

AC 2007-541: EFFECTIVE “WRITING TO COMMUNICATE” EXPERIENCES IN ELECTRICAL ENGINEERING COURSES

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Effective “Writing to Communicate” Experiences in Electrical Engineering Courses

Abstract

To help develop essential communication skills that engineering graduates need, engineering faculty must find ways to incorporate writing into the curriculum. There have been reports of impressive work integrating writing centers or technical communication professionals with engineering courses. However, most engineering programs do not have access to such resources. Writing has been effectively integrated into many senior design courses. Nevertheless, students’ skills would be further developed if writing were included throughout the undergraduate engineering curriculum. But how can electrical engineering faculty do this? Research reported in the literature describes constructivist and knowledge transformation frameworks of how writing helps build knowledge in the sciences. Building on these theories, successful writing experiences in engineering are “writing to communicate” rather than “writing to learn”. This paper highlights several key aspects of integrating effective “writing to communicate” experience into undergraduate electrical engineering courses by an engineering professor in a practical way. These aspects include authentic investigation, motivation for communication, tying the writing to the technical content, a well-defined audience, providing useful practice for an engineering career, and not being overly burdensome to the engineering faculty instructor. Specific examples, student response, and lessons learned from activities in sophomore-level *Circuits*, junior-level *Electronics* and a senior-level elective on *Optoelectronics* are presented.

1. Introduction

To help develop essential communication skills that engineering graduates need, engineering faculty must find ways to incorporate writing into the curriculum. There have been reports of impressive work integrating writing centers or technical communication professionals with engineering courses.^{1,2,3} However, most engineering programs do not have access to such resources. Writing has been effectively integrated into most senior design courses. Nevertheless, students’ skills would be further developed if writing were included throughout the undergraduate engineering curriculum. Giving students many opportunities to demonstrate their “ability to communicate effectively” (ABET 3g) is desirable. But how can electrical engineering faculty do this?

Research reported in the literature describes constructivist and knowledge transformation frameworks of how writing helps build knowledge in the sciences. Building on these theories, successful writing experiences in engineering are “writing to communicate” rather than “writing to learn”. In Section 2, this paper briefly describes these theories and then presents six guidelines for integrating effective “writing to communicate” experience into undergraduate electrical engineering courses by an engineering professor in a practical way. These guidelines include authentic investigation, motivation for communication, tying the writing to the technical content, a well-defined audience, providing useful practice for an engineering career, and not being overly burdensome to the engineering faculty instructor. In Section 3, specific examples from sophomore-level *Circuits*, junior-level *Electronics* and a senior-level elective on *Optoelectronics* are presented. These are intended to serve as representative examples of

assignments and to illustrate how grounding experiences in writing to communicate theory can help enhance effectiveness.

2. Writing to Communicate

A vast amount of literature exists on writing across the curriculum (WAC)^{4, 5, 6} which emphasizes the importance of writing for enhancing learning. WAC divides writing into three categories: transactional to inform or persuade an audience, poetic as an art form, and expressive for oneself to think through a problem or formulate a thought.⁷ Much of the WAC movement in the US has focused on expressive writing as the most beneficial when “writing to learn” and thus has minimized the importance of “transactional” writing as merely reflecting back teacher-generated information. However, within the scientific genre where engineering may be situated, transactional writing or “writing to communicate” plays a crucial role in the construction of knowledge. As described by Keys⁸, “writing in scientific genres promotes the production of new knowledge by creating a unique reflective environment for learners engaged in scientific investigation.” Through transactional writing, students take ownership of concepts and make scientific knowledge their own. Thus writing has been linked to developing important critical thinking skills.⁹

So, how can an authentic “writing to communicate” experience be integrated into a traditional engineering course in a practical way? Constructivist and knowledge transformation theories of science learning view writing as a way to help students learn. Building on these theories, the literature, and her own situated experience, the author has developed six guidelines that are useful in designing effective “writing to communicate” experiences in engineering classes:

1. authentic investigation
2. motivation for communication
3. integrating the writing into the class
4. well-defined audience
5. providing useful practice for an engineering career
6. not being overly burdensome to the engineering faculty instructor

Constructivist learning theories emphasize authentic investigation as important for learning science.¹⁰ Students are motivated by having a clear purpose for writing. For example, a motivating purpose might be to understand their own experimental results or communicate to others. Keys found that if students have opportunities for authentic investigation, they “take ownership of the inquiry question or problem, they usually accept writing about their investigation experiences as a natural outgrowth of the process, and can become enthused about communicating their findings to others.”¹¹ In the examples presented in this paper, engineering students can conduct authentic investigations in the laboratory, with computer simulation, by reading each other’s writing, or in researching the literature and then writing about the knowledge gained. This learning and writing process follows the knowledge-transforming model of Berieter and Scardamalia¹² since as students go between the “content space” of gathering data, conducting experiments etc. and the “rhetorical space” of writing to communicate to an audience of their peers, they create their own knowledge.

