ChE classroom

SAFETY AND WRITING
Do They Mix?

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The chemical engineering profession has long voiced a concern that engineers often graduate with inadequate training in chemical safety and with less-than-desirable writing skills. Some educators have reacted strongly to these concerns and, in response, have developed entire courses on chemical safety[1] and technical communications.[2] Pitt[3] has argued the futility of teaching laboratory safety and suggested the "benefit of 'safety awareness' teaching must be to increase people's motivation." Educational research has found writing "a unique mode of learning—not merely valuable, not merely special, but unique . . . higher cognitive functions, such as analysis and synthesis, seem to develop most fully only with the support of verbal language—particularly it seems, of written language."[4] If we can, therefore, uniquely blend safety and writing into our curriculum, we create a possible mechanism to motivate our students' safety awareness.

This paper highlights how I have blended safety and writing into my laboratory instruction to improve both safety awareness and written communication. This experience should offer creative ways for other engineering educators to effectively and efficiently integrate safety and written communication into their own curriculum.

MOTIVATION

We offer a two-course unit operations laboratory sequence which our majors take in their sixth and seventh semesters. The laboratory projects in one course (one credit hour) emphasize momentum and heat transfer principles, while the second course (two credit hours) emphasizes mass transfer operations. Using lectures and laboratory demonstrations sprinkled throughout these two courses, we introduce the students to the elements of statistical analysis of data, experimental design, and model building. With these tools, they can then undertake "an appropriate laboratory experience" that satisfies the Accreditation Board for Engineering and Technology (ABET) curricular content criteria.[5]

With regard to safety and written communication, ABET's criteria clearly state that the engineering professional must have (the bold-face emphasis is mine)

- *. . .an understanding of the engineer's responsibility to protect both occupational and public health and* ***safety . . .***
- *The engineering design component must . . . include a variety of realistic constraints such as . . .* ***safety . . .***
- *Instruction in* ***safety procedures*** *must be an integral component of the students' laboratory experience.*
- *Competence in* ***written communication*** *in the English language is essential . . . the development and enhancement of* ***writing skills*** *must be demonstrated through student work in engineering courses.*

The unit operations laboratory serves as a natural environment to meet those criteria. If we add to the laboratory other ABET criteria, such as design content, open-ended problems, and oral communication, we either dilute the "hands-on" experience of our three-credit hour laboratory sequence or transform it into a course deserving of six or more credit hours.

With the Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) starting to demand that university laboratories comply with federal regulations regarding chemical storage, waste disposal, and chemical hygiene, the task of meeting all the ABET, EPA, and

OSHA requirements becomes nearly intractable. Fortunately, our department offers a three-week, one-semester-hour course on chemical laboratory safety that all students enrolled in Freshman Chemistry must successfully complete by passing a written examination. This *passive* method of safety instruction, however, does not insure compliance with the federally imposed regulations. Therefore, we sought to devise a laboratory environment which *actively* promotes safety as well as meeting the ABET, EPA, and OSHA requirements.

APPROACH

The problem of cramming more material into a limited curriculum needed addressing. My solution was to merge two seemingly unrelated topics—safety and technical writing. I patterned this integration of safety and written communication after a similar structure at Dupont's Seaford Nylon Plant, where I had previously worked. At Seaford, the safety program actively involved everyone from the technical superintendent right down to the clerk typists. Stressing personal responsibility for a safe workplace seemed to instill a strong sense of safety awareness in the participants. Since safety audits served as a good means to actively involve the people at Dupont, I decided such an activity could work equally well with my unit operations laboratory students.

All successful businesses require frequent and concise communication between their operating units. The company memorandum is the principal mode of written communication because it promotes a rapid exchange of clearly and concisely written information. Similarly, I adopted the memo as the principal way for our students to communicate within the laboratory. It allows me to quickly cut to the essence of the students' work without spending hours reading comprehensive reports. Others have used memos and other short written communication techniques for similar reasons.[2,6-8]

COURSE SETTING

Our blending of safety and technical writing occurs in the mass transfer operations course, which meets weekly for a one-hour common lecture and a five-hour laboratory session for the individual sections. Before the first laboratory session, I randomly assign the students to groups and projects. An individual student group has responsibility for only one project during the entire semester, and the group periodically issues written and oral reports to summarize its progress. To expose our students to the other laboratory projects, the groups having primary responsibility for each project plan short experiments for the other groups to perform during scheduled visitations to their projects. Such a laboratory structure openly promotes active communication between groups.

LECTURE AND LABORATORY ACTIVITIES

In this section I outline the specific activities I have successfully used to teach safety with written communication in our undergraduate laboratories.

