INTERACTIVE ASSESSMENT OF LEARNING OUTCOMES IN INTRODUCTORY ELECTRICAL ENGINEERING CLASSES

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Abstract

The paper discusses the student learning outcomes in introductory level electrical engineering courses in terms of ABET criteria for program educational objectives. Courses taught by resident faculty in FSU are based on hands-on classroom and lab activities with one-on-one student-instructor interaction. In addition, web support is used in all introductory classes to enhance the assessment process. The paper presents the student profile, program objectives, and discusses the importance of the introductory courses on recruitment and retention as well as adequate preparation to the upper level. Student background, interests, and career goals are continuously monitored through surveys. Learning outcomes are assessed by several tools such as course-specific evaluation forms, journals, minutes, and focus groups. Since each student has a different learning style, continuous monitoring helps understanding the differences among students and enhances teaching style to increase the students’ attention and productivity.

Introduction

Assessment, feedback, and program improvement are the most crucial elements of the ABET accreditation process. These three concepts are interrelated since assessment tools provide feedback information to improve the program. The quality of a program relies on the adequacy of the implemented assessment methods, interpretation of the gathered information, and the response time of the feedback system to improve the curriculum. Since ABET has not prescribed any assessment methodology, every institution develops its own system to evaluate educational outcomes and students’ performance. It is well known that no assessment tool is perfect, and each method has strengths and weaknesses. Program objectives, characteristics of the student population, class sizes, course delivery format, interaction between faculty members and between students and faculty are the basic parameters to be considered in the search of an effective and meaningful assessment system.
This paper describes the assessment procedures implemented in introductory level electrical engineering courses of the Collaborative Electrical Engineering program jointly offered by Frostburg State University (FSU) and University of Maryland College Park (UMCP). The outline of the program is presented in the following section with an emphasis on its features that affect the assessment methodology. Whereas all introductory courses are delivered in a traditional classroom format, the unique structure of the program requires that special considerations be taken in the development of a feedback system for curriculum improvement. Objectives and expectations set for introductory courses are described in terms of ABET 2000 criteria for program educational objectives. The paper describes the classroom level assessment methods implemented in various courses. The feedback system is discussed based on the observations and experience gained in the resident portion of the collaborative electrical engineering curriculum over the first six years of the program.

Outline of the Program

Frostburg State University (FSU) has been offering four-year Electrical Engineering program since 1997 in collaboration with University of Maryland College Park (UMCP). All introductory courses, upper division labs, and project courses are delivered by FSU faculty in traditional format. Most of the upper level classes are offered by UMCP Department of Electrical and Computer Engineering via Interactive Video Network (IVN). Following the ABET Accreditation Committee visit in fall 2002, the “Frostburg Collaborative Electrical Engineering Program” has been accredited as a separate program of the University of Maryland’s Clark School of Engineering.

Students are initially admitted to FSU through the regular admission process. If they are interested in electrical engineering, they declare major as “Physics” with concentration in engineering. Students apply for formal admission to Clark School of Engineering at UMCP typically during the spring semester of their sophomore year. Following a review of their transcripts, if they meet the requirements, they virtually transfer to UMCP, however, continue taking all classes on the FSU campus. In addition to all lower division courses, upper level electives in general education, math and physics curriculum, and upper division engineering courses involving lab or design component are offered by FSU faculty. Junior and senior level lecture courses are usually offered by UMCP faculty through Instructional Video Network (IVN). Upon completion of all requirements, students receive their electrical engineering degree from UMCP’s Clark School of Engineering.

The Collaborative Engineering model has been a cost effective solution to extend the educational resources available at UMCP, the flagship institution of the University System of Maryland, to Western Maryland served by Frostburg State University, which is the only four-year higher education institution west of the Baltimore-Washington metropolitan area. The personnel cost is minimal, since 15 – 18 credit-hours of the on-site EE courses are taught by one resident electrical engineering faculty. One full time physics faculty and one part-time adjunct faculty provide low-cost support to the program teaching 9 credit-hours of the curriculum. From the students’ standpoint, less expensive
and simple small town life, safer and more manageable campus, easier access to athletic and cultural activities, smaller class sizes, and more time to spend for study are the major advantages.

Small engineering classes at FSU allow implementation of studio-type classroom activities with one-on-one student-instructor interactions, which are essential in outcome-based engineering education. Resident faculty members know students’ strengths and weaknesses and can adjust the pace and style of their teaching accordingly. Collaborative engineering students have easier access to the instructors, advisors, and on-site lab, workshop, and computer facilities.

