INTEGRATION OF AN EFFECTIVE ANALYSIS COURSE INTO THE ENGINEERING CURRICULUM

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Abstract — *Usual courses in calculus and differential equations place little emphasis on real world applications. The need is not so much for inclusion of more mathematics courses into the curriculum but it is crucial to require students to use their mathematical skills to model and formulate engineering problems. There are several ways of introducing the art of applying mathematics to engineering problems. One method consists of integration of an "Engineering Analysis" course into the curriculums. The object of this paper is to present the format of the course. Topics include transform methods, applied statistical analysis, Fourier analysis, optimization methods and numerical solution of partial differential equations. In addition, students are required to apply technology as an instrument to expedite solution of the problem, inspect the solution and discover new information. An assessment procedure based on the data collected throughout the semester can be used to enhance teaching in the subsequent semesters.*

Index Terms — Assessment, ABET, Course Learning Objectives, MATLAB, MINITAB.

INTRODUCTION

It is a common concern of engineering students and faculty that usual courses in calculus and differential equations place insufficient emphasis on the modeling and formulation of physical problems. In addition to four calculus courses most engineering programs require an additional mathematics course from a list of several optional mathematics courses and statistics and probability courses. It seems that in most cases the amount of mathematics included in the engineering curriculums is quite adequate. However, the ability to construct a proper mathematical setup for a given engineering or physical problem is not developed in the student to a sufficient degree. In other words, the need is not so much for inclusion of an additional required mathematics course but it is important to require students to use the skills that they have gained in taking mathematics courses to model and formulate engineering problems. Because of these, in the beginning of this millennium a new and a required beyond calculus course titled "*Engineering Analysis*" was integrated into the mechanical and electrical engineering curriculums at Saginaw Valley State University (SVSU). The course is composed of selected topics of engineering mathematics that are needed for students to gain sufficient ability in modeling and implementation of mathematics. Here mathematical concepts are presented from the viewpoint of their application rather than from that of their purely logical development. Topics are selected so that they could help to pave the way for using the current technology and to cope with related demands in the future.

COURSE INFORMATION

The course information is as follows:
Title: *Engineering Analysis* (ME/ECE 302).
Prerequisites: Calculus and Differential Equations
Format: Lecture with interactive computer application and workshop sessions
Number of Credits: Three credits.
Schedule: Fall and winter semesters (each semester is 15 weeks in duration).
Enrollment: About 60 (total).
Textbook: A standard *"Engineering Mathematics"* textbook [1, 2].
Supplementary Material: A series of handout notes and instructions related to the topics.

Common Course Topics:

This is a lecture-based course supplemented by computer simulation sessions using MATLAB [3] and MINITAB [4]. To keep the course within its reasonable number of credits, the scope of topics is limited to important topics that are common for mechanical and electrical engineering majors. Standard topics include classification of mathematical models, transform methods, complex variables approach, applied statistical analysis, Fourier analysis, partial differential equations (pde) including their numerical solutions using the *finite difference method*. In addition, 20% of the course is a mixture of special topics that are exclusively need for mechanical or electrical majors. Prior to the development of the course and after discussion with departmental colleagues it was decided to cover the following units:

Unit 1: Laplace Transforms
Unit 2: Statistical Analysis and Reliability
Unit 3: Fourier Analysis, Fast Fourier Transform
Unit 4: Partial Differential Equations
Unit 5: Special Topics

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Units one through four are equally important for both majors whereas topics of unit five are selected so that the needs of both majors are satisfied. This is handled thorough multiple projects and questions relevant to each major. Typical topics for unit five include Optimization, Graph Theory, Markov Process, Monte Carlo Method and Matrix *Eigenvalue* Problems. Each unit is introduced in a manner that invites students to think and comprehend. As a result, homework sets and projects are assigned to reflect the needs of both majors. In addition, inclusion of unit two satisfies the ABET [5] requirements that engineering graduate needs to understand fundamental concepts and applications of probability and statistics. Time duration to cover each unit is about three weeks or six 90-minute long lectures.