Students are more likely to see the value of writing when it is tied to the technical content. As Pesante says “Learning is most effective when it takes place in context and when it is reinforced

through the students' course of study.”¹³ In all of the examples in this paper, an engineering professor rather than a writing professor grades the writing. Thus the quality of the writing and the technical accuracy of the work are inseparable. This adds legitimacy to the claim that writing is important.

The writing to communicate experience is enhanced by specifying a particular audience. Writing for an audience requires the writer to be detailed and explicit so that the reader can understand. Characteristics of “reader-based” prose as distinguished from “writer-based” prose are summarized in Poe and Freeman²: clear, simple prose, standard format, appropriate technical vocabulary, and effective document design and use of figures including captions. In each of the examples presented in this paper, the audience is specified to be peers in their class or in the class behind them i.e. sophomores audience for junior authors. This helps the students to focus their thoughts and choose appropriate presentation, level of detail, and content. It may also be presented as a new challenge. Because their peers will actually read and in some cases evaluate their work, the student authors must be careful not to assume the reader already knows the subject. This is very different than writing for a professor or other expert which students usually do in class assignments.

Typical laboratory reports and homework solutions may not be representative of the types of writing that students will need to do later in their careers particularly in industry. Thus it is important to find alternatives such as user's manuals, memos, or summaries that might be more useful.^{14, 15} For technical writing, it is important to incorporate graphics, figures, and equations as this is a distinguishing aspect of technical writing.¹⁶

Engineering educators often object to the time required to evaluate or grade writing assignments.⁹ Thus, the practical aspect of integrating writing into this experience means ensuring that it is not overly burdensome to the engineering faculty member. In all of the examples in this paper, no special expertise in writing is required besides the typical familiarity with technical writing that most engineering instructors have. Thus these experiences may be more readily transferable to other institutions than other innovative but potentially expensive WAC approaches. When applicable, the quality of the writing typically improves if multiple drafts with revisions are included.^{2, 17} However, in the examples presented here, the decision was made not to include multiple drafts to minimize the grading burden on the engineering faculty member.

3. Examples from EE Courses

In this section, examples of effective writing to learn experiences from several electrical engineering courses are presented. These experiences are from sophomore, junior, and senior level courses but not senior design. They include activities for lecture, homework, and laboratory. For each one, the experience is described and then how the experience is based on the six guidelines of effective writing to communicate experiences described in Section 2 is presented. Student response and lessons learned are also included. These examples are intended to serve as representative examples of assignments and to illustrate how grounding experiences in effective writing to communicate theory can help enhance effectiveness. Each example could be used in other courses besides the one mentioned. Certainly, multiple experiences throughout each course and the curriculum are essential to develop communication skills.

A. User's Manuals on Circuit Simulation Software (Sophomores as Homework)

In a sophomore Circuits class, Engr 60, students had a homework assignment where they had to write a User's Manual for PSpice. They were instructed to read some introductory material in the PSpice companion to their textbook¹⁸ and to work through the examples in those chapters. Half of the points for this homework assignment were for producing correct output for two examples from the book and half of the points were for writing the User's Manual. Specific instructions that the students received were

Write a User's Manual for PSpice OrCad Release 9.1 for students in Engr 60. This document should be prepared using a word processor. It should be sufficiently detailed so that an Engr 60 student who had never used PSpice before could use ONLY this document and the software to produce graphical output such as that generated from Example 3 (i.e. perform DC sweeps).

This experience incorporates the six guidelines presented in Section 2. Students conduct their own *authentic investigation* by experimenting with the software so that they learn enough to conduct simple simulations and be able to write about the process. Students are *motivated to communicate* the results of their investigations and to help peers learn how to use the software. Since the students have been told by the instructor and have heard from upper-class students that simulation will be an important part of this course and subsequent courses in electrical engineering, they are motivated to learn how to use it and see a clear *tie between this assignment and technical content*. Students are given the *specific audience* of their peers. Writing User's Manuals is a common task for many engineers in industry particularly those involved in product design. Thus students can see that they are emulating practices performed by working engineers and can clearly see how this would be *useful later in their careers*. This assignment is *not overly burdensome to the engineering faculty instructor*. It is part of a weekly homework assignment rather than an additional assignment, the instructor does not have to write his/her own manual, and the students can see examples of several manuals by sharing the results with the class. In fact, one such manual written by a student was so good that it was distributed to all of the students in the class so that they could learn what effective manuals looked like. It was used by the instructor and other instructors as a reference for subsequent classes of students.