The distance education component of the program seems to be the major inconvenience for students. Whereas all courses offered by UMCP ECE department are broadcasted via two-way interactive audio-visual transmission; students feel a certain level of frustration when they experience the transition from being in a small class setting with one-on-one interaction with the instructor to become the remote part of a much larger student population on UMCP campus. As the program has grown in total enrollment, over the last few years a considerable number of students who completed the lower division portion of the electrical engineering curriculum have either physically transferred to UMCP or switched to related majors such as Physics and Computer Science as a result of this frustration. On the other hand, the survivors take advantage of the information technology more than traditional students and can develop distance communication and teleconferencing skills, which they will eventually need in their career to work with remote partners.

Curriculum

The catalog description of contents and prerequisites of electrical engineering courses at FSU are identical to the courses with the same catalog numbers offered at the Electrical and Computer Engineering department of the University of Maryland. Figure 1 shows the composition of the EE curriculum in terms of credit hours offered by FSU and UMCP for a regular student who starts with a sufficient math background to take a calculus class in the first semester.

![Figure 1 Sharing of the on-site and distance education components of the curriculum.](image)

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The FSU portion of the curriculum includes math, physics, chemistry, and general education courses in addition to electrical engineering courses. Detailed description of the curriculum is available on the program’s home page\(^2\).

The distribution of electrical engineering courses taught by FSU faculty and televised from UMCP is shown in Figure 2 by semesters. ENES 100, Introduction to Engineering Design, which is typically taken during the first semester, is the only Engineering Science course required for electrical engineering majors. As Figure 2 clearly shows, the fifth semester forms a transition period between two different delivery formats in engineering courses. All lower division classes meet in a computer-based classroom or lab environment and students have one-on-one interaction with the instructor. Students face the challenges of the distance education as they take three upper-division fundamental classes, namely Digital Electronics, Systems and Signals, and Computer Organization in the fall semester of their junior year. In order to make the transition easier, juniors are encouraged to take a 2-credit elective from the resident EE faculty during the fall semester.

![Figure 2 Distribution of required engineering courses in the EE curriculum.](image)

**Educational Objectives of Introductory Electrical Engineering Courses**

The expected outcomes constitute the basis in the development of an assessment system. Expectations from each EE course in the collaborative engineering curriculum have been determined in terms of ABET 2000 criteria, which require that the program provide students with

a) an ability to apply knowledge of mathematics, science, and engineering

b) an ability to design and conduct experiments, as well as to analyze and interpret data

c) an ability to design a system, component, or process to meet desired needs

d) an ability to function on multi-disciplinary teams

e) an ability to identify, formulate, and solve engineering problems

f) an understanding of professional and ethical responsibility

g) an ability to communicate effectively

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h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
i) a recognition of the need for, and an ability to engage in life-long learning
j) a knowledge of contemporary issues
k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

All educational objectives and expectations are clearly stated in course syllabi and discussed with students during at the first class meeting. The ABET criteria addressed by each of the introductory courses of the Collaborative Electrical Engineering program are mapped in Table 1.

Table 1 – ABET 2002 criteria addressed by on-site EE courses

| Course Code | Course Name                                      | Credit Hours | Contact Hours | Typical Section Enrollment | a | b | c | d | e | f | g | h | i | j | k |
|-------------|-------------------------------------------------|--------------|--------------|----------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| ENES100     | Introduction to Engineering Design              | 3            | 4            | 15 – 20                    | ✔            | ✔            | ✔            | ✔            | ✔            | ✔            | ✔            | ✔            | ✔            | ✔            | ✔            | ✔            | ✔            |
| ENEE114     | Programming Concepts for Engineers              | 4            | 6            | 12 – 16                    |               |               |               |               | ✔            | ✔            |               |               |               |               |               |               | ✔            |
| ENEE241     | Numerical Techniques in Engineering             | 3            | 4            | 10 – 12                    | ✔            | ✔            |               |               |               | ✔            |               |               |               |               |               |               |               |
| ENEE244     | Digital Logic Design                            | 3            | 4            | 10 – 12                    | ✔            | ✔            |               |               |               | ✔            |               |               |               |               |               |               |               |
| ENEE204     | Basic Circuit Theory                            | 3            | 4            | 10 – 12                    | ✔            | ✔            | ✔            | ✔            | ✔            |               |               | ✔            | ✔            | ✔            | ✔            | ✔            | ✔            |
| ENEE206     | Fundamental Circuits Lab                        | 2            | 4            | 10 – 12                    | ✔            | ✔            | ✔            | ✔            | ✔            |               |               | ✔            | ✔            | ✔            | ✔            | ✔            | ✔            |

Assessment Methodology

The assessment system is based on two sets of information sources: surveys and evaluations. Surveys are used to obtain the characteristics of the student population, students’ expectations, satisfaction level, and career goals through the program.

