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Integrating Effective 'Writing to Communicate' Experiences in Engineering Courses: Guidelines and Examples*

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Incorporating writing into the curriculum is a challenge for engineering faculty. Constructivist and knowledge transformation frameworks of how writing helps build knowledge suggest that successful writing experiences in engineering are 'writing to communicate'. Drawing from that literature, the author advocates five guidelines for integrating effective 'writing to communicate' experience into undergraduate engineering courses: authentic investigation, tying the writing to the technical content, an authentic well-defined audience, providing useful practice for an engineering career and not being overly burdensome to the engineering faculty instructor. Specific examples of activities based on these guidelines, from classroom, homework and laboratory activities in sophomore, junior and senior-level classes serve as suggestions for faculty seeking to creatively incorporate writing throughout the engineering curriculum.

Keywords: Effective communication; integrated writing assignments; technical communication; writing in engineering; writing to communicate

INTRODUCTION

TO HELP DEVELOP essential communication skills that engineering graduates need, engineering faculty must find ways to incorporate writing into the curriculum. The literature contains many reports of impressive work by technical communications professionals and engineers working together in writing across the curriculum [1], writing centers [2], interdisciplinary courses [3] and programs [4], and other support systems many of which are nicely summarized by Ford and Riley [5]. Creative programs focusing on technical communication and engineering are ongoing at a variety of institutions including Rice University [6], Virginia Tech [7], Northwestern University [8] and in multi-university collaborations such as the CDIO Initiative (Conceiving-Designing-Implementing-Operating Real-world Systems and Products) [9]. The most common integration of writing in engineering curricula is in design courses. For example, with collaboration between technical communication and engineering faculty, writing has been effectively integrated into design courses at the senior-level [10, 11, 12], in sophomore engineering design clinics [13], and first year introductory design courses [14]. In addition, some excellent examples of integrating writing into nondesign courses have been presented such as a junior/senior bioengineering course [15], an introductory materials science course [16] and a summer research experience in bioengineering [17]. Such collaborations may indeed be the best way to effectively teach technical communication. However, many engineering programs do not have access to such collaborative resources.

Nevertheless, engineering students' communication skills would be further developed if writing were included throughout the undergraduate engineering curriculum and if this could be done by engineering faculty [18]. Giving students many opportunities to demonstrate their 'ability to communicate effectively' (ABET 3g) is desirable. This is a challenge for engineering faculty as Moon says: 'Despite the recognized importance, it is not easy to develop and implement a curriculum that fosters such skills' [19]. Given that engineering curricula and faculty are already busy, how can faculty integrate effective communication experiences throughout the curriculum?

There is a body of literature on writing that, although not familiar to most engineering educators, may be helpful in designing engineering assignments. Constructivist and knowledge transformation frameworks show how writing helps develop knowledge. Building on these theories, successful writing experiences in engineering are 'writing to communicate'.

GUIDELINES FOR ENGINEERING EDUCATORS

A vast amount of literature exists on writing across the curriculum (WAC) [20, 21, 22] which emphasizes the importance of writing for enhan-

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cing learning. WAC divides writing into three categories: transactional to inform or persuade an audience, poetic as an art form, expressive for oneself to think through a problem or formulate a thought [23]. Much of the WAC movement in the US has focused on expressive writing as the most beneficial when 'writing to learn'. 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 Keys [24], '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 [25]. Transactional writing includes writing within the workplace which is particularly important for preparing engineering students for their future careers [26, 27].

So, how can an authentic 'writing to communicate' experience be integrated into a typical 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 five guidelines [28] for designing effective 'writing to communicate' experiences in engineering classes:

1. Authentic investigation
2. Tying the writing to the technical content
3. Authentic well-defined audience
4. Providing useful practice for an engineering career
5. Not being overly burdensome to the engineering faculty instructor.

Having guidelines may be especially helpful for faculty trained as engineers who tend to, as Ford says, 'be writers who want directions and think of writing in terms of concrete rules' [29]. However, in keeping with Ford's recommendation that students should not think of templates as formulas but as starting places for rhetorical creativity, these guidelines and the examples presented below are also intended as starting points to assist engineering educators in the difficult creative task of effectively integrating writing in all of their courses. Communication assignments might be particularly challenging for instructors who are non-native speakers. Nonetheless, these guidelines might help such instructors focus on integrating writing that would be most comfortable for them rather than avoiding such assignments altogether because grammar or punctuation may not be their strength.

