a manual on how to use a particular type of

workstation as an exercise in persuasive technical writing:

The operator's workstation acts as the interface between the operator and the processes being monitored and controlled. It is often referred to as the human interface to the process. The workstation consists of devices that allow the operator to perform his or her duties in an efficient manner.

Utilizing all available documentation, the student will be able to use each of the devices provided with the operator's workstation to access displays, overlays, and environments; determine if display objects are pickable; and perform various windowing operations.

There is nothing particularly wrong with this text, but it could be improved. For starters, it is boring.

Many users do not bother to read manuals and this gets them into trouble from which technical support must then rescue them. By adding a benefit, you can motivate users to read the manual and operate the system properly, which can help reduce operator error and call volume at your help desk.

Here is the same text rewritten to make it clear to the reader the benefit of reading the document:

Your job is to monitor and control processes in your plant. The operator's workstation can help you do that job better and faster.

In this module, we'll explore all of the parts of your workstation, including the monitor, touch screen, keyboard, annunciator, keypad, mouse, trackball, and printer. In addition, you'll learn how to:

- *access displays, overlays, and environments*
- *determine whether a display object can be selected*
- *perform windowing operations.*

#6. Do one (or two) more drafts than you normally would

In writing, as well as many other activities, the law of diminishing returns applies. The more time you put into the work, the smaller the incremental improvement of the results for each additional hour of labor. The biggest gains occur in the beginning of the work, but as you continue, the return on your effort gradually shrinks (Figure 1).

Many of us work on our writing assignment until we get to Point A in Figure 1. Then, because we are busy, or prefer to move on to other things, we stop and hand in what is essentially our first draft. This is the kind of unpolished copy that makes you as the author cringe when you revisit and reread it. These types of rough drafts leave many readers scratching their heads and wondering, "What is the author trying to say?"

Mediocre writers stop at Point A, but they could make their writing better, stronger, and clearer by putting in a

little more time and effort. How much better can the document get, and how much time will be required?

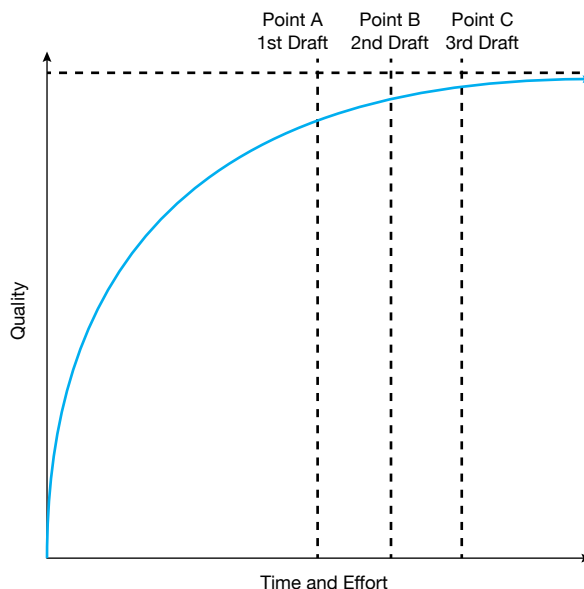
For the average engineer working in industry, I suggest you push forward to Point B even though you might feel like stopping at Point A. To move from Point A to Point B, you need to do one more draft, which usually includes careful editing and rewriting problematic sections. At this somewhat-early stage of the curve, the extra time you put in yields a quality improvement substantial enough to justify the added effort.

If you're an engineer who writes, you can stop at Point B. Many of the engineers in your organization that you consider decent writers, but who are not professional technical writers, probably write at the Point-B level. If, however, you are a professional technical writer or editor, or the document you are working on is of critical importance, you should do yet one more rewrite or edit, which will get you to Point C.

I would advise you to stop at Point C. Rewriting anymore will provide too little incremental improvement and too little return for the extra time invested. It simply doesn't pay off.

#7. Be consistent

Use consistent and correct grammar, spelling, nomenclature, symbols, units of measure, style, etc. The reason is simple: If you are inconsistent, you are automatically wrong at least part of the time. For example, do not use "USA" and "U.S.A." in the same document.



▲ **Figure 1.** When you develop your first draft into a second draft, the added effort pays off with vast improvements that make your document easier to read and more useful. As you develop the document further, the incremental improvements will gradually taper off.

Table 1. Check for these common errors to ensure your writing is clear.

	Incorrect	Correct	Why
Subject and Verb Disagreement	In reference to your recent letter, your address on our files are correct. An order form, as well as a post-paid envelope, are enclosed.	In reference to your recent letter, your address on our files is correct. An order form, as well as a post-paid envelope, is enclosed.	The subject of the sentence is "address," not "files." The subject is "order form," which is singular and so the verb should also be singular.
Problematic Pronouns	John, George, and me met to discuss the job. We met with Mr. Brown, Mr. Smith, and yourself in New York.	John, George, and I met to discuss the job. We met with Mr. Brown, Mr. Smith, and you in New York.	Read the sentence with each subject one at a time, you will discover that "me" should be replaced with "I," and that "yourself" should be replaced with "you."
Dangling Modifiers	After finding the missing report, the search was ended by the administrative assistant.	After finding the missing report, the administrative assistant ended the search.	The modifier, "after finding the missing report," modifies the assistant and not the search.
Displaced Modifiers	The payroll teller recommended First Carrier over Federated, whose delivery service is very prompt.	The payroll teller recommended First Carrier, whose delivery service is very prompt, over Federated.	If First Carrier is recommended, it must be the prompt company, not Federated.
Run-On Sentences	Your projected cost for fiscal 2017 is \$650,000, however, this figure may vary because of a variety of factors.	Your projected cost for fiscal 2017 is \$650,000. This figure may vary because of a variety of factors.	The "however" is the start of a whole new thought with its own subject and verb.
Unparallel Structure	Operators should carry out maintenance activities safely, carefully, and in a detailed manner.	Operators should carry out maintenance activities safely, carefully, and thoroughly.	Use the same pattern of words to show that ideas have the same level of importance.

