Innovative Writing Assignments in Engineering to Enhance Learning, Thinking and Motivation

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Abstract

Three benefits of incorporating writing in engineering curricula are presented. The first benefit is in improving the communication skills which are essential for engineers and are attained through practice. The second benefit is in enhancing learning and is achieved by utilizing the complex process of writing to heighten the level of understanding. The third benefit, though difficult to recognize and even more difficult to promote in a society (and educational institutes) steeped in the behaviorist tradition, is in promoting meaningful learning by cultivating motivation internal to students themselves. The boundaries of writing activities are broadened to include that of stating a paragraph or even one complete sentence such that it may be incorporated in engineering without undue strain. A two-year trial of incorporating four types of writing assignments in six different courses (a total of 12 classes) at Michigan Technological University shows that writing assignments can be designed to achieve different degrees of the three aforementioned benefits. It is found that different types of writing activities need to be assigned depending on the status of course (elective vs. required) and on the composition of the students taking the course (upper division vs. lower division; majors vs. non-majors).

INTRODUCTION

Students groaning and even protesting are common occurrences when writing assignments are announced in engineering classes. Their negative feeling toward writing activities is quite understandable that they are in general not verbally oriented and espouse the misconception that engineering problems are solved simply by applying fundamental laws and manipulating symbols in a mathematical domain. They do not realize that most engineering problems are solved through

communicating ideas, through clearly conveying both facts and reasons. In fact, this paper postulates that writing activities are beneficial to engineering students in three distinct ways as explained below:

Writing as a Communication Medium in Engineering Profession

Some instructors are concerned that if they include writing in their courses, their students would believe they are emphasizing irrelevant subject matter. However, there is ample proof that writing is central to the work of engineers. In a three year study of the writing of professional engineers, it was found that they spend up to 25% of their time writing, and those who become managers write more than that. It also shows that over 90% believed that carefully critiqued writing should be included in some of their engineering courses. (Flynn and Jones, 1990) These engineers identified writing as a fundamental way for communication. In another recent study conducted at the Ft. Worth facility of the General Dynamics Corporation, engineers ranked improved writing skills near the top of their educational needs. (General Dynamics, 1986) The Society of Automotive Engineers (1994) and American Society for Engineering Education (1996) stress the importance of communication skills. Consequently, communication skills are included in ABET 2000 (1997) as one of eleven specific student outcomes that will be assessed for accreditation. Therefore, we need to not only convey this reality to our students but also actively help them acquire the requisite skills.

Writing as a Learning Tool

Besides the obvious benefit of improving the communications skills of students, assigning writing activities is important because writing enhances learning. This positive relationship between writing and learning, as demonstrated in numerous works of such rhetorists as James Britton (1975), Janet Emig (1971) and James Moffett (1983), is thought to be achieved because writing employs more ways of apprehending and exercising knowledge than either simply speaking, listening, or thinking about a subject matter. Language, whether spoken or written, is not only an outward representation of the thought, but it is also the instrument of thought that regulates and guides the thought itself. In fact, this belief forms the basis for the Writing Across the Curriculum movement which in the United States began in the mid 1970's and is flourishing in such diverse institutions as UCLA, the University of Vermont, the University of Chicago, and Michigan Technological University.

Writing as a Motivation Generator

Another benefit is that writing can be used to cultivate in students as internal motivation that is necessary before meaningful learning can take place. (Csikszentmihalyi, 1977; Cho, 1997) This important point has been neglected because the society in general and educational institutes in particular are steeped in the behaviorist tradition. Writing can be employed to promote internal motivation mainly because the process involved in writing is student-active. The ultimate goal

of education is to make the students responsible for their own learning.

Granted that writing needs to be included in engineering curriculum, the practical question is who teaches it. Although it is a common practice that the responsibility of the language department to make sure that students know to write well, this approach is not effective. Writing, like many other intellectual pursuits, is largely a matter of developing skills. Moreover, good writing depends greatly on regular practiced with that skill. However, in a typical engineering curriculum consisting of over forty courses, the students may have only two or three courses (beyond their freshman composition courses) which involve carefully critiqued writing. The lack of writing activities can lead to the deterioration of whatever writing skills the students have acquired in their first or second year. More importantly, language departments should not be held solely responsible for developing any student's awareness of the conventions and expectations of writing in his or her specified field. In short, engineering departments have to shoulder much of the responsibility in culturing an important ability in a good engineer, namely writing skills. Therefore, it is counterproductive for engineering instructors to hold onto the common belief that their courses have already got so much that there simply is no room for any "soft" elements such as writing. In short, they cannot afford not to include writing activities in their course.

