A Case Study in Motivating Students and Fulfilling ABET Criterion 3 through Materials Science

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Abstract

How does one meet ABET criteria and motivate students to learn well while maintaining our regional university's policy of essentially open enrollment? A case study of a materials science course, MEEN 3344, at Texas A&M University – Kingsville (TAMUK), is presented. Techniques were developed to increase students' interest in materials science, motivate them to study harder, increase their passing rate on the FE Exam and increase their earned grade point average. In the process of preparing for a successful ABET reaccredidation visit in the fall of 2003, it was found that these techniques were also useful in fulfilling ABET Criterions that dealt with science, engineering and math knowledge, communication, life-long learning, and contemporary engineering issues (Criterion 3: a, g, i, and j).

Students from several engineering majors may take the rigorous course, so fundamental concepts and materials selection are emphasized, rather than focusing exclusively on one area, such as metallurgy. If students meet a set of performance criteria, they are allowed to waive the final exam. Knowledge assessment and retention are maintained through other exams, quizzes, and assignments. Students are assigned an essay and must make a "Show & Tell" presentation on new, contemporary, or personal materials of interest. Each chapter's lecture includes discussion on current materials, material selection and design examples from the author. Review questions similar to those on the FE Exam are discussed and incorporated into exams. Student presentations, lecture notes, a syllabus and schedule, exam reviews, sample exams, and links of interest are maintained on a course web page.

Student surveys, a completely successful ABET reaccredidation, an increase in TAMUK's FE pass rate from 69% in 1999 to 96% by 2004, and extremely low drop/failure rates in the Materials Science course are indicators of the success of the techniques.

Introduction

The technical content or "hard science" contained in a Materials Science course for engineering students is well defined, with numerous well-written textbooks and web sites. The art of motivating engineering students to do well in the course, prepare to be a practicing engineer, pass the FE exam, and the broader scope of meeting the ABET accreditation Criterion 3 are not always well defined. The author will share his experiences in meeting Criterian 3: a, b, c, e, g, j, l, and r, and will concentrate on those that do not necessarily deal with learning technical content, such as crystal structures, for example.

Most of Texas A&M-Kingsville's approximately 6,200 students come from South Texas, but there is wide diversity in the population, with students from more than 35 states and more than 43 countries. The student body is split almost equally between men (53 percent) and women (47 percent). Eighty-two percent of students are undergraduates. Ethnically, the campus and engineering students reflect the demographics of the area, with 62 percent of the students Hispanic, 27 percent white, and five percent African American. About six percent, mostly graduate students are international students. The University is located in Kingsville, a city of 25,000 that is the home of the legendary King Ranch. Corpus Christi and its beaches are just 40 miles to the northeast, and the border with Mexico is 120 miles to the south at Brownsville. Kingsville is about 500 miles south of Dallas.

Although no minimum grade point average (GPA) is required to take the course, engineering students must maintain a 2.0 GPA to graduate, and are required to take the first semester of engineering chemistry, calculus, and be enrolled in, or have taken the second semester of engineering physics. Although the average engineering student at TAMUK desires to do well in their courses, students are allow to retake any course twice, and some students feel that a "C" grade is acceptable.

Fundamentals of Materials Science and Engineering, 2nd edition, by William Callister is the required text for the course. Previously, the 5th and 6th editions of Materials Science and Engineering: An Introduction by the same author were used.

The class typically meets 3 times per week for 50 minutes each time, although some semesters it is taught twice a week for 80 minutes each time. The Texas State Legislature mandates that only straight letter grades, A-F are used, with no +/- modifiers. For this course, the following grading scheme is used:

1)	Homework & essay assignments	30 %	A = 90%
2)	Quizzes (9%) and Participation (1%)	10 %	B = 80%
3)	3 exams	40 %	C = 70%
4)	Final exam	20 %	D = 60% F = 59.49%

The outcomes of this course were measured and feedback to the students was given through homework, essays, classroom presentations, quizzes, surveys, three exams during the semester, and the final exam.

Motivational Tools

For many students, the shear joy of learning new and exciting concepts is not a consistent motivator, although it can be cultivated. Likewise, pride in one's work, and rising to the challenge of excelling in a course is also not a consistent motivator for many of our students, but can be instilled, and is evident in our high achieving students, and in some graduate students. Most students fear final exams, however, and will take extra pains to get out of taking a final exam. Also, all want to get something for "free", and like extra credit. Below are listed several "Carrots" used to motivate students to learn, prepare them to pass the FE Exam, and to have good material selection skills as practicing engineers. More details can be obtained from the author's web site [1], which contains a current syllabus, and all items listed in the paper, such as previous student presentations, lecture notes, review exams, useful links and so on.

