ELECTRICAL ENGINEERING 215 — A CASE STUDY IN ASSESSMENT

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Abstract — While assessment is a ‘buzz-word’ at many universities, the United States Air Force Academy (USAFA) has actively applied assessment techniques over the past two decades. This paper addresses the assessment approach, techniques and outcomes that have evolved the required electrical engineering core course for all non-engineering majors, Electrical Engineering 215 (EE 215). The statistical data is derived from 8354 cadets, who were enrolled in EE 215 from its initial Spring 1991 offering through Spring 2000. The emphasis is the Spring 2000 semester. The USAFA’s automated assessment tool is a macro-driven, excel-spreadsheet that records all graded events and produces objective statistical assessment data. The assessment challenge, facing any academic institution, is to establish cost-effective procedures that provide the necessary assessment outcomes without requiring excessive academic-staff efforts. This case study illustrates example procedures, tools, benefits, and problems in collecting multi-section, core-course assessment data. In summary, the USAFA assessment procedures and developed course material has general academic community application.

Index Terms — assessment, case study, core course, Electrical Engineering 215.

INTRODUCTION

For over two decades the United States Air Force Academy (USAFA) has required all cadets to take at least one course in electrical engineering. In the eighties one such course was Electrical Circuits 310 (EE 310); however, approximately 20% of the cadets made D’s or F’s during the 1986-87 academic year. After much consideration, it was suggested that the principal reason for the low grades was that the course taught the basics of circuit analysis, but the cadets could not appreciate the applications—so they would not do the required course work to achieve an acceptable grade [1].

Based upon this informal assessment, the academy began a formal assessment process to fix this problem. The first step was to answer the following question. Why have non-engineering majors take an electrical engineering course? The current answer to the stated question is the goal of the existing Electrical Signals and Systems course, Electrical Engineering 215 (EE 215). Specifically, all cadets need to develop an understanding of electrical systems and the value of these systems to the Air Force and society [2]. This goal is the result of the evolutionary process that transformed the required course material from circuit analysis in EE 310 to system applications in EE 215.

The cadets could readily appreciate the value of communication systems, which range from the basic telephone to complex military applications, but they lacked the fundamental knowledge to design such systems. Dr. Albert Rosa, and others, suggested that a functional block diagram approach would be the key to bridging this knowledge gap [1]. Hence, typical electrical circuits were embedded into workable lab modules that the cadets could interconnect to accomplish basic system functions. The result is immediate visualizing of the system output without the need for all the mathematical underpinning of the specific individual electrical circuits.

Figure 1 is an example of two such modules. The first module is a function multiplier that has inputs of message signal (Vs) and carrier signal (Vc) and an output signal (Vo). The second module is a two-input adder that produces both the inverted and non-inverted outputs. Figure 2 is a typical application of the modules shown in Figure 1. Four individual function generators are used to create two separate message signals and two separate carrier signals. Then two of the function generators are connected to each function multiplier modules that, in turn, are connected to the adder module. The resulting output is connected to an oscilloscope operating in the spectrum display mode. This demonstration setup allows the cadet to vary individually the message and carrier signals and, in turn, observe the changes in the resulting spectra.

FIGURE. 1
FUNCTION MULTIPLIER AND ADDER MODULES

The utilization of various modules, such as those described above, allows In-Class-Exercises (ICEs) and self-
contained laboratory experiments, together with basic theory and relevant applications, to be integrated into an effective student-friendly learning environment. Since its inception, EE 215 has evolved and continues to evolve in order to provide USAFA with a relevant electrical engineering core course for non-engineering majors.

Block I: Signals and Signal Conditioning
- How electrical engineering principles relates to your discipline and your life.
- How electrical signals are produced and used.
- How to describe signals in the time domain and frequency domain.
- How to process electrical signal with electronic functions (adders, scalar multipliers, function multipliers, and filters).
- How to convert analog signals to digital format and vice versa.
- How to convert signals from parallel format to serial format and vice versa.
- How to combine multiple signals by allocating time slots for transmission.

