# Using Student Learning Outcomes Assessment to Assure EC2000 Program Effectiveness

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## Abstract

*The Electrical and Computer Engineering (ECE) Department of Gannon University has devised a process in which faculty define specific graded (key) assignments that are linked to the (course-level) student learning objectives. Each student must meet or exceed the minimum passing criteria defined in these key assignments to be eligible to pass the course. In this way, each student passing a course is measurably justified in having met the course objectives. By the virtue of the process, all students who graduate from the program must have also met or exceeded the minimum standard on every course objective, and consequently ensures that these graduates have all (individually) met or exceeded the overall program educational objectives.*

## Introduction

As part of its continuous-improvement process[1,2], the ECE department presented its program assessment process and results to the members of its industry committee, many of whom are intimately involved with ISO 9000 assurance processes and other quality process auditing procedures. In reviewing the information provided, the committee challenged our program to enhance the process *to ensure that each student going through the program will meet all the criteria.* The department responded by devising a process for mapping course objectives to the program outcomes that leads to defining the minimum grading policy for each course [5]. By linking the program outcomes to student learning outcomes, we can ensure that students meet or exceed the course objectives upon passing that class. As a by-product of the process, we also developed a more effective process for identifying objective evidence in support of meeting course objectives.

By the virtue of the process, all students who graduate from the program must also have met the course objectives, and consequently must have met the overall program educational objectives. The key point is that the assurance of meeting program educational objectives for every graduate (e.g., via Student-Learning Objectives Assessment) is different from justifying that the program meets ABET EC2000 criteria (Program Outcomes). Thus, in this paper, we:

1. Layout a process for justifying that a graduate from the program will indeed meet the program educational objectives.
2. Compare and contrast student learning outcomes assessment (SLOA) and program outcomes assessment (POA) as instruments for measuring the effectiveness of engineering programs.
3. Present an SLOA-based evaluation process that uses selected graded assignments to measure EC2000 criteria at the course level.
4. Discuss and outline the advantages, disadvantages and issues surrounding using graded assignments to implement SLOA-based evaluation process.

To better illustrate the concept involved in the establishing the minimum passing criteria to ensure SLOA and the differences in POA processes, we will first give brief discussion to the POA processes that are currently in place. Next, the correlation of course objectives to the program outcomes is given to further illustrate assessing course objectives *is a necessary condition, but may not be sufficient*. To further achieve a necessary and sufficient condition in claiming meeting course objectives is in turn meeting program outcomes in a SLOA process, we then give and discuss the process in using the minimum passing criteria.

**Program outcome assessment (POA) process**

The assessment of curricula takes multiple forms, and a wide variety of learning assessment tools have been successfully put into practice [2]. Most tools used to assess program educational objectives and outcomes are also important in establishing the curriculum success in meeting program educational objectives. Our program employs many of the standard program evaluation tools, including interviews with graduating seniors, course surveys, surveys with employers of our co-op students, and feedback from the industrial members committee. These serve as the input to the assessment processes which is fed back to the faculty for discussion and action item generation. Action items drive subsequent changes in the program, the curriculum, and the assessment process itself [5].

The ECE department program assessment process begins with the university mission. The university mission in turn impacts the department's educational objectives. The program outcomes are derived and judged based on the ABET criteria [1] and the IEEE department specific criteria as well as our department-specific competencies. These program outcomes are realized within the curriculum, and thus the mapping from the program outcomes and ultimately to the program curriculum becomes important. An effective assessment of the program outcomes includes an analysis of the correlation of the program outcomes to the minimum course set that comprise the program curriculum.

At Gannon University, we correlate the individual course objectives of all required electrical engineering courses to the program outcomes. With this correlation of each course's objectives to the program outcomes in place, we have a plan for how the program objectives will be met within the curriculum. Thus, one aspect of program outcome assessment focuses on assessing each course's objectives. By having a clear design for how all courses support the program outcomes, the collective course assessment in turn demonstrates how the program objectives are met based on the validity of the design.

Within this continuous-improvement process, each course objective and assessment method is carefully examined for a better coordination among courses and setup in order to reach a complete coverage of the program outcomes that lead to achieving the program educational objectives.

**Relationship between program outcomes and program educational objectives**

To better illustrate the POA process used at Gannon, Table 1 defines the correlation that exists between the program objectives and the program outcomes. To provide a useful background for the examples presented (Table 1 and following), the program education objectives are given here. However, any program objective statements could be used in the POA process described. Hence, the specific program objective statements are not critical to the discussion of the process.