Surveys

Because the students admitted to FSU declare their major typically by the end of the second semester, it is difficult to identify electrical engineering students in the freshman year. Since ENES 100 is the first required engineering course for EE, ME, and physics majors, students taking this course are surveyed to identify their demographic and ethnic distribution, math level, and high school performance. This survey also provides information to track students’ career goals through the program and interpret retention rates.

Sophomore and junior students are surveyed during the spring semester to obtain information about their satisfaction and receive their suggestions for program improvement. These surveys contain multiple choice and free response questions. Seniors fill an Exit Survey Form before graduation to provide feedback based on their experience.
in the program. Because the number of students at junior and senior level has been quite
small, free-response type suggestions have provided more meaningful data.

Evaluations

Evaluations are counterparts of measurements in engineering feedback systems. The
basic concepts of error, sensitivity, and noise apply as well in classroom measurements.
Similarly to the selection of correct sensors or transducers in a physical system,
appropriate evaluation method must be selected for data collection and proper filtering
schemes should be applied to condition the collected data.

A wide variety of conventional methods are available to assess student learning
outcomes. Most of the tools are based on statistical analysis to be applied in large classes.
Whereas statistical methods provide objective overview of the student performance for
large number of samples, they may inadequate or misleading in smaller classes. All
instructors would agree that better students usually provide meaningful and helpful
feedback on evaluation sheets. Emotionally stressed students may, in turn, reflect their
reactions on the evaluations. There is practically no way to motivate all students to take
the evaluations seriously enough to spend sufficient time for each question. The
emotional reaction of one student in a class of ten would result in an error of 10% on a
numerical scale. It is often possible to end up with a higher error due to group dynamics.
In such cases, numerical data should be interpreted with caution to distinguish
unreasonable information.

Another source of error results from different interpretation of questions by students. The
questions must be worded very carefully to prevent misunderstandings. Asking the same
questions in different words may reduce the risk of error due to unexpected
interpretations.

Timing of an evaluation is also important in obtaining meaningful results. Students may
give wrong feedback because of a frustration or confusion period during their learning
process.

The assessment tools used in introductory engineering courses are chosen or designed
keeping the above factors in mind. Instead of relying on fewer statistical evaluations, the
assessment process is distributed over the semester. The principal components of the
process are described below:

Prerequisite checks

At the beginning of the semester, each student is checked for course prerequisites by an
administrative specialist. It is the responsibility of the faculty assigned to the course to
keep a student in the course if prerequisites are not satisfied. Exceptions may be made in
special cases such as non-conventional or transfer students who have not followed the
standard sequence. The preparedness of students is additionally evaluated through a
“Background Evaluation Test” (BET) usually given in the second class meeting. Students
are informed in advance about the test and asked to review their notes. Based on the test results, the instructor may advise some students to withdraw. In the case of common lack of knowledge in some areas, the instructor spends extra time to compensate the weakness. BET serve also as a feedback for lower level courses.

Class Progress Evaluation

The class progress is evaluated at least one time around the mid-semester to receive student feedback about the pace and level of the course. Additional questions are given to determine how much time they spend to study the course, and how they feel about the teaching style. In order to help students individually, the instructor needs to identify the response of each student. However, a high level of trust must have been established so the students are honest in their responses. The authors have tried written and oral formats in different semesters. While private conference gives the instructor a chance to better know the student individually, the obtained feedback is sometimes subjective because some students hesitate to discuss their weaknesses face-to-face with the instructor.

Journals

Student journal is an alternative way to obtain feedback about students’ learning experience, strengths, weaknesses, or requests through the course. The authors have observed that students feel more comfortable and friendly when they write an e-mail. In ENEE 241 and ENEE 114 classes, students are required to send three journals in a semester, each one due one week before a test. The journals are mandatory and 10% portion of the final grade is earned by sending journals regularly on time. The feedback obtained from the journals is used in the review session held before the exam.

