TEACHING TECHNICAL WRITING IN A LAB COURSE IN ChE

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Have you ever been faced with a paragraph of technical writing such as the following?

An understanding of the characteristics of fluid flow within cylindrical pipes is an important aspect in the design and operation of equipment. Conveniently for the engineer, the flow of fluid within a pipe can be generalized in terms of a single dimensionless number called the Reynolds number. The two general types of flow behavior are called laminar flow and turbulent flow. Qualitatively, laminar flow corresponds to low flow rates in which the streamlines of the fluid flow are parallel to the line of the bulk flow. As the flow rate is increased, however, an unstable pattern is eventually observed in which eddies are present moving in all directions and at all angles to the bulk flow; this is termed turbulent flow.

Simply stating to the student "Be more direct" or "Try to be more cohesive" may not be sufficient for the student to understand how to improve the paragraph. Pointing out passages and specific ways to revise them, however, may lead to writing that is clearer, more concise, and more coherent.

This paper explains how technical writing[1-5] is taught in a laboratory course[6-8] in which 16-48 juniors are organized in groups of two to four, depending on overall class size. Over the span of one semester, the students perform the seven experiments listed below:

- *Temperature Measurement and Response Time*
- *Pressure and Vacuum Measurements*
- *Viscosity*
- *Determination of the Compressibility Factor, Z*
- *Comparison of Flow Measuring Devices for an Incompressible Fluid*
- *Calibration of an Orifice Meter for a Compressible Fluid*
- *Laminar and Turbulent Flow*

and then present the analysis of data in the form of written technical reports.

The teaching of writing in a student's major field of study [7-10] is "part of a 30-year-old trend in U.S. higher education known as 'writing across the curriculum' or 'writing in the disciplines'." [10] At the University of Missouri-Columbia, a Writing Intensive (WI) course "requires revision as a way of improving critical thinking … and … each course should include at least one revised writing assignment addressing a question for which there is more than one acceptable interpretation, explanation, analysis, or evaluation."[10] To meet the objective of improving their writing and critical thinking, students are required to take two 3-credit-hour courses designated as WI, one of which is an upper division course in their major field of study. In the Department of Chemical Engineering, WI courses have been frequently offered either in laboratory courses or in the capstone design course.

As a consequence of the need for revision combined with large class sizes, I have developed several methodologies to teach technical writing in a classroom setting. One goal has been to transfer to the classroom some of the effort devoted to commenting on each student's paper, and thereby teach aspects of good writing collectively rather than individually to each student via written comments. The methodologies presented herein pertain to the written component of technical reports and not to the conventions of technical writing, such as proper format and correct usage for equations, tables, and figures. Although these conventions are extremely important and are treated in the course, other resources are available.[11, 12]

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LESSONS IN TECHNICAL WRITING

To teach principles of writing, I use the book *Style: Lessons in Clarity and Grace*, by Joseph M. Williams.[13] Fundamental to Williams' approach is that good writers make informed choices. Although his book is not specifically focused on technical writing, the principles embodied within the book are general in nature. The sole caveat is that the writing principles may be too far afield from the technical writing of the students for direct or immediate incorporation into their own writing. To remedy this, I have adopted lessons covered by Williams but rewritten them using examples from technical writing, and, in fact, often with examples that the students have recently used or will use soon in their own reports. The balance of this paper explains how examples from Williams' book are modified to teach chemical engineering students elements of good writing and good technical writing.

Williams' book is divided into lessons, six of which are covered in the lab course:

Lesson 3: Actions
Lesson 4: Characters
Lesson 5: Cohesion and Coherence
Lesson 6: Emphasis
Lesson 7: Concision
Lesson 8: Shape

These six lessons also comprise the majority of the two sections of the book covering "clarity" and "grace," as given in the book title.

As a first example, Williams teaches in "Lesson 3: Actions," that "Sentences are clearer when actions are verbs."[13] An example he uses is[13]:

> *The Federalists' **argument** in regard to the **destabilization** of government by popular democracy WAS BASED on their **belief** in the **tendency** of factions to FURTHER their self-interest at the expense of the common good.*

In this sentence, actions (in boldfaced type) are not verbs (in capitalized type) but are nouns. Williams offers an improved version (indicated by the ✓) where many of the actions, formerly nouns, have now been converted to verbs[13]:

> *✓The Federalists **ARGUED** that popular democracy **DESTABILIZED** government, because they **BELIEVED** that factions **TENDED TO FURTHER** their self-interest at the expense of the common good.*

The original sentence highlights the pitfall of nominalization, whereby verbs have been converted into nouns. Such writing, although grammatically correct, often comes across as abstract and indirect and can be improved by making better choices as in the revised version.