To summarize, writing activity is seen to be beneficial to engineering students because it gives the students opportunity to develop an important engineering skills; it enhances learning through the rigors of writing; and, it promotes learning through the generation of internal motivation. The relationship among engineering, learning, and writing can be depicted in Fig. 1.

OBJECTIVE

The purpose of this paper is to propose a

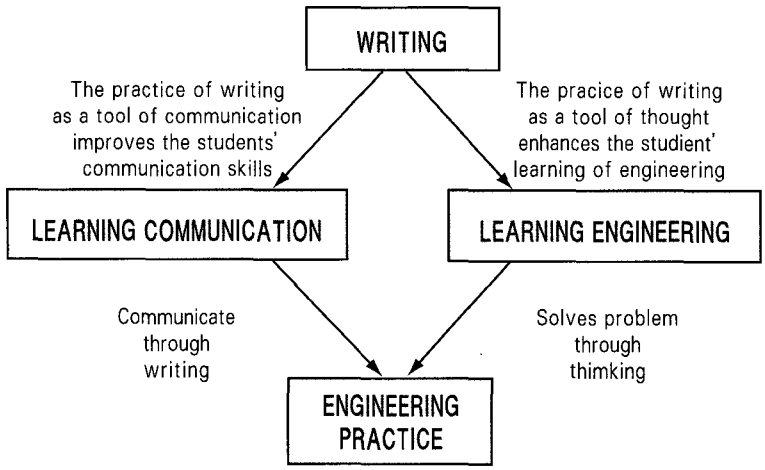

Figure 1. The relationship among engineering, learning, and writing

TABLE 1. The matrix of cases analyzed in this study

Case ID	COURSE			ASSIGNMENT			
	Type[2]	Student[3] Distribution	Student[3] Distribution	Long[4] paper	Short paper	Prob solv w/annot	Annotating prob soln
Ⅰ	EM331	R-N	0 / 0 / 25 / 33 / 0	S	-	-	-
Ⅱ	EM331	R-N	0 / 0 / 18 / 10 / 0	M	-	-	-
Ⅲ	ME474	E-D	0 / 0 / 3 / 18 / 2	S	-	-	-
Ⅳ	EM332	R-D	0 / 0 / 18 / 6 / 0	-	-	S	-
Ⅴ	EM332	R-D	0 / 0 / 28 / 4 / 0	S	S	-	-
Ⅵ	EM332	R-D	0 / 0 / 23 / 9 / 0	-	-	S	-
Ⅶ	EM332	R-D	0 / 0 / 27 / 18 / 0	-	-	S	-
Ⅷ	EM332	R-D	0 / 0 / 22 / 17 / 2	-	-	S	-
Ⅸ	ME474	E-D	0 / 0 / 0 / 19 / 8	M	-	-	-
Ⅹ	ME326	R-N	0 / 0 / 12 / 30 / 0	-	S	S	S
Ⅺ	ME591	E-D	0 / 0 / 0 / 0 / 9	S	-	S	S
Ⅻ	ME223	R-D	0 / 32 / 32 / 3 / 0	-	-	S	S

number of writing activities that can be easily incorporated in engineering courses and to show that writing assignments can be designed to achieve different degrees of the three aforementioned benefits.

METHODOLOGY

Different combinations of four types of writing assignments are incorporated in six different engineering courses (total of 12 classes in seven quarters) at Michigan Technological University (Table 1). As shown in Table 2, the selected courses represent an array that categorizes the courses according to their nature (elective vs. required) and to their student population (lower division vs. upper division; majors vs. non-majors). The discussions on the effectiveness of various assignments are based on surveys and course evaluations.