Carrot 1 – Exploration and Presentation of New and Exciting Materials

On the first day of each semester, all students are assigned to write a small (4 page) essay on a suggested topic, or one of their choosing. Recent suggested topics include polymeric solar cells, fuel cells, biomimetic actuators/muscles, artificial muscles, electronic ink, MEMS, auxetic or negative-Poisson's Ratio materials, and thin-film polymer video displays. They can use the Internet as a source, but must document their results, with no plagiarizing.

At the same time students are told that they are required to prepare a 4-minute presentation to the class, on a new or exciting material, of their choice. The presentation can use the same topic as the essay. A sign-up sheet is provided so presentations are spread out over the semester. The instructor must approve the topic, and each presentation must be previewed for accuracy. Most previous student presentations are posted on the course web site [2]. Some of these topics were: Magnetic Rheological Fluids, Solid Oxide Fuel Cells, Injectible Foam for Civil Applications, Electroactive Polymers, "Quiet Steel," Polution-fighting Paving Blocks, Dirt Glue, and Ceramic Engines. Each presentation is worth 1% of the student's total grade, or about equivalent of a homework assignment. Each student can make two presentations during the semester, the second one counts as extra credit.

Two questions beg to be answered; a) does the presentation make a difference in a presenter's grade? And do all students participate? In Figure 1 is shown the average course grade (blue) for studets who created presentations, and for those who did not (burgundy).

The data is a representative sampling over a four-year period. On average, those students who prepared and gave presentations received average course grades of 83%, or a B+. Those students who did not prepare and give presentations received average course grades of 70%, or a C. In essence, those who gave a presentation should expect to receive at least one letter grade higher than those who do not.

An average of 72% of the students gave presentations, with large fluctuations. Students from South Texas are typically from rural backgrounds, and reticent to get up in front of their peers and talk. If a brave soul will sign up early in the semester, and gives a good presentation, the class participation goes up. Encouragement from the instructor can help, but even when a presentation date is assigned, the student will not present if his/her fear level is too high.

Were there those students who had serious stage fright, but performed well on their exams? Yes, but typically less than one per semester. The students were very supportive of those with stage fright, because they knew they would have to get up and go through the ordeal themselves. A more typical scenario would be a student that took the class, but did not attend frequently, and ended up flunking. Most of these students would then retake the course, sign up early to present, complete most or all of their homework, and obtain a respectable grade. Completing the presentation and seeing their presentation on the class web site gave students a sense of accomplishment and confidence.

