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An Implementable/Sustainable Outcomes Assessment Process for an Electrical Engineering Program

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Abstract

The ECE department at WPI has adopted four principal means of assessing program outcomes: course-based assessments, assessments of each senior project by the project advisor, a comprehensive biennial review of senior projects, and an annual senior survey. The course-based assessment component is both one of the more important assessment aspects, and one of the more difficult to design and implement. This paper reports the format and implementation of the course-based assessment as well as the results of the first year of implementation for this component. It also outlines the role which course-based assessment plays with respect to other outcomes measures, such as student, alumni, and constituent surveys.

Introduction and Overall Assessment Framework

The Electrical and Computer Engineering Department at WPI has been involved with the ABET EC2000[1] process since its inception, having been visited in the fall of 1996 as one of two pilot schools in the change from prescriptive to outcomes-oriented criteria. For the ECE faculty the most difficult aspect of the EC2000 implementation has been development of an effective means of measuring and assessing student outcomes from the electrical engineering coursework, and relating these outcomes to the overall EE program objectives and outcomes. These difficulties have several origins, and result in challenges in both the design and implementation of an assessment program which is simultaneously meaningful, implementable, and sustainable with moderate resources. The following guiding principles appear helpful:

- Select a subset of courses and learning outcomes on which to focus (rather than attempting to measure and assess everything)
- Carefully relate the learning outcomes from courses and projects to the overall educational outcomes
- Obtain a complete set of measures for the outcomes, without excessive (and expensive) duplication, and
- Save an appropriate record of the assessment for future consideration and action.

This paper reports the results of the first year of implementation for this approach. It also outlines the role which course-based assessment plays with respect to other outcomes measures, such as student, alumni, and constituent surveys.

Course-Based Assessment

The ECE faculty, with input from major constituencies, has established outcomes, and objectives for the Electrical Engineering program, and are now developing a comprehensive list of

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performance criteria.[2] Following are the published educational objectives and program outcomes:

> The electrical and computer engineering department educates future leaders of the electrical engineering profession, with a program characterized by curricular flexibility, student project work, and active involvement of students in their learning. Through a balanced, integrated electrical engineering curriculum we provide an education which is strong both in the fundamentals and in state-of-the-art knowledge, appropriate for immediate professional practice as well as graduate study and lifelong learning. Such an education also prepares students broadly for their professional and personal lives, providing the basis for effective leadership and informed citizenship. The curriculum embraces WPI's philosophy of education, and takes advantage of key components such as the Interactive Qualifying Project to develop technical professionals who possess the ability to communicate, work in teams, and understand the broad implications of their work.
>
> Based on the above objectives, students will achieve the following specific educational outcomes:
>
> 1. Preparation for engineering practice, including the technical, professional, and ethical components
> 2. Preparation for the future changes in electrical engineering
> 3. A solid understanding of the basic principles of electrical engineering
> 4. An understanding of appropriate mathematical concepts, and an ability to apply them to EE
> 5. An understanding of the engineering design process, and ability to perform engineering design, including the needed teamwork and communications skills.
> 6. Demonstration of in-depth understanding of at least one specialty within EE
> 7. Demonstration of oral and written communications skills
> 8. Understanding of options for careers and further education, and the necessary educational preparation to pursue those options
> 9. An ability to learn independently
> 10. The broad education envisioned by the WPI Plan, and described by the Goal and Mission of WPI
> 11. An understanding of electrical engineering in a societal and global context.

The assessment strategy for the outcomes is centered around four efforts:

- Course-based assessments,
- Assessments of each Senior Project by the project advisor,
- A comprehensive biennial review of Senior Projects,
- A senior survey.

These activities are complemented by campus-wide activities to assess other aspects of the WPI program, notably the Interactive Qualifying Project (IQP), and to gather data on the accomplishment of longer-term objectives, principally through alumni surveys.

Course-based assessment is the focus of this paper. Following are the major components of the course-based assessment process:

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- Select courses to include in the process, aiming for a minimal number of courses which result in the assessment of all outcomes for all students.
- Determine performance criteria for each course, and verify that the complete set of criteria address all of the outcomes to be assessed.
- For each course offering, the instructor develops assessment tools (such as exam problems) which as a whole address all of the performance criteria
- During the course, results for each performance criteria for each student are maintained
- The assessment tools and results are reviewed by another faculty member.