Block II: Communications
- How to combine multiple signals by allocating frequency slots for transmission.
- How to vary (modulate) a high frequency sinusoid to carry information.

EE 215 COURSE SUBJECT CONTENT DATA

The course subject material is currently divided into three basic blocks: 1) Signals and Signal Conditioning; 2) Communications; and 3) Circuits. Each block is self-contained including theory, applications, homework, quizzes, and graded reviews (GRs). The final exam provides comprehensive coverage of the entire course. At the completion of each block the cadet should know [3]:

Block I: Signals and Signal Conditioning
- How antennas transmit and receive signals.
- How to calculate signal strengths for transmission or reception.
- How electromagnetic signals propagate.
- How to recover information from high frequency sinusoids (carriers).
- How to analyze a digital communication system.

Block III: Circuits
- Function of source, devices, and switches (e.g., batteries, resistors, capacitors, inductors, transformers, diodes, circuit breakers, and fuses).
- How to find equivalent resistance, capacitance, and inductance.
- Conservation of energy and charge in circuit analysis.
- How to analyze DC and AC circuits.
- How to convert AC signals to DC.
- How power is generated, transmitted, distributed and used.

EE 215 COURSE DEVELOPMENT

In addition to generating the academic course material to support the course goal and objectives, two additional factors were considered in developing this core course at USAFA. First factor is the number of cadets taking the course each semester, or year. Since the cadet enrollment is approximate 1000 students per class, 500 cadets per semester is a good planning number. This number of cadets for EE 215 per semester is modified slightly by considering: 1) a small reduction because some cadets may take it in the Summer semester; 2) a small increase because some cadets may retake the course; and 3) a larger reduction because EE 215 is not taken by engineering majors (Aero Engineering is an exception). Hence EE 215 was sized for nominally 400 cadets per Fall and Spring semesters. Since the maximum electrical engineering class size is 24 cadets, this course would require nominally 16 sections per semester. In practice, scheduling constraints have resulted in smaller classes with slightly more sections per semester.

The second factor is to insure uniformity in course material and grading standards across the various sections. The course director, who normally also teaches multiple sections of the course, is responsible for the uniformity of the subject material and grading criteria across all sections. It is the course director’s responsibility to develop the course syllabus, instructor notes, skills review, ICEs, laboratory experiments, study journal requirements, homework assignments, GRs and final exams.

The course director creates the GRs and final exam solution keys and defines the point weighting for each part and type of problem (e.g., 4-points for setting up the equation, 2-points for substituting in the correct values, 1-point for solving the equation and 1-point for the proper units). The cadet’s grades are recorded for each individual problem on the GRs and final exam. This approach allows...
statistical processing to measure the outcome for individual course objectives (e.g., TDM vs. FDM understanding).

The individual instructors, who vary in rank from Professor to Instructor, are allowed to teach their section(s) within the general guidelines provided by the course director. In any given semester, EE 215 will have many different instructors. The individual instructor develops and grades all quizzes for their section(s). During the GR grading process one-instructor grades a single problem for all cadets taking a specific version of the GR. This approach provides grading consistency across all sections to insure proper rankings of all cadets based on uniform criteria.

EE 215 COURSE ASSESSMENT TECHNIQUES

Assessment techniques may be divided into two basic categories, objective and subjective. The key to any assessment program is the development and application of automated tools to collect and process the objective statistical assessment data. EE 215 has such a standardized grading tool to collect all grades and provide historical data for future statistical analysis.

Instead of developing a customized data collection program that requires special training to use and maintain, USAFA chose to use the inherent capabilities of Microsoft’s EXCEL. The custom-macro features of EXCEL provide a user-friendly interface for both the individual instructor’s data input functions and the course director’s formal reporting role. EXCEL also provides convenient tools for summarizing and analyzing the historical data collected. The USAFA EXCEL spreadsheet program called ‘Grader’ has been successful demonstrated to support the objective assessment requirements for EE 215.