Safety Audit Team Reports

During the second laboratory session I form two-person safety-audit teams, issue a semester schedule for the teams, briefly discuss what safety items the teams should look for, and send the first team off to inspect the laboratory (see Table 1). Some of the items to look for include properly operating safety shower and fume hood, clear access to exits, properly labeled chemical containers, frayed electrical cords, and water spills. They are also asked to correct any unsafe situation and report their findings in a memo.

The team must complete their inspection before the other laboratory groups can begin working, a

TABLE 1
Safety Audit Team Checklist

Student-designed document used as a checklist for the safety audit teams. The results of the audit are then summarized in a memo and filed in a "red notebook." The procedure insures compliance with EPA and OSHA regulations.

Safety Audit Team Check List
Unit Operations Lab

Room 110

OK	Unsafe	Item	Item Description
		1	Safety shower operates properly
		2	Safety shower is easily accessible
		3	Fire alarms and extinguisher are accessible
		4	Chemical containers properly labeled
		5	Walkways are free of clutter
		6	Floors are clear of water puddles
		7	Lab is neat and in good working order

Comments:

Date: _____ Auditors: _____

process that takes about fifteen minutes. The very first audit uncovered a particularly dangerous situation—a safety shower that only a person over six feet tall could reach!

The students file these safety audit reports in a "red notebook" which I periodically review but do not grade. Should any safety item require immediate attention that the team cannot handle, they are instructed to personally contact the proper university personnel and to document the conversation in the audit report by also issuing a memo to the person they contacted.

After the first round of audits, I noticed that one student had composed a series of audit checklists for the five laboratory areas the teams had to check. Since these checklists greatly improved the team's efficiency, they were used in all subsequent audits. (Table 1 gives the checklist for one of the areas.)

This activity offers an excellent way to practice writing, to comply with EPA and OSHA regulations, and to encourage student ownership in creating a safe workplace.

Equipment Safety Analysis

After some brief introductory comments about the semester project, I discuss the laboratory section that concerns performing an equipment safety analysis. Bethea's *NIOSH Instruction Module Units V and IX*[9] serve as a guideline for the discussion. In their analysis, I ask the groups to include a sketch of the floor plan of the laboratory area in which they work, to list chemicals used and the proper disposal of waste chemicals, to review MSDS's for toxicity, flammability and incompatibility, and to identify all electrical, mechanical, and tripping hazards. Each group then summarizes their analysis in a memo. In the following laboratory period, the graduate teaching assistant and I orally review this ungraded memo with the groups.

Writing Workshops

During the common lecture period I run a series of workshops on technical writing in weeks two through four.

Agents of Wordiness Handout • The material I present on technical writing draws heavily from a short course I took in 1981 when I worked for Dupont, called the "Burger Course in Effective Writing."[10] Burger identified thirty-nine agents that contribute to wordiness, with the rankings indicating how frequently the agents occur (see Table 2). I distribute a handout that defines and gives examples of these agents, which I briefly review in the first lecture.

To warm students up to Burger's method, I start with a discussion of the number-one agent, "verb mutilation" and ask them to find the key verb thought in the first sentence in Table 3. This sentence mutilates the verb thought "to recommend" by turning it into a noun. The second sentence

TABLE 2
Burger's Agents of Wordiness

The following list Burger's compilation of agents that contribute to wordiness. Our discussion is limited to the first 29 agents since they occur more frequently than the last ten. We also suggest ways to eliminate them from the students' written communications.

Overpoweringly Important
1. Verb mutilation
2. Saying what goes without saying
3. Disregard of common elements
4. Overuse of the passive
5. The zero word

Very Important
6. Prepositionitis
7. The irrelevance
8. The wrong point of view
9. Failure to use second-time words
10. The trivium
11. Fractional anticipation
12. Zigzagging
13. The pointless modifying clause
14. The pointless third-level modifier
15. The impersonal introduction
16. The wrong number
17. The unnecessarily difficult verb
18. The club-member phrase
19. Pointless repetition
20. The long-winded negative
21. Modifier mutilation
22. Pointless attribution
23. Repetition plus

Important
24. The Misattached modifier
25. The bangbang paraphrase
26. The name substitute
27. Noun mutilation
28. The wrong "each"-type word
29. Failure to use prepositions

Unimportant
30. Failure to use indirect objects
31. "If" first
32. Name first
33. Preposition first
34. "The" first
35. Failure to use summary words
36. The long-winded affirmative
37. Failure to use the possessive
38. Overuse of the possessive
39. Failure to use the passive

TABLE 3
Examples of Verb Mutilation and Other Agents of Wordiness Used in Writing Workshop

The boldface-type words designate the problem areas in the sentence. Eliminating these agents leads to a clear and concise sentence about half as long as the original.