Constructivist learning theories emphasize authentic investigation as important for learning science [30]. 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' [31]. In the examples presented in this paper, engineering students 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 Scardamalia [32] 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' [33]. This idea is consistent with Ford's recommendation to 'teach students that writing is part of the technical process' [20]. Ramachandran et al. described successful multidisciplinary design projects which were linked to technical communication so that students appreciated 'that communication is part of the design process' [13]. For courses without large design projects, it is important to integrate the writing into typical course activities such as laboratory, homework or classroom discussions. In addition, 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.

Engineers may struggle with presenting their material appropriately for a given audience specifically in terms of minimizing jargon, being clear and concise and using graphics effectively [34]. 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 Freeman [3]: clear, simple prose, standard format, appropriate technical vocabulary and effective document design and use of figures including captions. Some of the difficulties students encounter in effectively communicating in the workplace rather than classroom have been linked to the problem of audience [12]. As Paretti summarizes:

> one of the major stumbling blocks students face is transferring communication skills from the classroom to the workplace is the difference between using texts in school (written and oral) to **perform knowledge** so

> that teachers can evaluate concept mastery and using texts at work to **communicate information** (emphasis in original) [35]

To enhance the effectiveness of technical communication assignments, Paretti suggests making 'the needs of the audience drive the content, organization, and design' [36]. In each of the examples described in this paper, the authentic audience is specified to be peers who themselves have a stake in learning the material. This helps the student authors 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 from writing for a professor or an expert, which students usually do in class assignments. Thus, in these assignments, students must consider their audience which helps them develop more sophisticated and transferable rhetorical skills [12].

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. For example, Keane and Gibson conducted a study of practicing engineers in Ireland and found that common writing tasks beyond reports included writing memos (67%), proposals (57%), minutes (54%), letters (47%) and manuals (33%) [34]. Also, 41% reported that ineffective writing causes problems in the workplace. Thus it is important to find alternatives for engineering undergraduates such as user's manuals, memos or summaries [37, 38]. For technical writing, it is also important to incorporate graphics, figures and equations as this is a distinguishing aspect of technical writing [39].

Engineering educators often object to the time required to evaluate or grade writing assignments [25]. Thus, the practical aspect of integrating writing into this experience means ensuring that it is not overly burdensome to the engineering faculty member. If engineering faculty say writing is important, but do not include it in grading, they send a mixed message to students [40]. In all of the author's examples, the instructor had no special expertise in writing 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 approaches. Certainly collaboration with colleagues who have expertise in teaching technical writing would be very helpful. However, even for engineering faculty who do not have access to such collaboration, well-respected technical communication textbooks might be useful resources for strategies and models for teaching [41, 42, 43]. For example, instructors could draw examples from such references to illustrate how to revise a lengthy memo for conciseness or appropriately incorporate graphics. Developing specific grading rubrics have been shown to be effective in enhancing uniformity in grading between instructors and the likelihood that students will respond to feedback [16, 44]. Although developing such rubrics requires a significant investment of faculty time, this investment might be beneficial in terms of minimizing grading time.

When applicable, the quality of the writing typically improves if multiple drafts with revisions are included [3, 45]. 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. Revision after peer review would allow for the benefits of multiple drafts without adding to the grading burden on the instructor [46]. In addition, although reflective writing activities such as journals have been shown to enhance student learning in engineering [47], these are not specifically considered here since they are examples of the 'expressive' rather than 'transactional' form of writing. Such activities also require the instructor to carefully consider how to minimize the grading burden or provide other incentives if the reflective activities are not graded.

EXAMPLES FROM ENGINEERING COURSES

Although integrating writing into a typical engineering course may seem daunting given the already full curriculum and the numerous competing demands on faculty time, this need not be the case. Effective writing to communicate experiences can be integrated into a variety of typical engineering undergraduate courses. Designing such activities requires creativity and is aided by the theoretical basis provided by the five guidelines described earlier. In this section, examples of effective writing to communicate experiences from several electrical engineering courses at the sophomore, junior, and senior level are presented. None of these are specifically design courses. Representative activities for laboratory, class time and homework are summarized in Table 1. For each one, the experience itself including how it is based on the five guidelines above is described. Student response and lessons learned are also considered. Each example could be used in other courses and other disciplines beyond the specific one mentioned. Certainly, multiple experiences throughout each course and the curriculum are essential to develop communication skills.

WRITING TO COMMUNICATE IN THE LAB

'Snazzy Diode Circuits' for juniors

'Snazzy Diode Circuits' is an experiment that has been used in a junior-level Electronics I class.