Williams' lesson, although instructive, may be too far removed for all students to recognize it in their own writing or to incorporate it directly into technical writing. To bridge this gap, the pedagogy of Williams' examples has been retained but now in sentences that are recast as technical writing found in chemical engineering:

> ***Determination** of the accuracy and precision WAS an important **basis** for the **selection** of a temperature-measuring device.*
>
> *✓We **SELECTED** a temperature-measuring device based on accuracy and precision.*
>
> *✓The **selection** of a temperature-measuring device WAS BASED on accuracy and precision.*

The second improved example is offered for writers who eschew use of the first person in technical writing. I personally use the first person in my own writing and allow students to as well, as long as it is not overdone. I find that use of the first person is especially effective and efficient when writing more informal office-type correspondence and industrial technical reports. I do recommend, however, that superfluous use of the first person be avoided, such as changing "our data, our equipment, our results" to "✓the data, the equipment, the results."

In "Lesson 3: Actions," Williams also addresses how actions can be hidden in adjectives such as in (adjectives boldfaced, verbs capitalized)[13]:

> *The data ARE **indicative** of the problem.*
>
> *✓The data **INDICATE** the problem.*

The modified versions presented to the students are

> *The results ARE **indicative** that the measured values ARE **representative** of the bath temperature.*
>
> *✓The results **INDICATE** that the measured values **REPRESENT** the bath temperature.*

In Williams' sentences above, the ideas may not be such a stretch for the students to understand and apply, but both sets of examples reinforce the idea that avoiding forms of "to be" (a weak verb) with adjectives and replacing them with active verbs (strong verbs) leads to more direct and clearer writing.

In "Lesson 4: Characters," Williams addresses the importance of having short, specific, and concrete subjects appear as what he terms the "characters" of sentences. Four examples are given that demonstrate a progression in the appearance of the subjects as characters[13]:

1. *There was a fear that there would be a recommendation for a budget reduction.*
2. *The fear of the CIA was that a recommendation from the president to Congress would be for a reduction in its budget.*
3. *The CIA had fears that the president would send a recommendation to Congress that it make a reduction in its budget.*
4. *The CIA feared the president would recommend to Congress that it reduce its budget.*

These four sentences, although exhibiting some similarities, differ markedly in directness and specificity. Version 1 exaggeratedly begs the questions[13]: Who fears? Who

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recommends? Who reduces? The second version provides the characters—the CIA, the president, the Congress—but they do not appear as subjects of verbs but rather as objects of prepositions. Version 3 places the characters in the subject position but remains loaded with nominalization. The final version remedies this last deficiency…and an interesting change has taken place. Although Version 4 is about the same length as the first, it has much more content and provides answers to all of the questions: Who fears? Who recommends? Who reduces?

To parallel the above example, I present four sentences that arise from the Viscosity experiment:

1. The solution used was subjected to measurement for its viscosity behavior.

2. The solution of 30 mole% glycerol in water used by our lab group was measured by a capillary viscometer for its viscosity.

✓3a. The viscosity of a 30 mole% glycerol in water solution was measured with a capillary viscometer.

✓3b. A capillary viscometer was used to measure the viscosity of a 30 mole% glycerol in water solution.

✓3c. We measured the viscosity of a 30 mole% glycerol in water solution with a capillary viscometer.

Version 1 begs the questions: Which solution? Used by whom? Measured by what? Version 2 provides some of these answers by introducing specific technical content, albeit as objects of propositions. Versions 3a –3c provide much more content and have eliminated some low-level content that may not be necessary. Although we see that in these latter three versions, the sentences are slightly longer than Version 1, this arises primarily because of the lengthy but specific description of the solution.

"Lesson 4: Characters" also treats the relative merits of passive vs. active voice with an example germane to technical writers (verbs capitalized, nouns boldfaced)[13]:

To determine if monokines elicited a response, ***preparations*** *… WERE ADDED….*

From a strictly grammatical viewpoint, the introductory clause is a dangling modifier, because it has an implied subject (I or we) that is not the same as the subject of the main clause (preparations). In fact, however, the usage above is so common, that most readers and writers of technical writing are perfectly comfortable with such dangling modifiers, especially if the alternative is[13]

To determine if monokines elicited a response, ***I*** *ADDED* ***preparations****….*

To address this issue (but not to resolve it!), I present the following:

By substituting into Eq. (1), the ***viscosity*** *of the mixture WAS DETERMINED.*

✓By substituting into Eq. (1), ***we*** *DETERMINED the* ***viscosity*** *of the mixture.*

✓The ***viscosity*** *of the mixture WAS DETERMINED from Eq. (1).*

Although these sentences only parallel the ones of Williams, they do highlight another common weakness in students' technical writing, namely, low technical content, which can be remedied as follows:

By substituting pure component viscosities into Eq. (1), the viscosity of the glycerol-water solution was determined to be 10 cP at 298 K.