Use of Technology

Each unit contains numerical treatment of related problems which requires computer. Following discussion of fundamental notions of computer-oriented numerical methods, students will be required to explore the content of the course by proper use of technology only to expedite calculations, inspect the results, discover, and interpret the behavior of the solution by varying parameters. The main commercial tools are MATLAB and MINITAB in which MATLAB provides an excellent environment for programming whereas the MINITAB resources allow for understanding of error analysis, using a variety of probability distribution models and reliability analysis using the Weibull distribution. MATLAB and Excel [6] are used for matrix-based problems and graphical representation of the results. The MINITAB can be used to develop reliability curves using Weibull distribution and to generate control charts. Often manual plots are generated on special probability papers for better understanding of the concepts. In this case actual data from electrical or mechanical labs are used. In certain cases programs using the obsolete codes such as Basic, Fortran or C languages have been used by few students who are proficient in these programming codes, and in few instances, several students have used Visual Basic within Excel. Such interests seem to fade out gradually and interests in programming within a relatively new environment such as MATLAB has increased.

COURSE LEARNING OBJECTIVES AND ASSESSMENT

For the assessment study, performance of individual students during the semester is recorded. Data include homework assignments, computer-based projects, in-class exams and a comprehensive final exam.

The Initial Survey

During the first lecture a survey is distributed to recognize student academic background and their computational skills. **Table 1** shows responses for two randomly selected samples (semesters) A and B. Numbers of responses are in parentheses. The higher number for "proficiency in at least one computer language" in sample B is because all mechanical engineering majors are required to take a 200-level course titled "*Computational and Experiment Methods*" prior to the "*Engineering Analysis*" course. In this 200-level course programming using MATLAB is a requirement and as a result, programming skills of students have improved significantly.

Expectation from Students

Students are required to maintain a notebook that contains lecture materials for the essential topics, application examples, instruction for using computer programs and results from the workshop sessions. Because the course requires students to explore the content of the course by appropriate employment of technology, MATLAB codes for the assigned projects must be presented for inspection and grading purposes. Students must show their own work and programming codes. Symbolic solutions from commercial tools will not be accepted for grading.

Grading Scheme:

Five *take-home* Assignment:	20 points each, 100 points
Five *in-class* Exams:	50 points each, 250 points
A comprehensive *final exam*:	100 points
Total:	450 points

A minimum of 315 points (70%) is needed to pass the course with a C grade.

Assessment Data

For illustration, results for two semesters A and B that were three years apart are considered for inspection. These semesters are labeled sample A (2005), and sample B (2008). Gathering data for more than one semester can provide the faculty with a long term view of student learning in the course. For the assessment we used the following data:

***Take-home* assignments:** five comprehensive homework and project sets, one for each unit
***In-class* exams:** five hourly tests, one for each units

A comprehensive final exam, two hours in duration

***Take-Home* Assignments--**Ample time (about two weeks) was given to students to complete each take-home assignment. Sufficient theoretical modeling corresponding to each project was covered in the lecture notes. Results: Satisfactory in most cases.

***In-Class* Exams:** Student grades in these exams were the main source of information to assess their understanding achievements in the goals. Besides poor management of the time, lack of success by those who did not do well was mainly because of improper use of mathematical manipulation, difficulties with *multi-variate* functions including the use of *"separation of variables"* technique for solving pde's. These results help the instructor to develop a correction plan in which adjustment of the content, provided additional examples and included pertinent questions in the assignments during the subsequent semesters. The grade distributions for the *take-home* assignments and *in-class* exams are shown in **Figures 1** and **2**.

The Comprehensive Final Exam: an in-class, 2-hour long, and comprehensive final exam (60% form units 1 through 4 and 40% from unit 5) was given one week after the final lecture. The exam format was given in the course syllabus. The final exam is normally closed book and notes but students can use a one-page with the essential equations. The statistical results corresponding to the final exam are shown in **Table 2** (the grades were assumed to be normally distributed.) A 70% or more score is considered as satisfactory to meeting of the corresponding Course Learning Objectives (CLO).

Mathematical Assessment:

The degree of uncertainty in the statistical results of the two samples A and B can be described by a confidence interval. Because we do not know the *population* mean and standard deviation (μ,σ) for each sample, we can use the Student *t-test* [7] to check whether the difference between these two *sample* means, $\Delta x = x_A - x_B$, is statically significant or not. For samples A and B (see **Table 2**) we obtain:

$$\Delta x = x_A - x_B = 72.5 - 67.8 = 4.7$$

The standard error of the difference between the two *sample* means, is given by [7]

$$s_e = [(s_A)^2/n_A + (s_B)^2/n_B]^{1/2} \qquad (1)$$

We obtain s_e=2.81. The corresponding "*t-value*" will be

$$t = \Delta x / s_e = 1.67$$

The *degree of freedom* (dof), v=n-1, for each sample and the combined samples will be,

$$v_A = n_A - 1 = 30$$
$$v_B = n_B - 1 = 27$$
$$v = v_A + v_B = 57$$

Now, using a 95% confidence level, i.e., α=1-0.95=0.05, and v=57 we find the critical t-value from the Table [7]:

$$t_{cr} = t_{0.025} = 2.0$$

This means that sample t value must be at least 2.0 to reach the $p<0.05$ level and because $t < t_{cr}$, the difference Δx=4.7 is not statically significant.