Be consistent in your use of styles, such as boldface, italics, underlining, indenting, highlighting, type size, and font. For instance, if in chapter one of a technical book, the chapter title is in 14-point boldface flush left, the subheads are 12-point boldface flush left and underlined, and the sub-subheads are in 12-point italics centered, this schemata should be used consistently in every chapter.

Some readers hold even minor inconsistencies and errors, such as typos, against you. It distracts them to the point that all they want to do is point out the mistake to you rather than concentrate on the valuable content your document provides. Even a flub as seemingly inconsequential as "Farenhite" instead of "Fahrenheit" can give the impression that you are careless, needlessly distract the reader from your content, and raise doubts about the accuracy or validity of your entire document — unfair as that may seem. You do not want your efforts to be wasted and your technical prowess overlooked, so be mindful of details and be consistent.

Table 1 lists some of the most common grammatical errors businesspeople and engineers make and how to correct each.

#8. Keep it short

The quickest and most effective way to make your document less intimidating is to keep it short. Not the document itself; it should be as long as is necessary to include all pertinent information. Rather, keep the components of the document short.

Use small words. Mark Twain famously said, "I never write metropolis when I get the same nickel a word for writing city." Similarly, do not write "utilize" when "use" means the same thing but is shorter and less pompous.

Keep sentences short. Use the "breath test." Read the sentence aloud at an even speaking pace. If you run out of breath before you get to the end, it is too long. To fix long sentences, find a place where a new idea begins, and divide the one long sentence into two shorter sentences at that point.

Break up paragraphs. Long paragraphs are visually intimidating, tiring to read, and can be confusing. Break long paragraphs when you begin a new idea.

Organize information into shorts sections and sub-sections. Make your writing easier to scan and digest by using headers, subheads, numbered lists, and bullets. If you must include material that seems to interrupt the flow of the document, such as a long form or checklist, put it in an appendix. In a book of 200 pages, readers prefer 20 chapters that are 10 pages each over 5 chapters of 40 pages each.

Bullets and numbers help make lists more readable. If the order in which you present the points does not matter, use bullets. When information is sequential, such as in an article on the seven steps to specifying the right motionless mixer for your process, present the points in order and number each point.

When using a numbered list to structure an article, consider putting the number in the title or deck of your

Using gendered words and phrases is a sure way to make yourself appear dated and risk alienating your reader.

document to peak the reader's interest and grab their attention. Readers will be compelled to read your document to find out, for example, the seven steps necessary to specify a motionless mixer.

Although bulleted and numbered lists are easy to write and easy to read, do not overuse them. Documents that are page after page of bullets and numbers become monotonous, and many readers will simply not read the lists.

#9. Use gender-neutral language

Decades ago, engineering was a male-dominated profession, and in the 1980s, only 5.8% of engineers in the U.S. were women. However, this is no longer the case — today, about 18–20% of engineering students are female (6).

Because of this change in demographics, as well as the need to foster an inclusive work environment, engineers must avoid the use of sexist and gendered language. Using gendered words and phrases is a sure way to make yourself appear dated and risk alienating your reader.

Do not use words with the suffix “man,” such as policeman, weatherman, mailman, etc. Instead, use police officer, meteorologist, letter carrier, etc. This will make your writing more inclusive, as well as more accurate because these positions are held by both women and men.

When a sentence structure seems to force you to use gender-specific language, an easy solution is to rewrite the sentence to make the subject plural. Instead of “The customer pays no interest on his account balance,” rewrite this as “Customers pay no interest on their account balances.”

You may also use “he or she” and “him or her,” instead of indicating an individual gender in cases where you cannot simply make the subject plural. *CEP* follows the Associated Press (AP) style guidelines (with some modifications), and accepts the use of the singular “they” as a gender-neutral singular pronoun instead of using “he or she” and “him or her.”

#10. Use visuals and captions thoughtfully

Many engineers and technical writers use graphics from source documents to add visual interest to a white paper or technical article. If you do this, you must understand the contents of the graph, chart, or diagram well enough to write a meaningful and clear caption to accompany it. If you do not understand what the graphic is showing well enough to do that, either ask someone who does know or do not use it.

Always include meaningful captions that are full sen-

tences. According to industrial writer John Cole, captions get twice the readership as the main text. Capture important points in visuals with captions to help get your message across (7).

A good caption communicates more information than the image alone. If you show a photo of a horse, for example, including “horse” under the image is a label, not a caption. Offer an interesting piece of information instead, such as “The average horse weighs over 1,000 lb.”

Be aware that much of the content on the Internet, text as well as graphics, is copyright-protected. You cannot simply lift a graphic from the web and drop it into your document. You need to get the publisher's or author's permission in writing.

While text and artwork can be copyrighted, copyright law does not typically protect data and information. You can use data that you find online and draw your own graphs, bar charts, or pie charts. As a courtesy, list the source of the data in a footnote or endnote.

I am not an attorney, however, so the safest bet is either to get written permission to use someone else's material, and if you can't, then do not reprint it at all.

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