1. My **recommendation** for the new system is that we replace the fouled heat exchanger tubes.
   Agents of Wordiness: Verb mutilation
2. The **replacement** of the fouled heat exchanger tube **is recommended.**
   Agents of Wordiness: Verb mutilation; Overuse of the passive
3. **It is recommended that we replace . . .**
   Agents of Wordiness: Impersonal Introduction; Pointless third-level modifier
4. I **would recommend** we replace . . .
   Agents of Wordiness: Unnecessarily difficult verb (conditional)
5. I recommend we replace . . .

TABLE 4
Original Safety Rules Handout

SAFETY

Safety is of the ultimate importance. The key to safety is your awareness of potentially dangerous situations. In this lab dangers include hazardous and flammable chemicals, moving equipment, and high-pressure steam.

SAFETY REGULATIONS

1. Goggles will be worn when corrosive chemicals are mixed from bulk, or dangerous chemical reactions are in progress.
2. Safety glasses are to be worn around moving machinery.
3. Loose ties, shirt cuffs, trouser cuffs, or other floppy cloth pieces are prohibited around moving machinery parts. Leather shoes and socks, or approved equal, are required at all times.
4. Cylinders of gas under pressure should be treated with respect. A dangerous situation is created if the valve portion is cracked from the cylinder. Gas cylinders should be locked to a solid structure when in use and when in storage. They should be locked to a cart when in transit. When not in use, safety valve-cap should be kept on the cylinder.
5. There will be no horseplay in the laboratory. The possibility of accident and serious injury is ever present.
6. Each member of the lab is responsible for knowing the location of 1) all fire extinguishers, 2) all safety showers, 3) all exits, and 4) all first aid supplies.
7. No cola bottles, food of any sort, paper cups, paper towels, or scratch paper is to be brought into or consumed within the laboratory.
8. There will be no smoking within the laboratory.
9. All containers of liquid must contain a label with the following information: name of material contained, strength or purity if known, date placed in container, name of person doing the placing. Any container not labeled is to be emptied, washed and returned to the storeroom.
10. Keep your work area neater than you found it.

TABLE 5
Safety Rules Rewritten to Reduce Wordiness

SAFETY

Safety is everyone's concern. Awareness of potential dangers is the key to safety. Laboratory dangers include hazardous chemicals, rotating equipment, and high-pressure gases.

SAFETY PRACTICES

1. Goggles and protective footwear must be worn in the laboratory.
2. Loose clothing or jewelry are prohibited near rotating equipment.
3. Pressurized gas cylinders must be: securely anchored when in use, securely anchored and capped when stored, and strapped to a cylinder cart and capped when moved.
4. Horseplay is prohibited in the laboratory.
5. Everyone must know the location of all fire extinguishers, safety showers, exits, and first aid supplies.
6. Smoking, food and drink are prohibited in the laboratory.
7. All liquid containers must be labeled with the following information: contents, concentration, date, and experimenter.
8. Keep your work area clean.
9. Properly dispose of all chemical waste.

seems to improve the situation but it actually results in another mutilated verb as well as use of the passive voice. I offer the third sentence, but this choice results in "the impersonal introduction" (Burger's #15) and "the pointless third-level modifier" (Burger's #14), while the fourth sentence suffers from an "unnecessarily difficult verb" (Burger's #17). We finally settle on the fifth sentence as an acceptable choice.

Safety Rules Review • When I first came to the University of Missouri-Rolla, I inherited the set of Safety Rules for the unit operations laboratory (see Table 4). As I examined the document, I found it lush with Burger's Agents of Wordiness and decided it would provide an excellent platform from which to discuss safety and technical writing.

Table 5 represents a major revision of the Safety Rules which resulted in more than a sixty percent reduction in the number of words. The review process uncovered many less frequently occurring agents, such as "the name substitute" and "noun mutilation." It also revealed the need to add a rule about waste disposal. Inspecting these "rules" in more depth, we find they actually represent safe "practices" rather than rules. This switch builds a more proactive attitude about safety.

E-Prime • Bourland[11] introduced a writing system called E-Prime, a name he derived from the following equation:

$$E' = E - e$$

In this equation, E represents standard English and e represents all forms of the verb "to be." Therefore, E-Prime English eliminates the verb "to be" from use. This practice eliminates most of the passive voice, much of the subjunctive mood, and some participial uses. As a further revision to the Safety Rules, I ask the class to consider rewriting them in E-Prime. Table 6 gives some examples of the Safety Rules written exclusively in E-Prime.

Readability Results • To quantify the effect of

TABLE 6
Examples of Safety Rules Written in E-Prime

1. Always wear goggles and protective footwear in the laboratory.
2. Do not wear loose clothing or jewelry near rotating equipment.

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.