Table 1 Examples of applying writing to communicate guidelines to engineering course activities

		Lab	Class	Homework	
	Guidelines	*Junior Electronics "Snazzy Diodes"*	*Senior Elective "Fabulous Friday"*	*Sophomore Circuits User's Manual*	*Senior Elective First Homework*
1	*Authentic investigation*	Lab experiment; peer review	Literature research	Experimenting with software	Research trade magazine; relate to personal experience
2	*Tying writing to technical content*	Diodes are topic in course	Focus on current topics in area of course	Simulation important in circuits	Exploring course topics beyond text
3	*Authentic well-defined audience*	Peers	Peers	Peers	Peers
4	*Providing useful practice for an engineering career*	Memo	Presenting new info; leading meeting	User's Manual	Summarize from nontraditional source
5	*Not being overly burdensome to engineering faculty instructor*	Peers help review	Counts as homework, uses class time	Provides multiple examples	Counts as homework

Within the first few weeks of the semester, there are a variety of diode circuits that instructors might want students to understand. The concepts underlying their function are similar, most importantly using an appropriate model for the behavior of the diode to describe the response of the circuit for a variety of input conditions. Hands-on exploration is vital for learning these concepts. Thus learning about diode circuits is an example of something that occurs often in engineering education: a topic where there are many related applications, in this case circuits, of the same relatively simple underlying engineering concepts. Working typically in pairs, students become 'experts' by experimenting with one particular diode circuit in the lab. They then communicate their knowledge by writing a memo (one per team) to their classmates explaining the behavior of their circuit. Students then evaluate peers' memos to learn about all of the five to seven circuits that were investigated by the entire class.

Students were given the following guidelines for their memos:

> 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, 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 one-page memo is useful practice for later in students' careers particularly in industry.

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 from 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 limited to one page of text.

After conducting this experiment with slight variations [48] with over seventy students in five different course offerings, 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 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 many times. Some students are particularly motivated by doing something that is different from 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.

WRITING TO COMMUNICATE CLASSROOM ACTIVITY

'Fabulous Fridays' in senior elective

In a senior level elective on optoelectronics, the last fifteen minutes of each Friday class was devoted to 'Fabulous Friday' where one student led a discussion of a recent article which he/she had previously distributed to the class [50]. 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:

1. Find an interesting article related to a topic we have discussed in class. Sources such as *Scientific American, IEEE Spectrum, or Laser Focus World* might be good places to start. Pick an article with enough information to provide for good discussion. (Articles of several pages are probably more suitable than news briefs.)
2. Provide copies of the article for us to read and at least two discussion questions by the two class periods before your discussion day. You can email the questions to your classmates.
3. Email a brief summary of your article with your discussion questions by the start of the class period before your discussion day to your instructor. Your summary should include a complete citation for your article, an explanation of the main system/technology/device/process described as well as its advantages and disadvantages. Highlight any new terms that might not be familiar to your classmates. Explain how this topic is related to those discussed in ELEC 480.
4. Lead the discussion on your day. You may need to do some additional research to help with this.

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, lasers for food inspection, photonic military clothing, 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, 1 point for the questions, 3 points for the summary and 3 points for leading the discussion.

The five guidelines discussed above 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 an authentic 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 ensure that every student has the opportunity to present.

Student response 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 end of the semester evaluations, several students specifically mentioned 'Fabulous Fridays' as an aspect of the class that contributed the most to their learning.

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 has 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.

WRITING TO COMMUNICATE FOR HOMEWORK

1. User's manuals on circuit simulation software for sophomores

In a sophomore Circuits class, Engr 60, students were given a homework assignment where they were asked to write a User's Manual for the circuit simulation software, PSpice. They were instructed to read some introductory material in the PSpice companion to their textbook [50] 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 five guidelines. 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 their curriculum, 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 simulating 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 weekly homework 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. The author and other instructors used it 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 earlier, the best student manual was excellent and served as a reference for future classes.

From this experience, the author learned several lessons. 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, in this case incorporating the writing into a laboratory might have been better than a homework assignment since students were 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 to sophomores in Circuits explaining the concepts of input and output resistance in a memo and preparing a tutorial on how to use *Electronics Workbench Multisim*, a circuit simulation software package. The sophomores can conduct reviews of these memos or tutorials and provide feedback to the juniors.

