THINKING AND WRITING IN UNDERGRADUATE ENGINEERING EDUCATION

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1. INTRODUCTION

In general, engineering courses are quite successful in achieving many of their objectives but miss certain important elements such as deep thinking on the student's part, free exploration of thoughts and ideas, connecting technical subjects to students' daily lives, and expressing such connections in writing. This paper discusses some ideas on why engineering educators need to address these issues, what can be done in this area, and how. Examples from a number of mechanical engineering courses I have taught over the years are included.

Writing Across the Curriculum (WAC) has been around for a long time now (Walvoord, 1996). Deep thinking or critical thinking has received increasing attention in academic circles and in the press (Arnold, 2004). It is possible to find information about writing assignments in engineering classes (Sharp, *et al*. 1999), especially in engineering education meetings (Sharp, 1995). This paper summarizes my own experience, observations, and conclusions concerning thinking and writing assignments in engineering classes.

First let's review what is normally done in undergraduate engineering courses when it comes to thinking and writing. Most thinking takes place in the context of understanding engineering concepts, principles, and their applications. Among other things, this includes studying examples and solving problems in engineering subjects. A refreshing departure comes in project-oriented courses, usually taken at the freshman and senior levels, when students are engaged in brainstorming, evaluating various alternatives, and considering ethical, safety, social, aesthetic, etc. aspects of an engineering problem. In some cases, students may be asked to explain a concept or a complex point in their own words. Other than a negligible amount in homework assignments, writing experience is usually limited to laboratory and project-oriented courses (e.g., laboratory reports, interim and final project reports, perhaps journals). In rare classes, students may be asked to choose a high point in the day's lecture and write about its relevance. As can be seen, either the scope is narrow or deep thinking and purposeful writing exist in different spheres.

It is true that students are encouraged and even required to think and write in some humanities and social science courses they take. However, there is no real reason why such activities should be limited to what they do in, say, philosophy, history, or English courses. By not entirely leaving this precious territory to our colleagues in other disciplines, engineering educators can send a powerful message to engineering students, destroy some of the myths about us and our profession, and strengthen engineering education in the process. Why not encourage more thinking and writing in engineering courses to nurture the student's skills in these areas and enrich their engineering education experience? How do we begin to do it with no compromise in rigor and no sacrifice in class time?

2. BENEFITS TO ENGINEERING EDUCATION

Engineering students are busy. In addition, the reward system in many engineering courses encourages mastering how to perform some problem-solving tasks in a relatively routine way. As a result, most of our students do not pose, reflect, and think. Engineering educators need to break this pattern. If the student's ability to think is cultivated further, they may carry this behavior pattern to other things they do in life, which could lead to a higher sense of achievement and satisfaction. At a minimum, such an approach could bring more clarity and purpose to what they do in general. If we can combine more thinking with meaningful writing, numerous educational benefits (professional and personal) to the student could result.

As we all know, a college education should be more than just taking many courses and passing tests. If our students truly internalize course concepts and connect with them in a personal way, they may experience something so valuable that we cannot provide in a traditionally-run engineering class. It is desirable to have a better integration of school life and daily life, academic and nonacademic worlds, and technical and nontechnical aspects. We can and, I believe, should make our students ask the following questions to a larger extent than they have been doing: "What am I doing? What am I trying to accomplish? Why am I doing it?" In addition to the positive motivational effects of such exercises, I wouldn't want to teach a course in which such questions never arose.

The type of thinking-and-writing exercises that will be discussed in the next section (i.e., self-reflection papers) lead to a careful and thoughtful analysis of course topics resulting in an enhanced and deeper appreciation that crystallizes their thoughts of the course material. This personal investment in their learning process (i.e., thinking about course-specific topics and writing that crystallizes their thoughts about them) challenges the student and motivates them to do logical thinking and reasoning.

Well-chosen assignments increase the student's ability to express technical subjects to a nontechnical audience, which is generally considered to be an area of improvement for engineers and engineering students. They reinforce the idea that thinking and writing are important, and that they need to be able to think and write well.

There are other practical benefits resulting from these activities. If a course or student portfolio is being constructed, student self-reflection papers would make a valuable addition to it. They could also help in satisfying certain educational outcomes deemed essential by the Accreditation Board of Engineering and Technology (ABET). Occasional written or oral comments from you or a well-supervised grader would add a personal touch that goes a long way. Such feedback makes students feel that we really care and are personally invested in their thoughts and development. Another tremendous benefit is that we end up having a large pool of practical and daily life examples related to what we teach. Some topics discussed by students are so interesting that incorporating them into what we teach in future semesters has enormous pedagogical value. Thanks to them, I now have a good collection of a large number of exciting and relevant topics that I can draw upon whenever I teach those classes.