The subjective assessment data is principally derived from questionnaires. The cadets critique both the course subject material and the instructor’s classroom performance. Also, the end-users, which are the USAF officers to whom the cadets are assigned after graduation, of USAFA’s educational product provide both written and verbal feedback on the effectiveness of individual academy graduates.

EE 215 COURSE STATISTICAL DATA

The statistical data used in this paper is derived from 8354 cadets who were enrolled in EE 215 from its initial Spring 1991 offering through Spring 2000. The emphasis is upon the Spring 2000 semester, which includes seventeen sections, ten different teachers (2 professors, 1 associate professor, 4 assistant professors, and 3 instructors), and 370 cadets.

Since the unacceptable high percentage of D’s and F’s observed in EE 310 was the initial motivation in developing EE 215, the reduction of D’s and F’s are considered first. Figure 3 illustrates that the cumulative D’s and F’s for the initial ten-year period have averaged below ten percent, which is within an acceptable level for USAFA standards.

The initial problem of excessive low grades observed during the mid to late 1980s in EE 310 has been eliminated by the introduction of the new EE 215 course.

Next, consider the question of uniformity in grades across different sections with different instructors. Figure 4 shows the Spring 2000 section scores (maximum, average and minimum) sorted by average. Section T2A has the highest average while section M1A has the lowest average. The longest bar (labeled ALL) indicates the combination of all sections. Eight-section’s averages were above the combined average and nine-section’s averages were below the combined average. Note that all averages remain within a 12% spread. If the high (T2A) and low (M1A) averages are dropped the result yields a variation of less than 5%, which demonstrates the desired successful uniform grading achievement across all EE 215 sections.

Figure 5 compares EE 215 final exam and course scores from the Spring 2000 semester. Note the large exam excursions in the lower third of the cadet ranking. In most cases the other course scores (quiz, homework, ICE, Lab, etc.) result in a final course score that is approximately 5% higher than the cadet’s final exam score. There are, however, two notable exceptions. The data in Figure 5 clearly indicates those cadets that recognized their need to ‘ace’ the exam to either make a ‘C’ or ‘PASS’ the course. In those cases some of the final exam scores are 25% higher than the final course scores. In these exceptional cases, the final course score is a better indicator of the cadet’s efforts in EE 215 rather than their mastery of EE 215 material.
The Spring 2000 final exam contained fourteen problems. The first six exam problems were required to be worked, while only four out of the last eight problems were required. Hence each cadet’s grade was based on the ten problems worked as shown in Figure 6. While trying to analyze the data, it became obvious that the data collection system was not properly utilized. The scores of worked problems were recorded simply for problems one to ten. Hence, the identity of which four of the last eight problems were worked was lost. Upon further study of the data, it became apparent that three different final exam versions were available, but which specific version each cadet took was omitted in the data collection process. Therefore, the unique identity of the first six problems worked by individual cadets was also lost; so that none of the problem numbers in Figure 6 are traceable to the specific question asked. Hence, the correlation of final exam problem scores to specific teaching objectives is not possible. As a consequence of the errors included in the data collection process, the data in Figure 6 is of very little assessment value. The data collection process has been corrected for the Fall 2002 semester, so that this type of error will not be encountered in the future. This is an example of the assessment process correcting the application of a tool rather than modifying the content of a course.

Since USAFA’s Electrical Engineering program had a previous six year accreditation by Accreditation Board for Engineering and Technology, Inc. (ABET) and recently successful completed the ABET accreditation visit in the Fall of 2002 [4], this paper summarizes an extraction of the formal assessment results from calendar years 1997-2002. The activities used to assess how well EE 215 met its objectives are listed in the matrix below [5]. These objectives were measured across all graded events in the entire course as indicated in Table I.