Students found this assignment challenging. Of the twenty-seven students in the class, only twelve submitted a tutorial. On the syllabus, students were told that they could drop several homework assignments. Thus many students chose not to do it. Those who completed the assignment believed that it was useful and forced them to learn how to use the software so that they could explain it to others. The tutorials were graded based on presentation, completeness, and content. The quality of the tutorials varied quite a bit. Six of the twelve students wrote two pages, four wrote one page, one wrote three pages, and one wrote four pages. As stated above, the best student manual was excellent and served as a reference for future classes.

Several lessons were learned by the instructor from this experience. An important lesson is that the writing assignment should be a required part of the course since engineering students will often try to avoid writing if possible. As such, incorporating the writing into a laboratory might be better than a homework assignment if students are given the freedom to drop some homework

assignments. Students benefited from seeing examples of other students' work and from having specific guidelines. Useful products resulted from the assignment which were valuable for successive classes of students.

This framework of having students write for peers or a class behind them can be used with other topic areas. For example, the author has had juniors in *Electronics* write memos to sophomores in *Circuits* explaining the concepts of input and output resistance. The sophomores can conduct reviews of these memos and provide feedback to the juniors. The author has also used this in a Junior-level *Electronics* course where students write a tutorial on how to use *Electronics Workbench Multisim* for sophomores in the *Circuits* class. The sophomore students reviewed the tutorials and their comments were given to the juniors. In the author's experience, juniors produced better documents for these assignments that sophomores did. This may have to do with their increased level of comfort with the technical material as well as the fact that all of the juniors were Electrical Engineering majors while the sophomores were Electrical and Industrial and Systems Engineering majors.

B. "Snazzy Diode Circuits" Investigation (Juniors in Lab)

"Snazzy Diode Circuits" is an experiment that has been used in a junior-level *Electronics* I class. Students become experts by experimenting with one diode circuit in lab. Students communicate their knowledge by writing a memo to their classmates explaining the behavior of their circuit. Students then evaluate peers' memos to learn about all of the circuits. Specific instructions that the students received in lab were

Standard silicon diodes (4007 or 1N4148) are recommended unless a Zener was required as indicated by a Z next to the diode circuit symbol. Use a 4V (peak) sinusoidal voltage as the input voltage for initial analysis. For each circuit, the analysis should include

1. What does the circuit do? Can you suggest a more descriptive name for the circuit?
2. What does the output voltage look like as a function of time?
3. What does the transfer characteristic (output versus input voltage) look like?

Instructions for the write-up were as follows:

A formal write-up is required for this lab. This is due on **Monday, October 11, 2004 by 2:20 PM**. Please submit one report per group as a word document attached to an email to Dr. Lord slord@sandiego.edu. Your document should be entitled E301C#.doc where # is your circuit number which will be assigned in lab. You may turn your report in to Dr. Lord anytime before it is due. Note that **NO LATE LAB REPORTS** will be accepted.

Your report for this lab will be different than our usual ELEC 301 write-up. Please write a 1 page memo (exclusive of figures) to your classmates describing the basic function of your circuit. Your memo will be your classmates' resource for learning about your circuit.

Instructions that the students received for the peer evaluation were:

1. Using complete English sentences, provide a review of the 2 memos for the circuit with a number one greater than yours. (For example, if you did a memo on Circuit 2, you should review Circuit 3. If you did Circuit 5, you should review Circuit 1.) Be honest in your assessment of how much you learned from the memo and how easy it

- was to understand. In addition to written comments, provide a grade for each memo for Presentation (0-3 pts), Content (0-3 pts), and Analysis (0-4 pts).
2. Which of the circuits do you think is the "snazziest" and why?
 3. Which circuit do you feel most confident about explaining? Why?
 4. Did you learn more from experimenting with the circuit in lab or reading the memos?
 5. Of all of the memos, which memo (specify by authors) do you think did the best job at a. Presentation, b. Content, c. Analysis, and d. Overall?
 6. What do you think was the most valuable part of this lab experience?
 7. Do you have any suggestions for improving this lab for next year's class?