**Program Objectives:**

Pgm Obj 1. Sound preparation for adaptation in exciting, rapidly-changing areas of technology and the passion for lifelong learning

Pgm Obj 2. Ability to respond to ethical and public issues, including safety, social, environmental concerns, and understanding of how engineering solutions affect the wider society

Pgm Obj 3. Ability to apply personal values to daily and professional life, the development of skills necessary for exercising informed literary and aesthetic judgments, and a development of an appreciation of diverse cultures and societies

Pgm Obj 4. Foundation in problem formulation and problem-solving skills to include the following:

- <u>Sound preparation in general science and applied mathematics</u>
- <u>Strong electrical engineering and applications</u>
- <u>Strong computer and software systems development</u>
- <u>Effective use of computer-aided design & analysis tools</u>
- <u>Quality engineering design experience</u>

Pgm Obj 5. Ability to communicate effectively in both oral and written forms, and skills for effective work within multi-disciplinary teams which foster leadership qualities

Our department has adopted the ABET (a) – (k) as part of the program outcomes. Through a series of faculty discussions, we added three department-specific competencies that derive from the IEEE-defined (EE) program criteria, and correlated these outcomes with the program objectives.

Based on the correlations defined and reviewed in the outcomes process, Table 1 indicates the completeness of how the program outcomes meet the program educational objectives. As the program is built upon a specific set of courses, the key assessment question is *how to measure the effectiveness of the courses that constitute the program* in helping students achieve the program objectives and the program outcomes. Thus what remains in the processes is the need to assess each of the defined program outcomes within the courses or other educational delivery units that constitute the program.

Table 1: Correlation between program educational objectives and the program outcomes

| | Pgm Obj 1 | Pgm Obj 2 | Pgm Obj 3 | Pgm Obj 4 | Pgm Obj 5 |
|---|---|---|---|---|---|
| **ABET Criteria:** | | | | | |
| A) Apply knowledge of Mathematics, Science, and Engineering | X | | | X | |
| B) Ability to design and conduct experiments; Analyze and interpret data | | | | X | |
| C) Design system, component, or process to meet needs | X | | | X | |
| D) Function on multi-disciplinary teams | | | X | | X |
| E) Identify, formulate, and solve engineering problems | X | | | X | |
| F) Understanding of professional and ethical responsibility | | X | X | | |
| G) Ability to communicate effectively | | | X | | X |
| H) Broad education necessary to understand impact of engineering solutions | X | X | X | | X |
| I) Recognition of need to engage in lifetime learning | X | | X | | |
| J) Knowledge of contemporary issues | X | | X | | X |
| K) Ability to use techniques, skills and modern tools | X | | | X | |
| **ECE Department specific Competencies:** | | | | | |
| 1) Knowledge and ability to apply mathematics including probability, statistics, and discrete mathematics | X | | | X | |
| 2) Develop systems containing hardware & software components | X | | | X | |
| 3) A&D of Complex electrical & Electronic Devices | X | | | X | |

## Processes used to assess each of the program outcomes

The electrical engineering curriculum and the steps taken to effectively implement the curriculum are the main vehicles that ensure the program outcomes (ABET criteria and department-specific competencies) are met. Because of the importance of the curriculum in meeting the criteria, the faculty regularly update a curriculum matrix to describe how each of the course objectives for all required courses relates to the program outcomes.

The ECE department maintains a curriculum matrix that gives the overall view of correlation between ECE courses and the corresponding program outcomes. The curriculum matrix is in fact a collective overview of a more detailed curriculum matrix that relates each course's student learning objectives to the program outcomes. The overall curriculum matrix is maintained on-line, and is updated each semester when faculty enter their course objectives on-line [3, 4]. This process is part of a course-exit survey system [3], and includes faculty entering portions of their syllabus online. Figure 1 illustrates the objectives correlation of course objectives to the program outcomes for one course.

| | ABET Criteria | | | | | | | | | | | Department Specific Competencies | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Department courses with objectives | A | B | C | D | E | F | G | H | I | J | K | 1 | 2 | 3 |
| **ECE465 Power Electronics** | | | | | | | | | | | | | | |
| Objective 1 | X | | | | X | | | | | | | | | X |
| Objective 2 | | X | | | | | | | | | | | | |
| Objective 3 | | | | | | | | | | | X | | | |
| **Next ECE course** | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

Figure 1: Partial curriculum matrix mapping course objectives to program outcomes

As part of the department's assessment processes, the overall curriculum matrix is reviewed at the end of the semester along with the prior semester's survey data at a special faculty meeting. The matrix provides information on overall program evaluation and completeness. It also serves as a basis for illustrating how the courses that constitute the program collectively meet the program outcomes defined in Table 1.