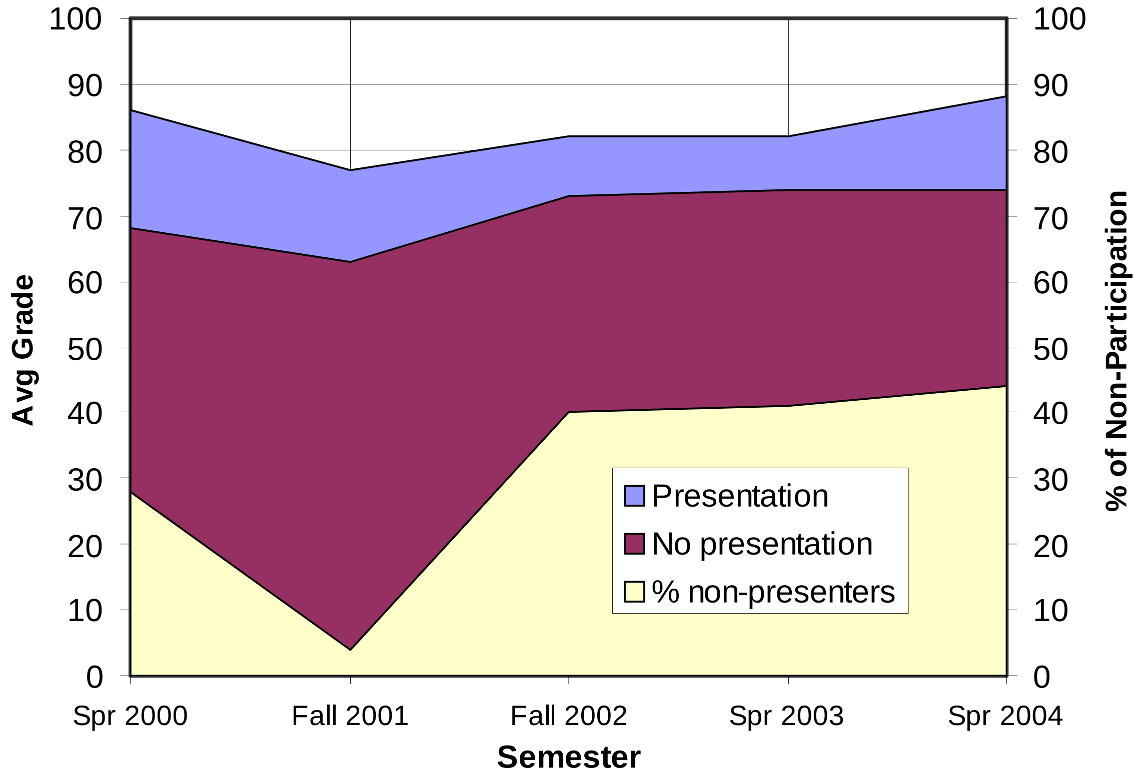

Figure 1. Average course grades for students who presented, did not present, and percentage of non-participation.

Carrot 2 – Waiver of Final Exam based on Performance

The most popular, and most controversial motivational tool is to waive the final exam for a student if he or she will: a) hand in all homework on time, b) get a total grade of 80% or better on their homework, c) attend class each day, missing no more than one day, or alternatively miss only one quiz, and d) get an average of 80% or better on all quizzes. In addition, the student must have passing grades on their midterm exams. The final grade is also scaled accordingly.

This "carrot" came about because of the author's realization that the students who attended class each day were also likely to be the ones who turned in all their homework, and typically received A's in the course. The "carrot" was formalized in an effort to bring more students into this category.

Some faculty criticize this incentive because of the fear that because some students will not study for the final exam, their knowledge will not be adequately retained, and because it is not the norm. In response it is noted that two or three intermediate exams were given each semester. The final exam is nothing more than a compilation of the same type of questions. The last intermediate exam is given approximately one week before finals, and naturally evaluates cumulative knowledge. The students who are able to waive the final exam already have the knowledge, skills and experiences of materials science cemented in their brains because they have met the performance criteria. Many students say that they end up studying more than they would have otherwise.

In Figure 2 is shown the average course grade (blue) for students who were able to waive the final, and for those who did not qualify (burgundy). The percentage of those who were required to take the final exam is show in yellow. On average, those who qualified to waive the final exam received a final grade of 86%, or a grade in the B+/A- range. Those who did not qualify to waive the final exam received an average grade of 67%, or about a C-. An average of 61% qualified to waive the final exam, with a high of 69% and a low of 45%. Those who qualified to waive the final exam received on average, almost two letter grades higher than those who did not qualify. Student surveys about this "carrot" are discussed below.