3. EXAMPLES

When it comes to the details of a self-reflection paper (i.e., topic, format, grading), experimenting with different ideas is highly recommended. Typical length of an assignment may be one, two, or more pages. It depends on the instructor's goals and preferences. No handwriting, of course. It is a good idea to specify margins, font size, and spacing for uniformity. Assignments can be given during or at the end of the term. In grading, one possibility is to give equal weighting to each of the following three areas: idea, content, and grammar. Sometimes I make grammar fifty percent of the self-reflection paper grade. For an improved final product, it is possible to give an initial score and, if it is less than the perfect score, to allow students to recapture up to a maximum of fifty percent of the remaining points in a second attempt. Emphasizing correct grammar at the time of assignment is important to send a strong message to the student. How seriously students take such an assignment definitely depends on your attitude and how you convey it.

Unlike some other pedagogically-sound ideas, the suggested approach does not require additional class time unless the instructor chooses to have class discussion on some of the ideas and insights presented by students. Furthermore, there is no compromise in course rigor. If a grader is used, a discussion of expectation levels and grading standards with the grader at the outset is necessary and important.

Self-reflection paper topics should be inspiring, exciting, and challenging. Typical time-tested topics that I have used in five mechanical engineering courses over the years are provided as possible examples to get started.

3.1 Sophomore level

Normally, ME 2630 Thermodynamics is the first mechanical engineering course taken by sophomore students majoring in our program. The major course objectives are understanding the first and the second laws of law of thermodynamics, and being able to apply them to idealized practical problems. This is a course in which concepts and conceptual thinking are important.

Typical self-reflection paper topic: "What is the most important thing you learned in this course and why?"

Since both the first and the second laws have profound philosophical implications, student essays are tremendously interesting and moving. Perhaps for the first time, students begin to understand that engineering and life are not two separate compartmentalized issues. They realize that there are limits to and consequences of what they can do. Some others choose a subject like units and unit systems. Reading the ideas and the conclusions of young women and men at this early stage of their engineering education tends to be fascinating at times.

3.2 Junior level

1) ME 3300 Fluid Dynamics cover hydrostatics and the principles of fluid motion including subjects like piping systems, surface resistance, and compressible flow. Applications of the fundamental principles are important in this course. Students can easily relate to the structures and systems studied in this junior-level course.

Typical topic: "Choose a course topic and discuss how it relates to a device, system, or process you are familiar with. Explain."

Pipes are everywhere. All bikers and runners can relate to the drag force. Student essays in this course make references to surfing, cars, car races, parachutes, aircrafts, water hoses, canoes, boats, squirt guns, sports, toilets, milking systems in dairy farms, swimming pools, and their co-op or internship experience. For me, it is amazing to see how many practical examples I have never thought about are discussed in their essays. When I teach the course next time, these examples serve me well in explaining the relevance of the course topics to a new wave of students.

2) ME 3630 Applied Thermodynamics builds on what students learn in the first thermodynamics course and discusses various power plants, refrigeration systems, gas mixtures, and combustion processes.

Typical topic: "Choose a course-related topic (e.g., air pollution, certain refrigerants, air conditioning, energy conservation, engines) and discuss its impact on society."

Students in this course have a higher level of maturity than the students in the first thermodynamics course. Furthermore, they have a greater level of awareness of the issues in their major. Personally, I learn from their insights and viewpoints all the time, however different they might be from mine sometimes.

3) ME 3640 Heat Transfer cover the three modes of heat transfer (conduction, convection, and radiation) and heat exchangers (any device that facilitates exchange of heat between a hot fluid and a cold fluid). This course is a very important building block in their undergraduate engineering education and a prerequisite to a number of senior-level technical electives.

Typical topic: "How does what you have learned in this course fit into your overall mechanical engineering education?"

Most students are quite able to articulate on how this course is connected to their overall undergraduate study. A discussion after the assignment reinforces their understanding of the horizontal and vertical integration of the Heat Transfer course into the curriculum. If I try an essay topic like the one described in ME 3300 Fluid Dynamics, they write about a wide variety of topics like different parts of a car, windows, cooking and various cooking appliances, engines, heating and cooling applications, solar energy, computer components, the human body, fins, video game consoles, and motorcycles.

3.3 Senior level

ME 4520 Power Plant Design is a senior-level technical elective course on steam power plants, gas turbines, renewable energy, and power plant economics. Most students in this course are within one year of graduation. In addition to their written progress and final reports for their term project, each student has individual assignments.

Typical topic: "Choose a course-related topic (e.g., air or water pollution, plant safety, nuclear power, power deregulation, energy conservation) and discuss its social (and/or economical and/or environmental and/or ethical) aspects."

Students are required to cite a minimum number of references (publications or the Internet sources) in this assignment. After an assignment is finished, we conduct a class discussion on the issues.

4. CONCLUSION

There are sound reasons for giving carefully-selected thinking-and-writing assignments in engineering courses. If implemented properly, this approach brings numerous educational benefits. These assignments contribute to the development of thinking and written communication skills in the student, and lead to an enhanced and deeper appreciation of the course material. Although a few students would rather not have such an assignment, overall student response has been very encouraging and gratifying. Some excited students talk to me before and after they write their essays. Based on unsolicited and solicited comments from my students, I shall continue this practice until I retire. Such assignments were not common when I was an engineering student in the 1970s. I wish they were.

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