✓By substituting pure component viscosities into Eq. (1), we determined the viscosity of the glycerol-water solution to be 10 cP at 298 K.

In "Lesson 5: Cohesion and Coherence," Williams explains how to lend a sense of cohesion to writing. He offers two sentences, one with an active verb and one with a passive verb[13]:

A) The collapse of a dead star into a point perhaps no larger than a marble creates a black hole.

B) A black hole is created by the collapse of a dead star into a point perhaps no larger than a marble.

He then asks which sentence, A or B, fits better in the passage given below[13]:

Some astonishing questions about the nature of the Universe have been raised by scientists exploring black holes in space. [A or B] So much matter compressed into so little volume changes the fabric of space around it in puzzling ways.

As indicated below, sentence B lends a sense of cohesion to the passage:

✓Some astonishing questions about the nature of the Universe have been raised by scientists exploring **black holes in space**. *A* ***black hole*** *is created by the collapse of a dead star into* **a point perhaps no larger than a marble**. ***So much matter compressed into so little volume*** *changes the fabric of space around it in puzzling ways.*

The reason is that readers find text more coherent when sentences end with new information (in bold) and then begin sentences with old information (in bold italics). This is called the Old-to-New strategy. My experience is that very few undergraduate students are familiar with this strategy for achieving coherence in writing. To apply this Old-to-New technique, I present to the students the five-sentence passage which began this article:

[1]*An* **understanding** *of the* **characteristics of fluid flow** *within cylindrical pipes is an* **important aspect in the design and operation of equipment**. [2]**Conveniently for**

the engineer, *the **flow of fluid** within a pipe can be generalized in terms of a single dimensionless number called the* **Reynolds number**. [3]*The two general types of flow behavior are called* **laminar flow** *and* **turbulent flow**. [4]*Qualitatively, **laminar flow** corresponds to low flow rates in which the streamlines of the fluid flow are parallel to the line of the bulk flow.* [5]*As the flow rate is increased, however, an unstable pattern is eventually observed in which eddies are present moving in all directions and at all angles to the bulk flow; this is termed **turbulent flow**.*

The first sentence (Sentence **1**) introduces a number of possible new ideas (bold type) as to the topic of the paragraph, and in fact introduces too many ideas. Sentence **2** violates the Old-to-New strategy by not beginning with Old information (bold italics), but instead introduces additional New information, namely a new character "the engineer," in the form of a dangling modifier. Sentence **2** next proceeds to the "flow of fluid," which is Old information, and then introduces New information, the Reynolds number. In sentence **3**, the Reynolds number should now represent Old information, but instead this topic is dropped and two types of flow are now introduced, which leads to further new information, namely "laminar flow" and "turbulent flow." Sentences **4** and **5** then proceed to follow the Old-to-New strategy by defining laminar and turbulent flow. The location of turbulent flow at the end of the fifth sentence, however, is where readers expect to find new information.

An improved version of the paragraph, which more closely adheres to the Old-to-New strategy, is given below:

✓[1]*Two general types of fluid flow behavior are observed and these are referred to as* **laminar and turbulent flow**. [2]*Qualitatively, **laminar flow** corresponds to* **low flow rates** *in which the streamlines of the fluid flow are parallel to the line of the bulk flow.* [3]***As the flow rate is increased**, however, an unstable pattern is eventually observed in which eddies are present moving in all directions and at all angles to the bulk flow; this is termed* **turbulent flow**. [4]*These two types of **flow behavior** can be predicted by a single dimensionless number called the* **Reynolds number**.

In the version above, the topic sentence focuses on fluid flow behavior, and introduces the New information of laminar and turbulent flow. Laminar flow now appears as Old information in the sentence **2**, and is explained as New information by "low flow rates." In sentence **3**, the phrase "as the flow rate is increased" is the Old information in the form of a subtle, indirect link back to "low flow rates" from the preceding sentence. In sentence **4**, the connection to previous information is straightforward, and the paragraph is then summarized with the introduction of the concept of the Reynolds number. (Presumably, the paragraph could be extended with a definition of the Reynolds number and the corresponding regimes for laminar and turbulent flow. Alternatively, a new paragraph of the same content could begin with a paragraph transition back to the idea of the Reynolds number.)