Examples of Writing Assignments

Too often a "writing assignment" invokes

TABLE 2.
The summary of cases analyzed in this study

	for majors		for non-majors
	lower division	upper division	
Required	Ⅻ	Ⅳ, Ⅴ, Ⅵ, Ⅶ&Ⅷ	Ⅰ & Ⅱ
Elective		Ⅲ, Ⅸ & Ⅺ	

Note: 1. ME331 Fluid Mechanics for non-majors
ME332 Fluid Mechanics for majors
ME223 Thermodynamics for majors
ME326 Thermodynamics for non-majors
ME474 Combustion
ME591 Advanced Combustion

2. R Required E Elective
D Majors N Non-majors

3. F / S / J / S / G is the number of Freshmen / Sophomores / Juniors / Seniors / Graduate students

4. S single author
M multiple author

in engineering instructors and students alike a long formal paper. Even if the importance of writing activities in engineering courses is fully recognized, this misconception raises the question regarding the appropriateness of a writing assignment, given the limited time and resources of everyone involved. However, I would like to emphasize that

even writing one short sentence can be an effective writing activity in achieving some aspect of the three benefits. It is in this spirit that the following can be included as writing activities:

1. Writing a short research paper on the course's relevance to the real world or a short summary of materials presented in lectures.
2. Solving problems with annotation: interpreting the solutions obtained (usually some numerical values) and discussing their applicability in the context of the assumptions invoked.
3. Annotating solved problems: identifying the assumptions invoked and discussing their validity.
4. Writing a journal of log on work in a course.
5. Rewriting a document to balance visual, mathematical, and written

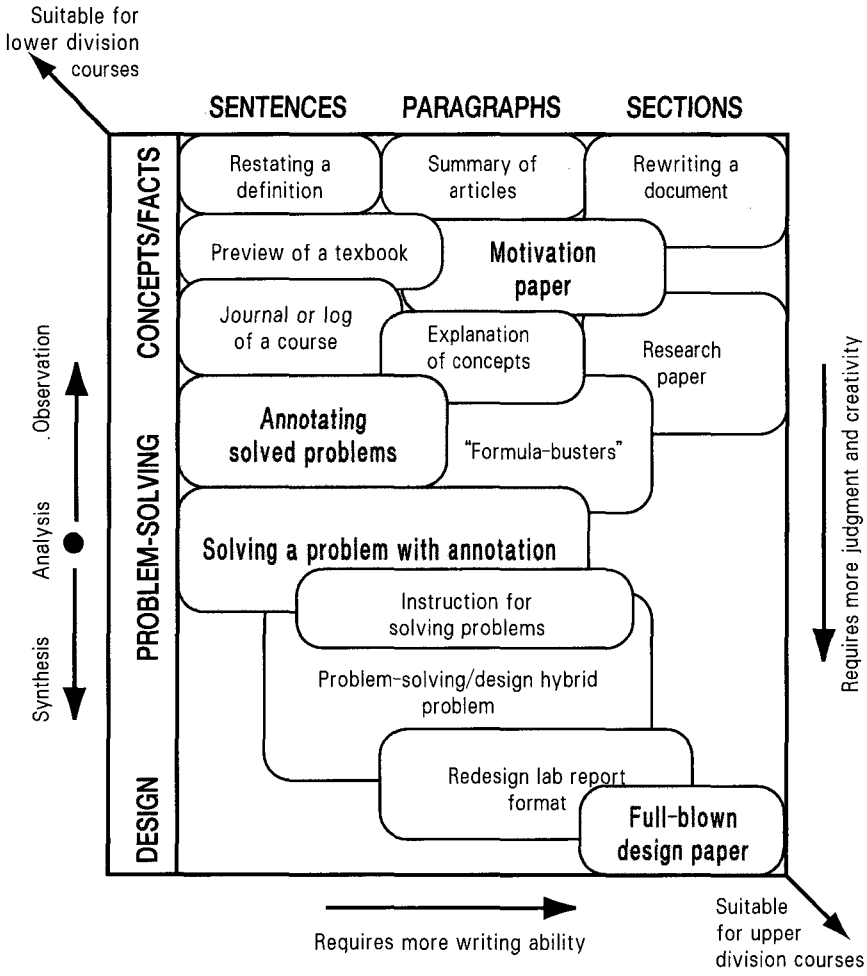

Figure 2. The matrix of writing activities for engineering students. The shaded activiti

components.
6. Speculating on novel solutions to problems.
7. Redesigning lab report formats.
8. Emphasizing synthesis and interpretive section of lab reports.