Thus far, the process outlined above is effective for program outcome assessment. Based on feedback from different constituents integrated into the assessment process, the program can achieve its intended educational objectives of a quality program with a process that supports continuous quality improvement. However, it falls short in the following areas:

1. A course meeting the defined course objectives does not necessary translate into *each and every student* in that class meeting all the course objectives.
2. A student passing a course even with a grade of A does not necessary means that student meets all the course objectives.

As a result, a student going through the program, even with an 'A' in every course will not *necessarily* meet all the *program* outcomes. Our industrial members committee met on July 18 and July 29, 2003 respectively and commented that our program looked effective and would achieve the program outcomes assessment. However, they echoed these same observations and challenged us to enhance the process to ensure that *each* student going through the program will meet *all* of the program criteria.

What we had done in implementing POA focused on the program view – i.e., what will be the expected outcomes are for the average student in the program, with the result that a student could graduate without having demonstrated competence in one or more key areas.

**Student learning outcomes assessment process (SLOA)**

Student learning outcomes define the learning objectives for a particular course, and are assessed for the purpose of measuring the student's ability to meet the course objectives. This assessment is focused on the student learning within the specific course or other educational delivery unit.

For example, a delivery unit could be an assignment, a seminar or class session, a set of sessions, or an entire course. Student learning outcomes and/or assessment can be entirely independent from program assessment.

**Linking SLOA and POA processes**

However, to overcome the shortfalls inherent to standard POA processes, we decided to align the SLOA process to the POA process by using some forms of course-specific judging criteria to determine our success in meeting the course objectives, and thus confirm that each student who graduates meets the program educational objectives. From this concern, we were challenged by the industrial members committee to device a process to focus the program assessment more clearly on student learning outcomes assessment.

From these observations, the department devised a process for mapping course objectives to the program outcomes that leads to defining the minimum grading policy. The point was to ensure that upon passing a class, all students can be assured of (at least minimally) meeting the course objectives. The result of this process is that once faculty establish the minimum criteria necessary to ensure that all students passing a course indeed meet the stated course objectives. The program can safely assure the validity and effectiveness of the correlation between the program outcomes and the program educational objectives. As a by-product of the minimum passing criteria process, faculty are immediately provided with straightforward method for determining useful objective evidence in support of meeting course objectives.

The detailed process to identify minimum passing criteria and the objective evidence has been reported in [5]. To illustrate the idea for further discussion of SLOA process, Figure 2 gives a summary of a syllabus from a senior-level ECE465 Power Electronics course that summaries how the criteria mapping procedure was integrated for this course. The hi-lighted components in the syllabus are the results of identifying minimum passing criteria.

------------------------------------ECE 465 Power Electronics Syllabus -----------------------------------

**ECE465 Power Electronics**
**Fall Semester 2003**

**Course Description:**
This course introduces the basic concepts of various topologies (ac-dc, dc-dc, dc-ac, ac-ac, etc) of power converters. The fundamental principles of switching components are discussed first prior to introduction of the design and application of the converters. Emphasis is on the design issues associated with the converters and the computer techniques (OrCAD) used for the performance evaluation and analysis. Experiments are part of the course.

**Prerequisites*:*** ECE333 or ECE324
**Course Objectives**:

1. Understand the fundamental principles on various power converter topologies, design of power converter, and the related performance analysis.
2. Develop skills in using contemporary software tools for modeling and its analysis.
3. Develop skills in the construction and parameter measurement of converters.

**Criteria Fulfillment Satisfied:**

- Foundation in applied math ---obj 1
- Conduct Experiment ---obj3
- Analyze & interpret experimental data ---obj3
- Formulate engineering problem ---objective 1
- Solve engineering problem ---obj1
- Ability to use technique, skills, and modern tools ---obj2
- A&D of complex electrical & electronics systems ---obj1

Correlated course objectives with program outcomes

**Course Outline**:

| Group | Topics | Units |
|---|---|---|
| A) Basic concepts in switching converters | Goals and Methods of Electrical Conversion | Chap 1 |
| | Review of Fourier Series | Appendix E |
| | Power Semiconductors | Chap 2 |
| | Homework or projects | Class notes |
| B) AC-DC Converter | Diode Circuits | Chap 3 |
| | Rectifier | Appendix D |
| | Thyristor | Chap 7 |
| | Controlled Rectifier | Chap 10 |
| | Lab work, projects | Class notes |
| | Mid Term | |
| C) DC-DC Converter | Power Transistor | Chap 4 |
| | DC-DC Converter | Chap 5 |
| | Lab work, projects | Class notes |
| D) DC-AC Converter | Various PWM controls, voltage control, dc link, inverter, etc. | Chap 6<br>Class of notes |
| | Homework or projects | |
| E) AC-AC Converter | Combined converters for specific application, etc. | Chap 11<br>Class notes |
| | Final Exam or Project | |

**Course Assessment Methods:**

| Assessment Methods | Objective 1 | Objective 2 | Objective 3 |
|---|---|---|---|
| Graded Homework | X | X | |
| Examinations | X | X | |
| Projects | X | X | |
| Lab Work | | | X |

**Course Assessment Method Details**:

**Homework:**

Homework problems shall be designed to test knowledge and comprehension in power electronics design issues and analysis.