<table>
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<tr>
<th>Assessment Method</th>
<th>Obj #1</th>
<th>Obj #2</th>
<th>Obj #3</th>
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<tr>
<td>Graded Reviews</td>
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<td>Pre-Laboratory Assignments</td>
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<td>Final Exam</td>
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- Objective #1 – Design and analyze analog and digital communication systems at the block diagram level.
- Objective #2 – Demonstrate knowledge of basic devices used in electronic systems.
- Objective #3 – Use the engineering problem solving method for well-defined and ill-defined electrical engineering circuits and systems problems.

All objectives for EE 215 were assessed and met. Having met the objectives, the goal of the course was met also.

For completeness, three specific subjective observations and results are included from EE 215 Final Course Reports [6].
• Observation: Duplicate material in EE 215, Physics 215, and Computer Science 110.
• Result: Removed duplicate material from EE 215 syllabus.

• Observation: The time-correlation of different course’s GRs creates unnecessary peak workloads on the cadets.
• Result: EE 215-format switched from a four-block with GRs to a three-block with GRs to change phasing of GRs to reduce the cadets’ peak workload.

• Observation: The EE 215 textbook requires significant revision to remove material deleted from the syllabus and to adjust for the new three-block format.
• Result: Current EE 215 USAFA published textbook is Introduction to Electrical Engineering a Course for Students Not Majoring in Electrical Engineering, 2nd Edition (edited by Donna E. Peterson and Cameron H. G. Wright)

EE 215 COURSE PENDING CHANGES

During the Spring 2003 semester, the current instructors are considering a major revision of the existing EE 215 syllabus [7]. The level of circuit analysis is still considered excessive for non-engineering majors and other current topics of major relevance are not included. In general, the current proposed changes are as follows:

• Block I: Revise title from ‘Signals and Signal Conditioning’ to ‘Introduction and Fundamentals’ and improve the presentation order of existing course material. Specifically, move several of the lessons to Block II and replace them with lessons from Block III.

• Block II: Revise the title from ‘Communications’ to ‘Digital Systems’. Major revision of this section is required to integrate existing material (ADC, DAC, TDM, etc.) with new material (digital logic, truth tables, K-maps, state diagrams, etc.) and move the communication applications to Block III.

• Block III: Revise title from ‘Circuits’ to ‘Communication and Radar Applications’. The material would be significantly revised to limit the amount of detail AC/DC circuit analysis. The existing communication applications moved from Block II will be supplemented with new material addressing introductory radar applications.

If adopted, the proposed changes to EE 215 will revise the course material to start with fundamentals and build to the applications. This approach should enhance the students learning experience and retention of the material for application during their Air Force career. The existing EE 215 textbook will require a significant revision to include the new material. The target schedule is to introduce the new material with a revised textbook in the Fall 2003 semester. Since EE 215 uses an USAFA published textbook, this is not an impossible task; but it will be a challenging endeavor for the course director and all contributing USAFA staff members to accomplish prior to the Fall 2003 semester.

SUMMARY AND CONCLUSION

In summary, USAFA has been successful in developing an electrical engineering core course (EE 215) that introduces all non-engineering cadet to the broad aspects of electrical engineering as required in the Air Force, or society in general. The course director structure of this course maintains uniformity of subject material and grading standards across many sections. The data collection system (Grader) simultaneously collects data for the cadet’s academic records and provides a database for objective assessment outcomes. Formal questionnaires provide the subjective assessment outcomes. The importance of validating the data collection process and correcting any deficiencies observed before applying the data to the assessment process is also demonstrated. In summary, EE 215’s development approach, assessment techniques and course material has broad application to the general academic community.

REFERENCES

[1] Verbal Communication with Dr. Albert Rosa currently a distinguished Visiting Professor at USAFA’s Electrical Engineering Department and key participant in the development of EE 215 and its predecessor course EE 310.


[7] E-mail titled EE 215 Changes from Lt Col Dave W. Kyger, Chief Communications Division, to Dr. Rosa, Capt Fuller, Maj Nace, Lt Col Peterson and Dr. Gilbert, Dated 12 February 2003.