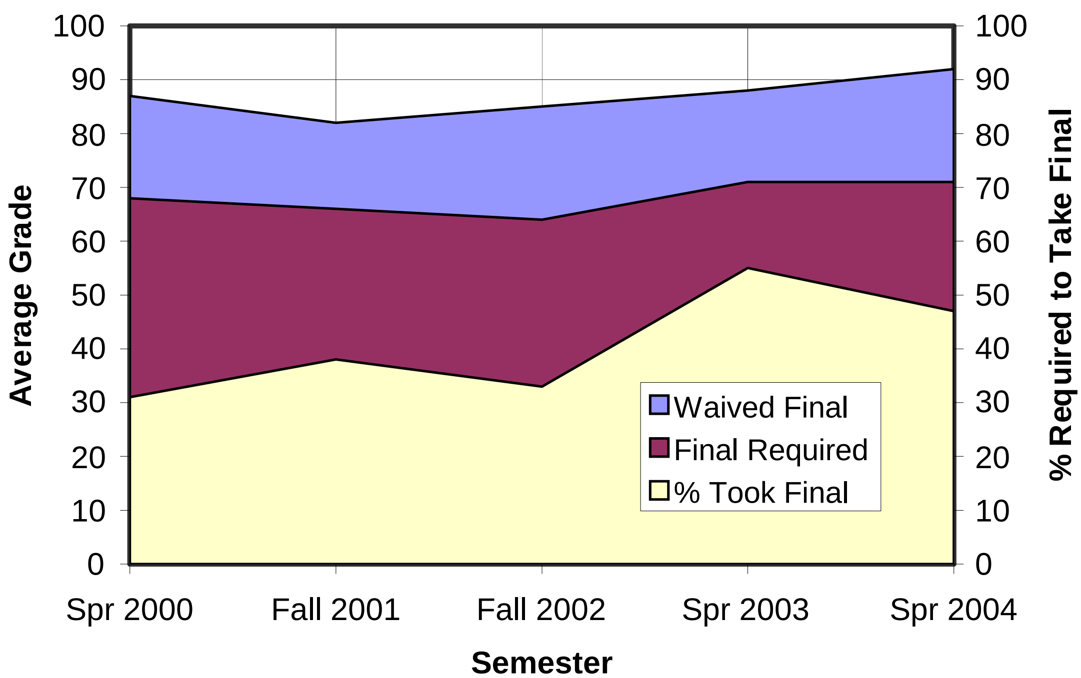

Figure 2. Average course grade for students who waived the final, non-qualifiers, and percentage who took the final.

Carrot 3 – Materials Science Will Help Students Pass the FE Exam

There is a section on the FE morning exam on materials science, so it is obvious that the class will help those who take the exam, if they have studied, so the key is to get the students to take the FE Exam seriously. Sample FE Exam review questions, similar in form and content are posted on the course web site. Very similar questions are incorporated into each exam. Two examples are:

1. *<u>None</u> of the following statements regarding metal fatigue are correct, <u>except</u>:*
   a) *Surface cracking decreases fatigue life.*
   b) *A cold-worked specimen will fail sooner.*
   c) *Nitriding (diffusing nitrogen into surface) treatment can improve fatigue life.*
   d) *A fatigue endurance limit is observed in pure aluminum.*

2. *<u>Which</u> of the following statements about a eutectic alloy are correct?*
   a) *The eutectic temperature is invariant.*
   b) *An alloy of eutectic composition solidifies over a range of temperatures.*
   c) *Two elements must be partially insoluble in the solid state to form a eutectic structure.*
   d) *A non-eutectic microstructure looks very stratified or layered.*

How does one know if the extra effort has actually helped more TAMUK students to pass the FE Exam? Although no direct data is available, two indirect references can be made: First, the author has been promoting and preparing students for the FE Exam since the fall of 1999. TAMUK's FE Exam pass rate has increased from 69% in 1999 to 96% by 2004. Second, exposure, repetition, and encouragement will always produce positive results. It is well known that engineering students with a GPA of 3.0 or better will virtually always pass the FE Exam.

The author does not mean to claim that the MEEN 3344 class alone produced the huge improvement in pass rates, but that it was a contributing factor. The university's College of Engineering has a FE Exam Review committee, of which the author has been a member since 1999. This committee has encouraged engineering students to make use of an intensive FE Exam Review course. Students who do not perform well on a final mock exam are not encouraged to take the exam, but rather review further and take the exam at the next sitting. *Incentives, publicity, and encouragement are probably the major reason for increases in pass rates.*

Fulfilling ABET Engineering Criteria 2000, Criterion 3:

While preparing for a completely successful ABET reaccredidation visit in the fall of 2003, it was found that the "carrots" listed above were useful in fulfilling ABET Criterions that dealt with science, engineering and math knowledge, communication, life-long learning, and contemporary engineering issues (Criterion 3: a, g, i, and j). The MEEN 3344 Materials Science course also filled other technical criterion (3b, c, e, f, k, and r), they are well addressed in existing literature. Meeting criterion 3a is inherent in all lecture, presentation, homework, and assessment activities of the course, and is integral in the motivational tools listed above. Each sub-criterion is listed and discussed below.

(a) How does MEEN 3344 help students learn to apply knowledge of mathematics, science, and engineering?

- Students must have the necessary prerequisite knowledge from chemistry, calculus and physics courses.

- Mathematical principles are applied through calculations in homework, quizzes, and exams.
- Scientific principles are applied through the same, and interpretation of graphical data and functional relationships.
- Engineering knowledge is applied by selection of materials and processes, based on fundamental principles.