*Expected Homework Projects*:

Proj 1: 1-phase diode bridge rectifier
Proj2: Basic concepts in thyristor converters
Proj3: 3-phase half-controlled bridge rectifiers
Proj4: Rectifier applications
Proj5: DC-DC Buck converter
Proj6: DC-DC converter applications

Identified assignments

**Examinations:**
The exam shall contain problems designed to test knowledge and comprehension in power electronics design issues and analysis.
*Expected Examinations*:
Mid Term Examination and possibly a Final Examination

**Project:**
The project shall be designed to give more than one way to meet the problem requirements and to utilize software tools in aid of design. A documented outcomes and/or demonstration of the design technique is required.
*Expected Project*:
Final Proj: Control of Electric Drive

Identified assignments

**Lab Experience and Report:**
The labs shall be designed to give basic understanding of parameter measurement of converter under study. In addition, the lab shall utilize software tools in aid of analysis. Lab report shall follow a prescribed format, and be graded on completeness, correctness, presentation and analysis of data.
*Expected Lab Experiments*:
Exp1: Controlled rectifier
Exp2: dc-dc converter applications

**Text Books:**

1) Fong Mak, Class notes for ECE465/GECE565;
2) Muhammad H. Rashid, *Power Electronics Circuit, Devices, and Applications*, 3rd Edition, Prentice Hall, 2004.
3) Marc E. Herniter, *Schematic Capture with Cadence PSpice*, Prentice Hall, 2001.

**Reference Texts:**

1) Mohan, Underland, Robbins, *Power Electronics Converters, Applications, and Design*, 2nd Edition, Wiley, 1995.

Course Policies:
….

**Grading Policy:**

Identified passing criteria

Passing Objective Criteria:

To receive a passing grade in this course, all students must meet the following minimum criteria demonstrating how well they have mastered the course learning objectives. Each objective is assigned one or more Key Assignments, which will be graded specifically on the course objective(s) and related program objective(s) listed below. Students will not be eligible to receive a passing grade for the course unless all Key Assignments are successfully completed, demonstrating minimal mastery of the course objectives.

- **Understand the fundamental principles on various power converter topologies, design of power converter, and the related performance analysis**
  *Demonstrate a foundation in applied math, ability to formulate eng problem, solve eng problems:*
  *Key Assignment*: Proj5 passed with a grade of C or better.
  *Description*: Proj 5 requires student to design a converter against criteria given and simulate to verify the design. Hence it is used as a gauge to "applied math", "formulate eng problem" and "solve eng problem"
  *A&D of complex electrical & electronics systems:*
  *Key Assignment*: Part A of Final Project passed with a grade of C or better for this section.
  *Description*: Part A requires A&D of an inverter design. Part B includes the design of filter and integration of a front-end converter. Successful completion of part A indicates the acquired skill.

- **Develop skills in using contemporary software tools for modeling and its analysis**
  *Demonstrate ability to use technique, skills, and modern tools:*
  Key Assignment: Part A of Final Project passed with a grade of C or better.
  Description: Part A of final requires student to apply software skills learned in the course independently in analysis and design of the problem. Correct completion of part A indicates the needed skills have been acquired.

- **Develop skills in the construction and parameter measurement of converters**.
  *Demonstrate a professional ability to conduct experiments, analyze & interpret experimental data:*
  Key Assignments: Exp 1 short report and Exp2 short-report (combined average of a grade of C or better)
  Description: Short reports are accepted only after the corresponding experiment has been conducted. Data are required to be analyzed accordingly.

