

Summary of Data and Summary of Changes Made to the Electrical Engineering and Computer Engineering Programs

This document summarizes, reviews, and analyzes data collected over a period of several years from the assessment process in the ECE Department. Some of the data are presented on a yearly basis, and some in summary form.

This document also provides a description of changes made to the Electrical Engineering and Computer Engineering degree programs in the years 2007-2014, with many of these changes directly traceable to information collected via the assessment process.

Course Outcomes and Course Assessment Forms

Every course in the curriculum (both undergraduate and graduate courses) has associated with it a set of course outcomes. Course outcomes are to a course what student outcomes are to a program. Course outcomes are broad statements that describe what students are expected to know and be able to do by the end of the course. These relate to the knowledge, skills, and behaviors that students acquire in a course over the span of a single semester. The course outcomes are listed on the ABET syllabus for each course. These syllabi appear in Appendix B.

The course outcomes for a given course are established by the faculty and are approved by the assessment and curriculum committees (as necessary for core classes). Course outcomes help the faculty organize the curriculum and establish the prerequisite structure. Course outcomes communicate to instructors of upper-level courses what students are expected to know upon completion of lower-level courses.

Creation, review, and proposing modifications to course outcomes in required courses (ECE 2250, ECE 2290, ECE 2700, ECE 3410, ECE 3620, ECE 3640, ECE 3710, ECE 3870) is the work of ad hoc committees composed of the faculty members with expertise in the subject matter of the course. Because core required courses are prerequisites for other courses, the course outcomes in core courses require the consensus of the instructors for the course in question and for the courses that follow (parties with a vested interest in the materials covered). In upper-level elective courses, individual instructors can propose modifications to course objectives without the need to consult formally with other faculty. All proposed changes are reviewed by the assessment committee before approval is granted to ensure some uniformity across the program.

The course assessment form lists the name of the course, the semester, the instructor name and contains a table listing the course outcomes. There is a column in the table that lists the measurement device used to make the assessment. Examples include homework, exams, quizzes, lab assignments, reports, etc. The last column in the table is for the instructor's assessment. The instructor rates the class as a whole on the attainment of each outcome. A 0-1-

2 scale is used: “0” indicates that the outcome was not generally attained, “1” is used to indicate that the outcome was satisfactory, and “2” implies that the outcome was attained beyond a minimal level. A “1” would signal that the outcome was attained but that greater attention to that outcome may be desirable next time the course is taught. When instructors are preparing to teach a course, they are encouraged to review the course assessment form from prior semesters and to consider previous outcomes in their preparations.

The course assessment form also asks instructors to respond to the following three open-ended questions.

1. “How well were students prepared for the course?” – This question aims to collect information relating to the achievement of course outcomes in prerequisite courses.
2. “List significant issues from student evaluations?” – Student course evaluations are conducted for all courses using an on-line system (IDEA). These evaluations contain quantitative and qualitative information on student responses. Instructors are asked to review the student evaluations and record any emergent themes.
3. “Discussion?” – Instructors are asked to record observations about those parts of the course that worked well or need improvement. Instructors should address issues raised in student evaluations. Instructors can recommend changes needed in the course or in prerequisite courses. This has been helpful as a location to record notes to improve the course the next time it is taught, such as where greater emphasis is needed, where the development can be accelerated, etc.

Each course in the department is assessed by the instructor at the end of each semester in which the course is taught. Instructors complete their assessments by filling out the course assessment form. Course assessment forms are turned in to a departmental staff assistant for long-term archiving. The Assessment committee chair reviews all of the course assessments each semester. Issues are taken to the assessment committee for discussion and action. This process has generated a wealth of information for evaluation and continuous improvement. This process has identified problems in prerequisite courses, needed curricular changes, and resource needs. Issues that arise during this process are documented in the departmental annual assessment report.

The numeric data (0-1-2 scale) on the course assessment forms indicate the degree to which students attained the course objectives. Each course supports one or more of the (a)-(k) Student Outcomes as described in the Course-to-Outcome Map in Table 4-2. Therefore the course assessments provide an **indirect** measure of the attainment of the Student Outcomes. For each of the (a)-(k) Student Outcomes a weighted average is formed by combining the course assessment scores with the Course-to-Outcome Map. These statistics are provided in Table 4-2 for the last six semesters for which data are available.