CONCLUSIONS

A three-credit beyond calculus course for the mechanical and electrical engineering majors has been presented. The course helps students to use their calculus and differential equation skills to model and formulate a wide variety of engineering problems. In addition, students are encouraged to use technology to expedite computation and inspect sensitivity of the solution with respect to the problem variables. Although the course is highly demanding but because it is directly related to the engineering concepts students seem to enjoy taking it. Lack of success for those who fail the course seem to be related to their mathematical skills and basic understanding of fundamentals of differential equations. Skills in writing program codes using MATLAB seem to help students to perform good in the assigned projects. The course also satisfies the ABET requirements regarding the probability and statistics content.

REFERENCES

[1] Zill, D. G., and Cullen, M. R., Advanced Engineering Mathematics, Jones-Bartlett (2006).

[2] Kreyszig, E., "Advanced Engineering Mathematics'", J. Wiley. 2006.

[3] MATLAB, the MathWorks, Inc., 3 Apple Hill Drive, Natick, MA 01760-2098, USA.

[4] MINITAB Inc., Pine Hall Rd., State College PA 16801-3008, USA.

[5] ABET *"Accreditation Board for Engineering and Technology,"* Baltimore, MD 21202 USA.

[6] Excel, Las Colinas Blvd., Irving, TX, 75039 USA.

[7] Mendenhall, S., Statistics for Engineers and Scientists, Dellen, Macmilan, 1988.

Table 1:
The Initial Student Survey

Topics	Responses	
	Sample A, 2005 (n_A= 31)	**Sample B, 2008 (n_B=28)**
Academic Standing	Senior (27), Junior (4)	Senior (23), Junior (5)
Mathematics Level	Calculus IV (31), an additional elective math/statistics (13)	Calculus IV (28), an additional elective math/statistics (2)
Programming Skills	Proficient in one language (4) Minimum skills (18) No comments (9)	Proficient in one language (11) Minimum skills (10) No comments (7)

Table 2
Grade Statistics for the Final Exam

Parameters	Sample A	Sample B
Minimum	60	62.5
Maximum	84.5	93
Mean	72.5	67.8
Std. Dev.	6.8	13.4
% Passing	88	91

Figure 1.

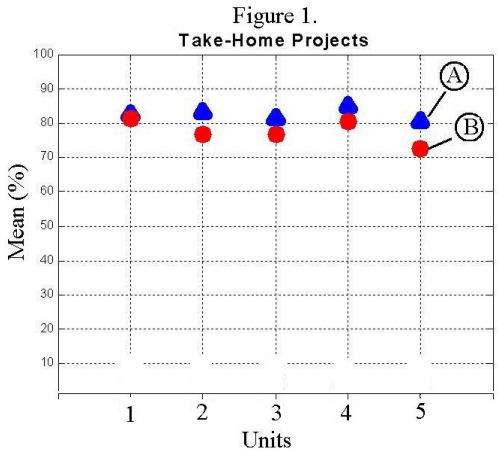
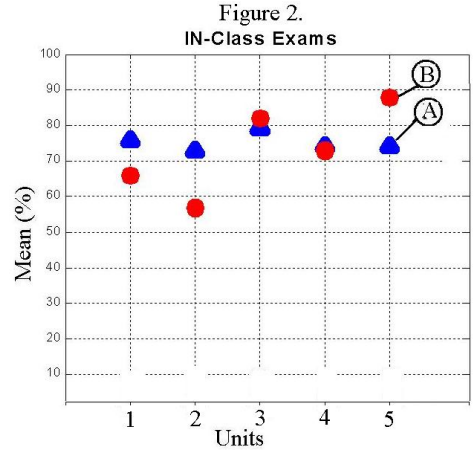
Figure 2.