With successful completion of the minimum passing criteria on all key assignments, the following is the overall grading for the class.

| | |
|---|---|
| Homework and projects | 50% |
| Mid-term Exam or project | 20% |
| Final Exam or project | 30% |

Identified relationships

**Relationship to Program Outcomes and Objective Evidence**:

| Program Outcomes Met | Course Objective | Objective Evidence |
|---|---|---|
| Foundation in applied math | 1 | Proj 5 |
| A&D of complex electrical & electronics systems | 1 | Final Proj |
| Formulate engineering problem | 1 | Proj 5 |
| Solve engineering problem | 1 | Proj 5 |
| Ability to use technique, skills, and modern tools | 2 | Final Proj |
| Conduct Experiment | 3 | Exp 1 and 2 |
| Analyze & interpret experimental data | 3 | Exp1 and 2 |

------------------------------------------end of ECE465 Syllabus ------------------------------------------

Figure 2: ECE 465 course syllabus

Figure 2 illustrates the syllabus format that the department adopted. The following key phrase is critical to note:

> "*To receive a passing grade in this course, all students must meet the following minimum criteria demonstrating how well they have mastered the course learning objectives. Each objective is assigned one or more Key Assignments, which will be graded specifically on the course objective(s) and related program objective(s) listed below. Students will not be eligible to receive a passing grade for the course unless all Key Assignments are successfully completed, demonstrating minimal mastery of the course objectives*"

This has been adopted as a standard phrase for the grading policy on each ECE course syllabus. This policy is announced at the beginning of the semester when the faculty reviews the syllabus with the students.

Figure 2 also illustrates another aspect of the key assignment concept: a resubmission policy. The course policy adopted by the department for all courses states: "*Students may elect to* *resubmit key assignments that have already been graded…"* The issue here is to ensure that students have the opportunity to learn – especially from their mistakes. Each key assignment essentially becomes a pass/fail criterion for the course, so the students must meet the minimum grading criteria for the assignment or fail the course. These concerns were clearly seen initially with the pilot courses. To ameliorate these effects, the department agreed that students should have the ability to resubmit key assignments, so they have the opportunity to demonstrate their mastery of the key (required) material.

Another aspect of the key-assignment policy is that it gives the faculty the opportunity to explain to the students what the program learning outcomes are, and how this course that they are taking helps them meet these outcomes. This focus on course and program outcomes was one of the lessons learned from the SLOA process.

**Advantages, disadvantages and issues surrounding using graded assignments to implement SLOA-based evaluation process:**

*Student's perspective*: At first, there were quite a bit of anxiety and concern among students knowing that they cannot pass the course even though they have done well for the rest of the assignments or examinations if they do not pass the key assignments. Mostly the concern is due to the "what if" they cannot complete the key assignments for whatever reason, it will not be fair for them to go through the entire semester's learning for nothing. To alleviate this concern, the following actions are taken:

- The re-submission of key assignments policy is instituted (see syllabus).
- Reminder to key assignments is made when the assignments are given.
- We found that students tend to pay more attention to key assignments and submit better prepared assignments accordingly. In the process of doing so, students are better aware of the course objectives and how they are measured. Students gave more comments to the class in their course-exit surveys.

*Faculty's perspective*: In the past, it is customary to collect objective evidence from a sample of poor, averaged, and good students' assignments. However, there is always a lack of justification of how those assignments collected satisfying the claim on meeting course objectives. There is always a warm and fuzzy feeling that the justification is embedded in the assignments if you look closely enough. With this proposed process, the justification on objective evidence is documented and easily assessable by others who are not necessary the instructor. This process has certainly simplified the burden on the Chair in examining the objective evidence submitted.

As a general rule, it is advisable not to adopt an examination or a test as one of the key assignments. It is much easier to administer the re-submission policy for key assignments if tests or examinations were not involved. It would require different sets of tests or examinations be given for re-submission. These additional tasks are taxing on the faculty's time in creating different sets of examinations questions.

*Program's perspective*: With the SLOA process in place, we can assure that every student graduate from the program will meet all the course objectives, which in turn allows us to justify that all students graduate from the program will meet the program outcomes. In essence, the

POA process remains the same but with an added sense of assurance provided by the augmented SLOA process in the above regard.

## Conclusions:

To date, all core ECE courses have been implemented with minimum pass criteria and key assignments. The department believes by implementing the key assignment policy and associated process, the measurement of course objectives will be accountable and backed by the justifiable objective evidence. Students will have a keen awareness of where they are being asked to demonstrate their abilities with respect to the course outcomes, and be aware of their progress. By passing the course, students will satisfy the course objectives, which in turn will meet the corresponding program outcomes. Therefore, as long as the overall curriculum matrix covers all program outcomes upon students' graduation, each and every student will meet all the program outcomes accordingly.

## Bibliography:


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[4] Mak, F, Yoo, W.S., Frezza, S., "Enhancing ABET EC2000 preparation using a web-based survey/reporting tool," *ASEE/IEEE 33rd Frontiers in Education Conference*, Boulder, Co, November 2003.

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## Biographies:

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