The Old-to-New Strategy thus reduces each paragraph to the introduction of new information in a topic sentence followed by a succession of sentences that proceed

↻ *New. First Sentence (topic sentence with transition from preceding paragraph)*
Old - New.
⋮
Old - New. Last sentence (concluding sentence)

In "Lesson 7: Concision," several strategies are presented for achieving concision, such as deleting meaningless words and doubled words. I combine this aspect of writing along with adding technical content to sentences, as indicated in the following examples.

The viscosity was basically measured with an accurate device called the Brookfield rheometer.

✓*The viscosity of the glycerol-water solution was measured with a Brookfield rheometer from 10-60 rpm.*

The full and complete data are in Table 1 for each and every shear rate.

✓*The viscosity data for the glycerol-water solution at 25 °C are in Table 1.*

In "Lesson 8: Shape," Williams teaches that writers should start sentences with subjects, next get to the verb quickly, and then get to the object. I use the following examples to make the same points with subjects boldfaced, verbs capitalized, and objects underlined:

*A **pump** for the process based on flow rate and efficiency WILL BE SELECTED.*

✓*A* **pump** *WILL BE SELECTED for the process based on flow rate and efficiency.*

We *WILL SELECT for the process <u>a pump</u> based on flow rate and efficiency.*

✓**We** *WILL SELECT <u>a pump</u> for the process based on flow rate and efficiency.*

The first pair of sentences above highlights how the verb can be moved closer to the subject, and the last pair indicates how the object can be brought closer to the verb.

STUDENT FEEDBACK AND ASSESSMENT

As is indicated in Table 1 (next page), students had a number of positive comments to the approach presented herein on teaching technical writing, and these reflect the majority of student responses. Another type of receptive feedback is that students have asked me to provide them, via the Internet or other means, with the examples herein.

Table 1 also presents some negative comments, which reflect the students' desire for exposure to more examples of technical writing and for the instructor to be more accepting of different writing styles. Several of these comments highlight

the peril of attempting to modify students' writing without sufficient appreciation for the difficulty of the task and for the sensitivity of the students.

Although the teaching of writing is difficult, both students and I generally notice an improvement in their writing. In response to the query "Please rate, in your own estimation, how much your technical writing improved" the students rated their improvement 3.4 on a scale of 1=*improved a lot* to 9=*improved very little*. The main areas of improvement I have observed are in concision, addition of technical content, and in applying the Old-to-New strategy.

SUMMARY

In this paper, examples are presented for teaching technical writing in a laboratory course to undergraduate students. The lessons presented to the students are adapted from the book *Style: Lessons in Clarity and Grace*, by Joseph M. Williams. Williams emphasizes the importance of informed choices in writing. His lessons are modified to bring them nearer to the technical writing the students are learning and practicing in the course, with the hope that the students will thus better be able to incorporate these ideas into their own writing.

As a side note, the medium for presenting examples of technical writing in the classroom has evolved from overhead transparencies to use of an interactive whiteboard to computer projection of word processing documents. The interactive whiteboard was especially effective in that I could edit and highlight, in color, in front of the students. Most recently, I have been using computer projection with colored text to illustrate the principles.

The writing lessons covered herein are generally presented to the students by first showing them the uncorrected versions and then eliciting their comments on ways for improvement. After this group discussion, the principle of the lesson is presented and further practiced interactively with additional examples. The exception to this purely interactive approach is for the Old-to-New strategy. Because this strategy is unfamiliar to many students and may appear complicated at first glance, I normally spend parts of two lectures teaching it. Sometimes I distribute paragraphs to the students in class and ask them to analyze the writing to see if it adheres to or violates the Old-to-New strategy. Other times, I have them analyze one or more of their own paragraphs.

TABLE 1
Selected Comments From Students on Writing Instruction.

Positive:
It was an excellent class for writing within the major.
The balance between technical learning and writing technique allowed for the development of important application skills that had remained unaddressed until then.
Explanations and examples of writing techniques were helpful.
Giving specific examples of certain writing to aid our writing really helped.
Excellent instruction on writing techniques.
Good examples of better writing and revision.
Learning how to technically write seemed like a very useful tool for not only later classes, but also future jobs.
Examples of good vs. bad writing. Active discussion and in-class revision practice.
Negative:
I recognize that the writing techniques are very good, but I feel there could be a greater acceptance of other writing styles.
Put notes (examples of writing) on a Web site.
The text bothered me, I can't say that I read it, but some of the concepts it presented seemed odd.
Would like to see more examples of students' reports presented and criticized in class.
Be more accepting of other people's writing.

ACKNOWLEDGMENT

The content of this paper draws heavily from Williams' book, and he additionally deserves credit for the formatting conventions I have used here to help illustrate the ideas in black-and-white print. I am also indebted to the Campus Writing Program at the University of Missouri-Columbia and to Martha D. Patton, who always pointed me in the right direction.

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