The departmental assessment committee (Profs. Nicoletti, Orr and Vaz) selected seven courses for course-based assessment:

EE2011 "Introduction to Electrical and Computer Engineering"
EE2022 "Introduction to Digital Circuits and Computer Engineering"
EE2111 "Physical Principles of ECE Applications"
EE2201 "Microelectronic Circuits I"
EE2311 "Continuous-Time Signal and System Analysis"
EE2799 "Electrical and Computer Engineering Design"
EE2801 "Foundations of Embedded Computer Systems"

These courses were selected because they are taken by an overwhelming majority of our students and because they contain the material that will help us assess the students' and the department's achievement in different areas. Course-based statistics will be collected on an individual student

Performance criteria were developed and agreed upon for each of these courses, forty-two in all. As an example, the criteria for EE2111 are listed below:

1. Solve for the frequency response of a first-order circuit
2. Solve for the frequency response of a second-order circuit
3. Explain the physics underlying the behavior of capacitors
4. Explain the physics underlying the behavior of inductors
5. Apply superposition to the solution of circuits
6. Find the transient response of a first-order circuit
7. Identify resonant behavior
8. Understand basic principles of transmission lines
9. To be able to manipulate complex numbers and phasors in the context of steady state AC circuits

All of these criteria are intended to measure students' progress towards the outcome "A solid understanding of the basic principles in EE". Criteria for other courses meet other outcomes, including an understanding of the design process, the ability to work on a team, etc.

The coverage of material for any of the courses will surely be more comprehensive than its set of performance criteria. However, the set is meant to provide some basic information about what the students have mastered (and to what degree), and will remain constant from one offering to the next. Then, the comprehensive set, along with the MQP evaluations and other assessment data is expected to paint an accurate picture of what our program is accomplishing.

Course instructors have the task of matching exam questions (or other evaluated student performance) to these objectives. As student work is graded, course-based assessment is kept in mind and scores are separately tabulated accordingly.

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The following is submitted by the course instructor in spreadsheet form: a list of student names, followed by columns containing the raw scores for the different assessments used, one column for each performance criteria. Other information is gathered to aid in any follow-up analysis, including the course grade for each student and the number of support staff (teaching assistants and senior tutors).

The raw data is then translated into a level of achievement rubric, defined below.

NA	Does not apply; cannot be measured
0	Did not complete the work required for this criteria, or completed it at a level less than '1'
1	Demonstrates severe misconceptions about the important concepts; makes many critical errors
2	Displays an incomplete understanding of the important concepts and has some notable misconceptions; makes a number of errors when performing important strategies or skills but can complete a rough approximation of them
3	Applies appropriate strategy or concepts without significant errors
4	Demonstrates a complete and accurate understanding of the important concepts

The instructors provide cutoffs necessary to translate the raw scores into these levels. In addition, they also save copies of the assignment and student work for the reviewer (another faculty member in the same area and familiar with the course). The reviewer examines this material to help ensure that the assignment is appropriate for the course objective and that the student performance translates correctly to the different levels of achievement.

Pilot Testing

This course-based assessment scheme was pilot-tested in three courses late in the 99-00 academic year. The results of this testing led us to the following conclusions:

- The system was feasible *if* we made our expectations clearer to the course instructors. Two of the three course instructors compiled an extensive report, exceeding the material required and probably taking more time than desired.
- The instructors all felt that the system was actually fairly easy to administer -- after they did it the first time.
- When selecting the student work that will be used, it is important that it be as specific to the course outcome as possible. For example, a lab might show students' understanding of op-amps as well as their ability to write lab reports. If the lab report grade is used, then it might be misleading if the lab reports were graded severely on style while the student in fact did show a good understanding of op-amps. This problem can be alleviated by breaking up the lab report score into two parts (technical content and writing).

Results from Initial Implementation

While the program is early in its implementation stage, some results can be presented here for one offering of one course: EE2111 in the fall of '00-01. The table below shows the results for some of the performance criteria. The data includes only students who passed the course. The

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complete set of data is saved, but it is natural to interpret these results for students who actually earned academic credit.

	Achievement Level					
Performance Criteria for EE2111	na	0	1	2	3	4
Solve for the frequency response of a first-order circuit	1%	20%	3%	13%	8%	56%
Solve for the frequency response of a second-order circuit	0%	4%	4%	9%	19%	65%
Find the transient response of a first-order circuit	0%	22%	14%	13%	22%	30%

The assessments used (exam questions) were reviewed by someone other than the course instructor and found to be appropriate. Individual student performance has been recorded and can be evaluated, but the cumulative results can lead one to some conclusions. The fact that students performed better on second-order circuits than on first-order circuits probably implies that whatever difficulties they had with the relatively easier material were overcome when performing similar analysis on more complicated systems. The lowest score for the set was for transient response. This was interpreted to be a reflection on problems encountered by the students who were concurrently taking the math course on differential equations, rather than having completed it in advance. The resulting mix of backgrounds (students who had completed differential equations and those who had not) is probably the root cause of the performance in this area. This kind of hypothesis can be re-examined when more data have been collected after future offerings of this course.

This leads to an important point that should be made about course-based assessment. A program could use the students' final course grades to attempt to assess its effectiveness towards meetings its goals, but this is not, in our opinion, feasible. A course grade is the cumulative result of study in an often wide range of topics. This can be seen from the EE2111 data -- the students' success with second-order circuit analysis would be merged with their problems with transient responses. In order for data to be effective in improving a system as complex as undergraduate engineering education, the data must be specific.