These writing activities are shown in Fig. 2 according to the extent of writing involved and the type of learning to be had. From left to right, the expected writing becomes progressively more complex. From top to bottom, the engineering content becomes progressively more comprehensive.

RESULT AND DISCUSSIONS

1. Long paper

The long paper (>20 pages) is designed to emulate reports typically composed in industry. Role playing is enacted to help the students clearly grasp the intended audience for their papers. In one example, students in Fluid Mechanics were asked to assume the role of NASA engineers and submit a written report to a NASA Director on the effect of zero-gravity field in the behavior of fluids. This exercise encouraged the students to carefully review all concepts and to reason from the fundamentals. In the end, I hope to help students synthesize scattered and compartmentalized information into a coherent, structured and interrelated body of knowledge, since the "plug-n-chug" mode of applying "formulas," which they would have memorized, becomes no longer applicable.

The typical response from the students in elective courses (Case III, IX, and XI) can be best summed up by a comment from a student at the end of the quarter: "The term paper gave me the opportunity to pull it all together." On the other hand, when the course is for non-majors (Case I and II), the results are divided: Some asked to "reconsider assigning a term paper [because it was] a lot of work" while others felt that "[the experience of writing a paper] will be beneficial to me in the future." From this comparison, it is apparent that a long paper assignment is suitable for elective courses in which the students are highly motivated to learn the subject matter.

Complaints about the extra work load in writing a long paper can be minimized by assigning it as a group project (Case I vs. II and II vs. IX). Writing assignments in a multiple-author format (maximum of three students per paper) provide students with valuable learning opportunities of working in a group situation where verbal discussion among the group members is promoted. In addition, there is a side benefit to the instructor as the grading time is substantially reduced. Providing some feedback before the papers are due (for example, by commenting on a rough draft) greatly improved the quality of papers by eliminating "last minute" papers. The above observations are found to be equally valid regardless of whether the students were taking the course as majors (Cases II, V, IX & XI) or as non-majors (Case I and II).

2. Short paper

The short writing assignment (~ 5 pages) is designed to raise the level of motivation in students taking required courses. When the students take a course "just because it is required," their motivation for learning is essentially external - namely, the grades

which are token (delayed reward) that can be exchanged for high-paying jobs after graduation. This attitude may explain the all too familiar case of "pulling an all-nighter" before exams and then on the following day forgetting everything one has "learned." Therefore, instilling self-generated motivation in students is seen to be essential before meaningful leaning can take place.

An example of a short paper assignment may be: Writing a report on the relevance of the course (i) to higher level course after talking to students who have had the same course, (ii) to engineering practice after talking to working engineers, and (iii) to engineering after reading an article in an engineering magazine or journal. At the least, this type of assignment is beneficial because it illustrates the continuity of knowledge and utility of the subject matter in the "real" world. Although the same message is found to some extent in the course textbooks and can be communicated to the students during lectures, these authoritative channels are not effective because the students perceive them as a part of system external to themselves. It is when the value of leaning is realized through "discovery" that the motivation to learn is generated from within. (Furth, 1981) This emergence of self-generated motivation, which eventually replaces the external factors as the primary driving force behind the desire to learn, is the ultimate goal of this type of writing assignment.

The responses from the students taking a required course (Case V and X) are very illuminating. In the reports, the students frequently used words and phrases such as "amazed", "surprise", "impressed", and "it became clear to me" to indicate their sudden recognition or refreshed awareness of the value of the subject matter that they were studying. The examples of the comments found in end-of-the-quarter course evaluations are: "improved my attitude toward the class and my major immensely", "I have learned more in this atmosphere", "I cared to learn more", "encouraged continued learning", "promoted desire to lean", "I learned something more than how to solve equations." These uniformly positive comments clearly indicates that this type of "discovery" can promote positive attitude towards learning and can establish learning habits that last beyond final examination.