In "Snazzy Diode Circuits," one *authentic investigation* is provided by the laboratory experimentation where students acquire new information to share with their peers. As students write memos to express their expertise about their circuit for their peers, they improve and reinforce their own understanding and improve their communication skills at the same time that other students learn the material. Another authentic reason that students have for writing is to communicate their review of their peers' memos. Since the writing is *tied to the laboratory experience* in "Snazzy Diode Circuits", it is perceived as integral to the class rather than an "add-on" which might cause resentment by students. Students know that they will learn about these circuits both by writing about their own and reading the memos of their peers. They are aware, from the beginning of the assignment, that the *audience is specified to be peers*. The student authors know that their memos will be their classmates' resources for learning about particular diode circuits. Thus they are conscious of the need to write at an appropriate level and include sufficient detail.

Writing a memo is useful *practice for later in students' careers particularly in industry*. Given that these circuits are relatively simple, they can be explained in a one-page memo. Practicing brevity is invaluable. Learning to effectively incorporate graphics is also critically important for writing in engineering. A one-page memo also facilitates having students evaluate each other's work since each document is brief. Finally, a memo may be perceived as more interesting by the students because it is different than the traditional lab write-up. Although the experience does require time for grading memos and summarizing evaluations, once the framework for the experience was developed, it is *not overly burdensome on the faculty member*. Grading is facilitated by having the memos be limited to one page of text.

Students were generally positive in their evaluation of this experience. There were no student comments that the writing was out of place or detracted from the laboratory. Rather than seeing the writing of the memos or the peer review as an unnecessary burden, students believed that the process was educational. Some students specifically commented on the value of writing for their understanding demonstrating writing to communicate as a knowledge transformation process.

*In generating a write up one is forced to understand as much as possible
I feel that gathering data and organizing it into a comprehensible format is the best way
to understand the intricacies of a circuit in a lab experiment.*

A few students commented on whether the writer had met the needs of the peer audience.

Writer underestimated his audience's knowledge by including a number of unnecessary graphs

I think he used a lot of terminology that would assume that the reader has some prior knowledge of diodes and circuits, but I guess that is acceptable since he is writing to his classmates.

Some students saw this as an opportunity to develop skills that would be used later in their engineering careers.

The difficulty came in explaining the circuit to our peers. This is what will be expected of us in the field and therefore it was a great lesson to learn from.

The most valuable part of the lab experience was in fact these memos. It saved us tons of time by not having us do analysis for all seven circuits but still let us see and understand how each one works. It helped us to completely understand our own circuits rather than simply do the lab and be done with it. This also helped us with our engineering communication skills in presenting our work to others.

The most valuable part of this lab was building the circuit and analyzing its output. This is a valuable skill for the field-probably number two behind designing circuits to meet specified goals.

Several lessons were learned by the instructor from conducting this “Snazzy Diode Circuits” experience over more than five years. Some students are particularly motivated by doing something that is different than a typical lab and lab report. This is evidenced by the excellent memos that some students produced. Some students really enjoy seeing other students’ work, often for the first time. To make the experience practical, not all students review all memos. Because different student reviewers have different standards, it is also important for the professor to independently grade and provide comments on the memos. This provides some consistency among the reviews.

C. “Fabulous Fridays” (Seniors in Class)

In Spring 2003, the last fifteen minutes of each Friday class in a senior level Optoelectronics elective was devoted to “Fabulous Friday” where one student led a discussion of a recent article which he/she had distributed to the class on Monday.¹⁹ During the first week of class, the instructor distributed and discussed the guidelines for “Fabulous Fridays” and students signed up to be the leader for a specific Friday during the semester. Instructions given to students included

- Find an interesting article. Sources such as *Scientific American*, *IEEE Spectrum*, *Laser Focus World*, and *Business Week* might be good places to start.
- Provide 9 copies of the article for us to read by the Monday before your Friday (if you have it ready by the previous Friday, I can have copies made)
- Email a brief summary of your article and at least 2 discussion questions by Thursday at noon to slord@sandiego.edu
- Lead the discussion on your Friday

Articles came primarily from *Laser Focus World* and *IEEE Spectrum*. This endeavor gave the students an opportunity to develop oral communication skills and the ability to critically evaluate new information from sources other than textbooks and lectures. Topics included applications of

LEDs for curing blindness, iris scanning for security, and thin-film photovoltaics. Some did outside research to enhance their discussions. Students enjoyed the range of topics. Leading a discussion was challenging for many including the instructor as she strives to balance her own participation, providing context or background, and letting the students lead.