However, this increase in specificity comes with a cost -- faculty time. Course instructors must select assessment of students' learning that target the performance criteria, save individual student records, and examples of student work. We have streamlined this process as much as possible by providing spreadsheets for the course instructors to use, reminding faculty at the beginning and end of terms, and keeping the number of performance criteria per course down to an absolute minimum. It is expected that as the data is accumulated and provided to faculty members for more meaningful discussions on how to improve our program, the time will be seen as well-spent.

Feedback Channels

The assessment effort is part of our department's Undergraduate Program and Projects Committees. Examples of how these feedback channels have successfully operated in recent

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history include the re-evaluation of course preparation based on the senior survey, and the reporting and discussions of MQP review results during ECE faculty meetings.

For course-based assessment, the feedback system begins with the reviewer who is asked to check the appropriateness of the material gathered for a given course and term. Next, a committee of faculty will be formed to review the course-based assessment results on a course-by-course basis, every other year. They will review the numerical findings that have accumulated (as much as six offerings of the course) and make recommendations to the Undergraduate Program or Projects Committees, as appropriate.

The course assessment data is being made available to the entire ECE faculty via a secure webpage. Results will be shown on an accumulating and individual offering basis. When preparing to teach a new offering, faculty can see what the problem spots were from previous offerings and plan a strategy to meet that challenge. Faculty who teach upper-level courses can also access information to see what areas they may wish to emphasize during review sessions.

Relation to other Assessment Tools

Each assessment component has particular strengths and weaknesses, and each addresses a subset of the overall program outcomes and objectives. Following is a summary of the major characteristics and contributions of each component:

Course-Based Assessment

This tool covers the broadest spectrum of educational topics and performance measures and it addresses the largest single aspect of students' educational activities: courses. Also, the measures used are primarily objective and quantitative (such as performance on exam questions). This provides a baseline for more subjective and non-normed measures such as self-reporting in senior and alumni surveys. Other contrasts to senior and alumni surveys include the measurement of one of the most important products of an academic department, credit granted for coursework. Also, since it is collected on an individual course basis, faculty can use the information to improve their teaching.

Biennial Senior Project Reviews

This alternate-year comprehensive review of the previous year's senior projects has long formed the cornerstone of our program assessment. WPI's senior projects are major, team-based activities that provide opportunities to demonstrate many educational outcomes, including both technical and other (teamwork, independent learning, communications skills, etc.) aspects. This review, conducted by a committee of two or three faculty serves as overall project quality control, and produces a report characterizing and quantifying (where possible) student performance against each of the outcomes as well as against the desired characteristics of engineering design. These reviews have been conducted since 1991, and the historical record of consistently-collected data has been quite useful in improving the project program.

Senior Surveys

Our most important constituency is our students, and input from the senior class has been systematically collected via senior surveys since 1997. Also, aperiodic surveys and interviews are conducted with other students in other class years or students identified by other measures, such as subdiscipline. The senior surveys provide self-reported data on students' level of satisfaction with various aspects of the educational program, and their level of confidence in

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their abilities on each of the outcomes. This self-reported data may then be compared to the objective data collected via the course-based and senior project assessments.

Alumni Surveys

ECE alumni have been surveyed aperiodically in the past, and this input has proved quite useful in major curriculum redesigns. As part of EC2000, WPI has taken on the task of systematically surveying alumni, with major input on questionnaire design from the major departments. These surveys will help us address the degree to which we are accomplishing our longer-term educational objectives

Future Developments

There are plans to improve the effectiveness of this program. These include the facility for the individual student performance to be made securely available to the student, so that progress towards graduation can be monitored in a way more specific than the completion of graduation requirements. The student performance is also going to be made available to departmental faculty, who can use it to study effects of changes in upper level course preparation because the improvement in knowledge would be far easier to gauge. It can also be used by faculty members when selecting student members for teams for the senior design experience.

References

[1] "Criteria for Accrediting Engineering Programs, Effective for Evaluations During the 2000-2001 Accreditation Cycle," Engineering Accreditation Commission, Baltimore, MD.

[2] "Stepping Ahead: An Assessment Plan Development Guide," Gloria Rogers, Jean Sando, produced at the Rose-Hulman Institute of Technology, copyright 1996.

Author Biographies

Denise Nicoletti is Associate Professor of Electrical and Computer Engineering at Worcester Polytechnic Institute. She received her Ph.D. degree from Drexel University in 1991. She was the WPI Joseph Satin Distinguished Fellow in 1993, and was the recipient of the WPI Eta Kappa Nu Outstanding Professor of the Year Award in 1992. Her areas of research are signal processing and nondestructive evaluation, and teaching assignments include signals and systems, introductory electrical and computer engineering, and graduate probability theory. Memberships: IEEE, Acoustical Society of America, American Society of Nondestructive Testing, Society of Women Engineers, Tau Beta Pi Honor Society, Eta Kappa Nu Honor Society, and Sigma Xi.

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