3. Problem Solving with Annotation

Here, the formality of long and short papers is discarded in favor of an informal writing activity which involves interjecting short sentences or paragraphs in mathematics-dominated, textbook-type problem solutions. The students are asked to furnish critical commentary or explanatory notes on each step of their solution, to interpret the final numerical values, and to discuss the limitation and/or the applicability of their solutions. The result of this exercise will be discussed in the next section.

4. Annotating Solved Problems

In this assignment students are required to take a deeper look at the solved examples and state the arguments used to develop the solution. This exercise cautions the students not to blindly accept or overlook subtle points, which can make engineering more

interesting. Having the problem already worked out allows the students to concentrate on conceptual, factual, and reasoning aspects of a problem rather than on mathematical manipulations. A sample instruction to the students on this type of writing activity is shown below:

> In this exercise, you are provided with a solution to a problem showing the mathematical steps. You are to scrutinize each step and identify the assumptions, if any, used in going from one step to the next. Then you are to assess validity of these steps in the context of the particular situation and conditions presented in the problem. You may conduct a more critical evaluation of the assumptions by estimating the extent of error introduced in the solution when the assumptions are incorporated into the solution.
>
> The main objective of this exercise is to help you become a confident problem solver by training you to pursue a solution process not out of random impulses or in memorized sequences but only when a reason dictates it. Writing down your reasons for undertaking a particular step in the solution process is to make your thoughts deliberate and explicit such that anyone, including yourself, can examine and re-examine their soundness. Interpreting and evaluating the final solution (usually a number) is to reflect and uncover the physical significance implied by the numbers. Basically, it is to give a life to otherwise meaningless numbers.

The incentive for developing the above writing assignment (type 3 and 4) comes from the fact that students are usually inundated with samples of solved problems that are practically devoid of written commentary to the solution. Failing to require explanations, reinforced by grading based on final answers (numerical values), inadvertently conditions the students to become technicians rather than original thinkers. Some recent engineering textbooks (Muson et al., 1994; Moran and Shapiro, 1995) have made an excellent initiative to turn this trend around by including extensive discussion in their solved examples. However, these types of writing need to be further incorporated in quizzes, exams, and homework. This need is strongly supported by the result of a survey in which Thermodynamics students (Case XII) were asked to rank the five types of problem solving situations in four categories. The types of problem solving situation are:

(type 1) Solving problems without annotation;
(type 2) Solving problems with annotation;
(type 3) Annotating solved problems;
(type 4) Seeing a problem solved with verbal annotation; and
(type 5) Seeing a solved problem with annotation.

The four categories for ranking are:

(C-1) Helped me to improve my problem solving ability
(C-2) Helped me to understand concepts
(C-3) It challenged me (I kept on thinking about them)
(C-4) It was enjoyable.

Annotating the solved problems, type 3, was ranked first in all categories, while

solving problems without annotation, type 1, was last. Additional support is seen in examples of written comments by the students at the end of course: "I may not get an A (in this course), but I have learned enough to get an A in any other class", "it really got me thinking", and "problem solving technique is increased at least twofold." What this means is that thought-provoking problems are seen to be not only beneficial but enjoyable as well.

The type 4 assignment is found to be suitable for sophomores (Case XII) who are not as yet proficient with engineering problem solving techniques which necessitates making valid assumptions to simplify either the given problem or the mathematics involved. Having a problem already solved allows the students to concentrate on the reasoning aspect of a problem rather than on mathematical manipulations. On the other hand, the type 3 assignment is found to be effective for upper division students (Case X and XI) who need to develop the ability to ask on their own an important engineering question, "what if…"

CONCLUSIONS

Writing should be incorporated into engineering courses because it is an important part of engineering activity and, perhaps more importantly, because it enhances and promotes learning. This desirable activity can become a natural component in engineering courses by broadening the boundaries of the writing activities to include that of stating a paragraph or even one complete sentence. To be effective, different types of writing activities need to be assigned depending on the status of the course (elective vs. required) and on the composition of the student taking the course (upper division vs. lower division; majors vs. non-majors).

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