(g) How does MEEN 3344 help students learn to communicate effectively?
- Each student is required to gain application through a 3 minute verbal presentation to the class on a pre-approved material or product. The student can do a second one for extra credit.
- Students must research the material, prepare a PowerPoint presentation, with references, and get approval.
- Essays are assigned; part of the grade is based on grammar and clear communication of new materials and ideas.
- Classroom discussion is encouraged.

(h) How does MEEN 3344 help students learn to understand the impact of engineering solutions in a global and societal context?
- Although evolution of materials and their impact on society are discussed throughout the course, and many students bring up the impact of engineering solutions in their presentations, no official outcome is designated.

(i & j) How does MEEN 3344 help students learn to recognize the need for and engage in life-long learning? How does MEEN 3344 help students learn to have knowledge of contemporary engineering issues?
- Students gain knowledge through an assigned essay, and presentations, where they must research new and unique materials. These new materials are typically mutations or variations of older materials, such as concrete that is lighter than water.
- Students are taught continuously that new materials and applications are being continuously developed and that if they want to stay current in their field, or remain employed, they must be aware of new developments.
- Each student will view approximately 20 three-minute presentations. Many of these may involve solutions to contemporary issues, such as bullet-proof vests for soldiers, or building materials that reduce pollution or protect against natural disasters.

Student Survey Results

Although student surveys can be somewhat subjective, the following compilation of survey results since the Spring 2003 semester compared well with exam scores, with the students being somewhat fearful of their own knowledge. All lectures are posted on the web in the form of pdf or PowerPoint files. Note that 77% like the computer projector for presentation of material. Those who retook the course say that the computer projector is better than acetate sheets on an old overhead projector. Over ¾ of the class likes the student presentations, and about 80% are motivated to study harder so that they will not have to take the final.

Although assessing technical content was not intended to be a part of this effort, it is informative to note that 86% of the students felt that they understood basic types of failure, 74% understood the difference between crystalline and non-crystalline materials, and 91% felt that they understood basic heat-treating processes. These content-related results should be correlated with exam, quiz, and homework results before too much weight is given to them.

Table 1 MEEN 3344 Compiled Learning Survey Results (2003-2004)

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
The instructor treats all students the same.	70.7	29.3	0.0	0.0	0.0
I understand the different types of failure and can recognize them.	21.9	64.6	13.5	0.0	0.0
I understand the difference between crystalline and non-crystalline materials.	11.7	62.6	23.7	1.9	0.0
I understand the basic heat-treating process.	24.1	67.5	8.4	0.0	0.0
This course will be useful as a practicing engineer.	52.0	35.0	9.1	3.8	0.0
The computer projector is an effective tool in teaching this material.	49.5	29.4	19.6	1.5	0.0
The student presentations are interesting and useful.	40.8	36.8	17.0	5.3	0.0
I study harder so that I will not have to take the final.	44.2	35.8	18.9	1.1	0.0

Summary

If performance criteria are set, and incentives are given based on meeting that criteria, it is evident that performance will improve, and that accreditations based on that criteria will be more easily obtained, but what might not be readily evident is how much of a performance boost will be obtained. In the case of this materials science course, the students base their performance on grades, while we base their performance on grades, pass rates on national exams, and performance as practicing engineers. If a student at TAMUK is motivated enough to prepare and give a 3 minute PowerPoint presentation on a new material of interest, he can expect to receive at least a letter grade higher than those who do not. Additionally, if he will complete all of his homework, receiving at least an average 80% score on that homework, attends all lectures, passes all mid-term exams, he will get at least a B+ or A-, and should pass the FE Exam. Furthermore, he will believe that he has obtained skills that will help him as a practicing engineer. The usefulness of this document, then, is ammunition to use in motivating students to complete their homework and attend classes.

REFERENCES

1. Peel, L.D., http://users.tamuk.edu/kfldp00/, January 2006
2. Peel, L.D., http://www.engineer.tamuk.edu/departments/ieen/faculty/DrLPeel/Courses/MEEN3344_table.html, January 2006

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Dr. Larry Peel currently serves as an Associate Professor of Mechanical Engineering at Texas A&M University – Kingsville. He also serves as the Mechanical Engineering Graduate Coordinator, and director of the Adaptive Structures Lab. His research interests include the fabrication and mechanics of rigid and flexible composite structures. Prof. Peel has applied to become a registered Professional Engineer in the state of Texas.