2. Relating to personal experience, homework for seniors

Designing a useful first homework assignment is often challenging since students are not yet familiar with much of the course material. Writing to communicate can be very effective for these initial assignments by helping student relate their personal experiences to the course material which aids in their motivation and learning. For example, in the first homework assignment for an elective course on Optoelectronics, students evaluated an issue of *Laser Focus World*, a trade magazine. They reviewed the *Back to Basics* article, determined their favorite advertisement and identified the section that they found most interesting. For their review, they were asked to:

> Summarize the content of this article in your own words using complete sentences. Then comment on how readable, understandable, interesting, and useful the article is. Would it be a good article for future students in this class to read? Why or why not?

Investigating the advertisements helped them learn about the diversity of current products and companies that make up the modern optoelectronics industry. The assignment also forced them to look at a magazine that they might have initially found intimidating and helped to build up some confidence in their own ability to learn from such sources.

In addition, students were asked to provide an example of where they use optoelectronics in their everyday life including explaining why optoelectronics is necessary or desirable and as much as they could about how the product/system works. Examples that students used included DVD players, LEDs for stoplights, garage door openers and safety systems. This exercise helped them connect the course material to their experience in a fun way and helps build student confidence and responsibility for their learning, key features of lifelong learning. This same type of question has also been used in the first homework of junior-level Electronics and could be used in the first homework for any course that could be related to products or systems in the everyday world.

Students typically briefly present their results of this first homework assignment to their classmates on the day that they hand in the assignment. Because everyone's responses are different, this is an opportunity for the entire class to appreciate the breadth of the discipline and its applicability in their lives.

The five guidelines are involved in the design of the experience. Students conduct an authentic investigation as they read through their issue of the trade magazine and choose their own products or systems to relate to the course. By its very nature, this experience explicitly ties the writing to the technical content of the course. When students present their ideas, they are communicating to an authentic well-defined audience of their peers. The instructor also serves as an audience for their written work. After graduation, working engineers will need to be able to learn information from nontraditional sources such as trade magazines and summarize this for their peers or managers. Being able to connect technical topics to everyday life is a valuable skill for a practicing engineer, perhaps particularly valuable in areas such as sales. Thus this experience provides useful practice for an engineering career. Finally, the experience is not overly burdensome to the engineering faculty instructor as this is part of a regularly assigned homework.

In this first homework assignment, students were also asked (as an extra credit question) to comment on how useful this homework assignment was to them. Sample student comments show that the students are reading critically while gaining confidence and new knowledge. Interestingly, these are several of the attributes described as measures of achieving lifelong learning skills [51].

> As engineers, we have to weed through a lot of material to get to what is important. I thought this was a good example of that weeding out process. I read the Back to Basics article completely, but I found

> myself only scanning some articles. They were just too full of technical jargon and what appeared to me as meaningless data.
>
> I now fear such magazines a little less. Before now, my Spectrums were indeed dust collectors, but now I am looking forward to flipping through the next issue.
>
> I enjoyed this assignment because it was not a textbook assignment. It was a like a field trip for me because I had fun and learned something at the same time.
>
> I believe that this homework problem will be very useful to me . . . I am able to read, express an interest in an article, and am able to relate what I have learned in school to something in real life. Very often, I feel that my education is not teaching me anything that I will use in real life, but this article helps to put things in perspective.

Among the lessons learned in working with students on this assignment over several years is that it is helpful to establish criteria for grading and important to make expectations for the assignment clear to the students. One aspect that has evolved is specifying the audience for this assignment to be peers rather than leaving it unspecified as the instructor. In general, students enjoy this assignment as something different that helps set the tone of the course as relevant to their lives. Some students particularly shine on this assignment. This may be due to their learning style, personality type or interests. These are not always the students who excel at more traditional homework assignments with numerical problems. Thus it provides an opportunity to highlight different students' strengths.

CONCLUSION

Engineering educators recognize the importance of helping students develop essential communication skills. Multiple opportunities to practice effective communication are needed throughout the engineering undergraduate curriculum. This paper aims to help engineering educators find creative ways to do this by recommending guidelines for designing effective 'writing to communicate' experiences for typical engineering undergraduate classes. These guidelines are based on constructivist and knowledge transformation frameworks of how writing helps build knowledge. The five guidelines are authentic investigation, tying the writing to the technical content, writing for an authentic well-defined audience, providing useful practice for an engineering career, and not being overly burdensome to the engineering faculty instructor. Several specific examples, student response and lessons learned from sophomore, junior and senior-level courses are presented. These examples include activities for class, homework and laboratory and serve as suggestions for other instructors in designing creative effective 'writing to communicate' experiences throughout the engineering curriculum.

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