Class-Work

All introductory electrical engineering classes meet in a computer based classroom or lab where each student can work individually on a computer. Taking advantage of the small class size, hands-on class assignments are given on the applications of the concepts discussed in the lectures. The instructor interacts with each student one-on-one basis and has the opportunity to identify the individual or common problem areas. This is the fastest feedback mechanism to improve the class performance.

Quizzes and Tests

Graded tests are certainly the most traditional assessment tool. In technical courses, many instructors see exams as a set of problems on the covered contents. However, they can be used as a powerful method to improve student learning if a diversity of questions are specifically designed to reflect the prescribed learning outcomes. The following test formats have been applied by the authors depending on the characteristics and expectations of different courses:
i. **Combination of multiple-choice, true-false, and free-response questions:** Typically 30 – 50 questions are given as hard-copy to test understanding of the covered topics.

ii. **Combination of open-ended questions and computer applications:** One part of the test is given to answer questions, write programs, or debug small program sections on paper. After the papers are collected, each student works individually on a computer to enter and run a program in a limited time.

iii. **Tests containing essay questions to discuss the learning experience and provide suggestions:** Students are asked to discuss the brainstorming results, team-work experience, participation of other team-members, challenges they faced in their design work or their suggestions to the instructor. This type of questions is graded based on the quality and consistency of the answers.

iv. **Open-ended case-study or analysis questions:** An open-ended technical problem, practical situation, or ethical dilemma is given to analyze.

v. **Open-ended synthesis or design questions:** A simple design problem is given. Students are asked to develop a design solution to meet given requirements within the practical constraints.

vi. **Online tests:** Web support is a powerful way to establish efficient communication and feedback even in small classes. FSU has a site license for Blackboard® software. Online tests have been especially used to guide students in their preparation for labs and to test their preparedness for experiments. Students are allowed to take the test any time before the lab experiment starts. 10 – 20 questions are randomly drawn from a pool of questions. The duration to answer the questions is limited. At the end of a session, the student sees only the total score, but not the answers or score for each question. The test can be taken several times, and the highest score is recorded as part of the experiment grade. This type of online test challenges the students motivates like a computer game and motivates them to review the text several times.

The implementation of the test styles described above in different courses is shown in Table 2. Quiz and test results are interpreted to analyze the student performance corresponding to the course outcomes. The results are shared in detail with the students in the class meeting following the quiz or test.

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Summary

Assessment techniques implemented in the introductory level electrical engineering courses at Frostburg State University are described. Electrical engineering is offered in collaboration with the University of Maryland and has been accredited as a new and separate program.

The assessment methods are developed considering the unique features of the program and ABET 2000 criteria for program educational outcomes. Because the class sizes are small, statistical data do not always provide adequate feedback. Diverse assessment methods are implemented to obtain feedback on student performance and educational outcomes. Interactive assessment involves more student input for program improvement. The assessment process is distributed over the semester to make quick adjustments in course delivery style.

Bibliography

2. FSU Engineering Programs Home Page, [http://www.frostburg.edu/dept/engn/engrmain.htm](http://www.frostburg.edu/dept/engn/engrmain.htm)

Oguz A. Soysal received the B.Sc., M.Sc., and Ph.D. degrees from Istanbul Technical University, Turkey. In 1983 he joined ABB-ESAS Power Transformer Company (Istanbul, Turkey) as an R&D engineer. From 1986 to 1993 he worked for Black-Sea Technical University, Turkey, as Assistant and Associate Professor. In 1987 he visited The Ohio State University (OSU) as a Post Doctoral Scholar, and in 1991-1992 he spent a sabbatical leave at the University of Toronto. From 1993 to 1997 he was with Istanbul University, Turkey, and Bucknell University, Lewisburg, PA, USA. He joined Frostburg State University in fall 1998. At present Dr. Soysal is Chair of the Physics and Engineering Department and he is teaching electrical engineering courses.

Hilkat S. Soysal received a law degree from University of Istanbul, Turkey. She practiced law in private companies and two state universities as a counselor. In 1993, she joined Istanbul University College of Engineering as a Lecturer. While teaching law courses for undergraduate engineering students, she did a graduate study in the Marine Engineering Program and received her M.Sc. degree in 1996. She continued to take graduate courses in marine engineering until she moved to the USA. Between 1997 and 2000, she took various courses in MBA and Computer Science, and engineering at various institutions. Since fall 2000, she has been working as adjunct faculty for the Department of Physics and Engineering at the Frostburg State University and teaching programming concepts and numerical techniques courses.