“Fabulous Friday” was a required part of the course. It counted as one homework assignment. The instructor graded this assignment out of 10 points with 2 points for finding an article, 1 point for distributing it, 2 points for their questions, 2 points for the summary and 3 points for leading the discussion. Given that there were more weeks in the semester than students in the class, the instructor initially planned on leading the discussions herself during the remaining weeks. After the students signed up during the first week of class, the extra weeks occurred late in the semester. As the semester progressed, several students expressed a desire to lead an additional “Fabulous Friday” as a way to earn extra credit for the course or to improve their performance over their first “Fabulous Friday”. Students were given the opportunity to do another “Fabulous Friday” for up to five extra credit points. For the two students who led two discussions, their discussions were more dynamic the second time.

This experience also incorporated oral communication as well as writing to communicate. The six guidelines discussed in Section 2 are embedded in the design of the experience. Students conduct an *authentic investigation* as they do literature research to identify an article and perhaps supplementary material. Since students are communicating to peers about what they learned by leading or participating in a discussion, they have a *motivation for communication*. The student writing the summary is explicitly asked to make the connection between the topic of the Fabulous Friday article and the course topics so that everyone can see that the *writing is tied to the technical content*. Students are addressing their peers in their remarks in the discussion as well as their summaries so they are *communicating to a well-defined audience*. Engineers in the workplace often present summaries, investigate new technologies, and/or lead meetings, so this experience provides *useful practice for an engineering career*. Finally, the experience is *not overly burdensome to the engineering faculty instructor* as there is not too much grading to be done and some class time is led by students so there is less need for the professor to prepare. It does, however, require organization at the beginning of the semester to insure that every student has the opportunity to present.

Student response to the class was quite enthusiastic as may be expected for a small elective course. Although students worked hard, they believed they learned a lot which made it worthwhile. During an informal midcourse evaluation all students commented on the value of and/or made suggestions on how to improve “Fabulous Fridays” in response to the questions “What do you like best about the course? What needs improvement? How could the course be improved?”

I like Fabulous Friday. It is a good change. We can see how the stuff we learned in class is being used in the real world.

On the end of the semester evaluations, two of the eight students specifically mentioned “Fabulous Fridays” as an aspect of the class that contributed the most to their learning.

“Fabulous Fridays” served as a learning experience for the students and instructor. In fact, the students themselves identified ways to improve the “Fabulous Friday” process thereby demonstrating not only effective communication but also lifelong learning skills. Throughout the semester, articles got shorter until one very short one proved difficult to understand. The class recognized this and discussed the criteria for a suitable article and subsequent articles were more appropriate. Based on these suggestions, changes were made to the instructions on “Fabulous Friday” to include more details on the type of article that would be suitable and the requirements for the summary. The instructor made changes to the guidelines and distributed them to the class for feedback. The new instructions were then ready for the next offering of the course or other courses where such an activity might be useful.

The framework developed for “Fabulous Friday” may be used in any course where it is beneficial for students to investigate current topics. Depending on factors such as the amount of course time available, course structure, number of students, it could be adapted so that students present in groups, several students lead fifteen minute discussions during the same class period, or used as an extra credit assignment. For example, the author subsequently used a modified version of this activity in a junior level Materials Science course where students had to identify one article related to current issues preparing copies and a summary according to the “Fabulous Friday” guidelines but the discussions were all held during the one week rather than on Fridays.

4. Summary

To help develop essential communication skills that engineering graduates need, engineering faculty must find ways to incorporate writing into the curriculum. Research reported in the literature describes constructivist and knowledge transformation frameworks of how writing helps build knowledge in the sciences. Building on these theories, successful writing experiences in engineering are “writing to communicate” rather than “writing to learn”. This paper described six guidelines for integrating effective “writing to communicate” experience into undergraduate electrical engineering courses by an engineering professor in a practical way. These aspects include authentic investigation, motivation for communication, tying the writing to the technical content, writing for a well-defined audience, providing useful practice for an engineering career, and not being overly burdensome to the engineering faculty instructor. Multiple opportunities to practice effective communication are needed throughout the curriculum. Several specific examples, student response, and lessons learned from sophomore-level *Circuits*, junior-level *Electronics* and a senior-level elective on *Optoelectronics* were presented. These examples include activities for class, homework, and laboratory and serve as suggestions for other instructors in designing effective “writing to communicate” experiences.

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