5. Know the location of the nearest: fire extinguisher, safety shower, exit, and first-aid supplies.

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7. Label all containers with the following information: contents, concentration, date, and experimenter.

editing the Safety Rules, I assessed the three versions for readability using Writing Tools Group's Correct Grammar™ for the Macintosh,[12] a software package that checks spelling, style, and grammar. Correct Grammar and other grammar-checking software, such as Reference Software's Gram · mat´· ik® and Que Software's RightWriter® also run in the DOS environment and check for readability.

Table 7 gives the results of the readability analysis of the Safety Rules. It clearly shows that by eliminating the major contributors to the wordiness of the Safety Rules we significantly reduced the number of both sentences and words and the percent use of the passive voice. The reduction in the total number of sentences corresponds to a simple elimination of irrelevant sentences. Two measures of readability, Flesch-Kincaid[13] and Gunning Fog Index,[14] show mixed results between the original and the revised documents. When we write the Rules strictly in E-Prime, however, two very interesting results occur: the passive verb tense disappears and there is a significant reduction in the educational level required to read the Safety Rules. The second result offers the true promise of E-Prime and shows it to be an economical and understandable mode of written communication that reduces fogginess. The reader cannot afford to misinterpret the intent of any technical communication that deals with critical issues such as safety procedures.

To answer the question posed in this paper's title—writing mixes very well with safety. Our unique blending of the two has definitely enhanced our students' safety awareness.

Final Examination • At semester's end, students take a comprehensive final examination. I include a section on writing to assess how well they can identify and suggest improvements to sentences taken from published scientific literature. Recent exam results showed that over 75% of the students could adequately identify the "agent of wordiness" and suggest significant improvements.

CONCLUSIONS

We have created a laboratory environment where students take an active role in safety. Audit teams foster a sense of laboratory ownership because the students assume responsibility for ensuring compliance with EPA and OSHA regulations.

We have also significantly improved our students' writing skills, as witnessed by a marked improvement in their memos and reports. Using ungraded memos has proved to be an effective and efficient way to check the students' progress, and they provide meaningful and timely feedback. The memos also give students an opportunity to practice writing by forcing them to continually "distill out" the important aspects of their work and present the product in a coherent form.

TABLE 7
Results of Readability Analysis from Correct Grammar™

Quantity Evaluated	Safety Document Versions		
	Original	Revised	E-Prime
Sentences	22	16	15
Words	298	110	108
Passive Sentences (%)	54	37	0
Flesch-Kincaid	9.0	10.0	8.8
Gunning Fog Index	7.1	6.6	5.3

To answer the question posed in this paper's title—writing mixes very well with safety. Our unique blending of the two has definitely enhanced our students' safety awareness. In addition, the safety and writing activities presented in this paper could be beneficial to any engineering discipline with a large laboratory safety component, especially if chemicals are involved.

REFERENCES

1. Carpenter, S.R., R.A. Kolodny, and H.E. Harris, "A Novel Approach to Chemical Safety Instruction," *J. of Chem. Ed.*, **68**(6), 498 (1991)
2. Amyotte, P., "A Communication Course for Engineers," *Eng. Ed.*, **81**(4), 436 (1991)
3. Pitt, M.J., "Can Laboratory Safety Be Taught?" *J. of Chem. Ed.*, **65**(12), A312 (1988)
4. Emig, J., "Writing as a Mode of Learning," *College Comp. and Commun.*, **68**(2), 122 (1977)
5. *Criteria for Accrediting Engineering Programs, 1990-91,* 1991 ABET Accreditation Yearbook, Accreditation Board for Engineering and Technology, New York (1991)
6. Yoxtheimer, T.L., "Utilizing Short Writing Assignments in Technical Courses," *Proc., 1986 Front. in Ed. Conf., ASEE/IEEE,* Arlington, TX, New York (1986)
7. Swanson, L.W., and H.M.R. Aboutorabi, "The Technical Memorandum: An Effective Way of Developing Technical Writing Skills," *Eng. Ed.*, **80**(4), 479 (1990)
8. Snell, L.M., "Teaching Memo and Letter Writing Techniques in the Classroom," *Eng. Ed.*, **80**(4), 481 (1990)
9. Bethea, R.M., *Incorporation of Occupational Safety and Health into Unit Operations Laboratory Courses,* NIOSH Instructional Module, U.S. Dept. of Health and Human Services, Cincinnati, OH (1991)
10. Burger, R.S., *How to Write So People Can Understand You,* Tinicum Press, West Chester, PA (1970)
11. Bourland, D.D., "A Linguistic Note: Writing in E-Prime," *General Semantics Bulletin,* **32-33**, 111 (1965-66)
12. Correct Grammar 3.0—For the Macintosh Manual, Writing Tools Group, Sausalito, CA (1992)
13. DOD MIL-M-38784B
14. Gunning, R., *The Technique of Clear Writing,* McGraw-Hill, New York, NY (1968) ❐