Table 4-2. Summary of Faculty Course Assessments, Electrical Engineering

Semester	Year	a	b	c	d	e	f	g	h	i	j	k
Fall	2010	1.5	1.6	1.6	1.7	1.5	1.8	1.7	1.7	1.5	1.5	1.5
Spring	2011	1.7	1.6	1.7	1.8	1.7	1.8	1.7	1.8	1.7	1.8	1.7

Fall	2011	1.5	1.6	1.6	1.8	1.6	1.8	1.8	1.8	1.8	1.7	1.6
Spring	2012	1.8	1.8	1.9	1.9	1.8	2.0	1.9	1.9	1.9	1.9	1.8
Fall	2012	1.6	1.6	1.7	1.9	1.7	1.9	1.9	1.9	1.8	1.8	1.7
Spring	2013	1.8	1.9	1.9	1.9	1.8	1.9	1.9	1.9	1.9	1.9	1.9
Average		1.7	1.7	1.7	1.8	1.7	1.9	1.8	1.8	1.8	1.8	1.7

We make the following observations. There is considerable variability in the input to the system: classes have different students over the years; different professors are teaching; the curriculum has undergone some modification. This makes it suspicious to comment on any trend that may be perceived. What these data show is that according to faculty perception, each of the outcomes is achieved at levels well above the “satisfactory” level. For purposes of combining with the other measures below, an average of all of the years is also computed.

Special Assessments for Student Outcomes (a) – (k)

By means of the mapping from courses to student outcomes (see **Error! Reference source not found.** on page **Error! Bookmark not defined.**), course assessment forms provide an indication of the attainment of the student outcomes by the students in the program generally. In addition, direct measures of attainment of the student outcomes for each student in the program are provided by special assessments.

Special assessments are designed to assess all students in the program on each of the student outcomes (a) – (k). To achieve this objective, these assessments are implanted into the curriculum in the core, required courses and are attached to specific projects, reports or assignments in these courses. Table 4-3 shows the assignment of student outcomes to courses in the core curriculum. Since these are courses in the “core,” these classes are taken by **both** the electrical engineering majors and the computer engineering majors. These assignments were developed by the department head and the chairs of the assessment and curriculum committees and are periodically reviewed by them.

Table 4-3. Special Assessment Course Assignments

Student Outcome	Course	Semester
(a)	ECE 3620 - Continuous Time Signals & Systems	Fall
(b)	ECE 3640 - Discrete-Time Signals and Systems	Spring
(c)	ECE 4840 - Engineering Design II	Fall/Spring
	ECE 4850 - Engineering Communications II	Fall/Spring
(d)	ECE 4840 - Engineering Design II	Fall/Spring
(e)	ECE 3710 - Microcomputer HW/SW	Spring
	ECE 4850 - Engineering Communications II	Fall/Spring
(f)	ECE 3810 – Engineering Professionalism	Fall/Spring
(g)	ECE 4840 - Engineering Design II	Fall/Spring
	ECE 4850 - Engineering Communications II	Fall/Spring
(h)	ECE 4840 - Engineering Design II	Fall/Spring

	ECE 4850 - Engineering Communications II	Fall/Spring
(i)	ECE 4840 - Engineering Design II	Fall/Spring
(j)	ECE 4840 - Engineering Design II	Fall/Spring
(k)	ECE 3410 - Microelectronics	Spring

Instructors of courses where a special assessment is assigned have some flexibility to choose the specific student assignment used for the special assessment. The assessment committee chair meets with each instructor prior to the start of the semester to discuss the special assessment process. The assessment chair and a departmental staff assistant make sure that the special assessments are completed during the semester and that appropriate documentation is turned in for archival purposes. Feedback from instructors and changes to special assessments are taken back to the department head for discussion. The main points from these discussions are documented in the departmental annual assessment report. Examples of specific student assignments that relate to the (a)-(k) student outcomes are listed below.

Student Outcome (a) - an ability to apply knowledge of mathematics, science, and engineering

- ECE 3620 – Computer programming assignment on numerical solution to differential equations: the zero-input solution.

Student Outcome (b) - an ability to design and conduct experiments, as well as to analyze and interpret data

- ECE 3640 - Computer programming assignment on finding the maximum step-size for an adaptive filter that maintains filter stability.

Student Outcome (c) - an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

- The reports generated as described in Table above for stages of the senior project design.

Student Outcome (d) - an ability to function on multidisciplinary teams

- ECE 3810 - Students complete a project design as a team and are graded as a team. Teams may contain both EE and CE majors (and are, to that extent, somewhat multidisciplinary). Teaming is scored based on design review in ECE 3810 and all design documentation.
- There are questions about working on teams on the senior exit questionnaire and in the senior exit interview, in which the computer engineers and electrical engineers are evaluated separately.

Student Outcome (e) - an ability to identify, formulate, and solve engineering problems

- ECE 3710 - Project assignment on design of a security system for a room using an array of sensors with different timing specifications and outputs.

Student Outcome (f) - an understanding of professional and ethical responsibility

- ENGL 3080 contains a unit on ethics.
- ECE 3810 contains formal presentations and teaching about ethics and professional responsibility. Written examination on ethical questions.

- There are questions about ethics on the senior exit questionnaire and in the senior exit interview.

Student Outcome (g) - an ability to communicate effectively

- ENGL 3080, ECE 3810, and ECE 4850 - Students turn in an extensive amount of written work.
- The senior project preliminary design review, critical design review, and final design documents are examples of student written work.
- The senior project presentation gives students the opportunity for oral communication.

Student Outcome (h) - the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

- ECE 4840/4850 - In the senior design document students describe the impact of their project in a global, economic, environmental, and societal context
- ECE 3810 contains formal presentations and teaching about these elements.
- There are questions about broad education on the senior exit questionnaire and in the senior exit interview.

Student Outcome (i) - a recognition of the need for, and an ability to engage in, life-long learning

- ECE 3810 - Students have learning modules in class with written evaluation questions.

Student Outcome (j) - a knowledge of contemporary issues

- ECE 3810 - Discussions, with written examination.

Student Outcome (k) - an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

- ECE 3410 - Laboratory assignment on analysis, simulation, and measurement of MOSFET amplifiers

Some of the special assessments have specific forms associated with them. Other special assessments use the graded, turned-in student work itself as the documented evidence. When specific forms are used, the instructor or the TA fills out the form while grading the student work and scores student attainment on a 0-1-2 scale. The form is retained and placed in an archive, and the student's work is returned to the student. In addition, a staff assistant enters student attainment scores in a spreadsheet so that average levels of student attainment can be computed on a per outcome basis. A summary of the special assessment scores for core courses taken by the electrical engineering majors appears in Table 4-4.

Table 4-4. Summary Special Assessment Scores

Outcome	Special Assessment Score
a	1.7
b	1.7
c	1.8

d	1.6
e	1.1
f	1.8
g	1.7
h	1.5
i	1.6
j	1.7
k	1.7

We make the following observations about these data.

- All of the scores are above 1 = satisfactory rating. All but one of the scores lie between 1.5 and 2 = excellent rating.
- Outcome (e) is the lowest. This is because of the rather narrow interpretation applied to this criterion on the evaluation forms. The outcome addresses the “ability to identify, formulate, and solve engineering problems.” The assignment used to assess this outcome in Microcomputer Hardware and Software (ECE 3710) asks students to design a security system using a minimum number of hardware timers. For purposes of assessment, the assignment is scored on a 0-1-2 scale. Students’ designs having the absolute minimum number of timers are scored with a 2, whereas students’ designs having one more than the minimum number are given a score of 1. Many students’ designs use a small number of timers but not the exact minimum number of timers. Therefore, the average tends closer to 1 than 2 because of the requirements for the assignment used on the special assessment form.

Another way of looking at this score is that, because we consider this outcome to be so critically important --- indeed, much of the curriculum is designed to support this outcome --- the special evaluation assignment used here has been particularly critical in its outlook. That is, this was a non-trivial problem, evaluated rigorously.

So, even though the assessment score for the particular special assignment was low, it is still in the “satisfactory” category. And, across the curriculum, this is one of the areas in which we consider to be one of our strengths, as further information below will substantiate.

Since these forms are intended to provide merely a **point measurement**, and many classes typically contribute to the outcomes, evaluators may also obtain additional information for an outcome by examining samples of student work, which will be available for review.

Senior Exit Survey and Interviews

Each graduating senior is asked to complete a senior exit survey. The survey includes questions about the program including the different areas of the curriculum, the pre-professional program (math, science, computer science), general education, and so on. The survey also asks students to evaluate their own knowledge and abilities on a 1-5 scale in the areas of the 11 student outcomes. While this survey does not measure their attainment, it measures the degree to which students perceive they have attained the student outcomes. Table 4-5 summarizes the results for the last several years (the results were normalized with a 0-1-2 scale).

Table 4-5. Senior Exit Survey Outcome Assessment (0-1-2 scale), Electrical Engineering

	2008	2009	2010	2011	2012	2013	Average
a	2	1.8	1.8	1.9	1.7	1.7	1.8
b	1.9	1.6	1.7	1.7	1.7	1.7	1.7
c	1.9	1.5	1.6	1.7	1.5	1.6	1.6
d	1.9	1.5	1.4	1.7	1.4	1.4	1.6
e	2	1.5	1.7	1.7	1.6	1.7	1.7
f	1.9	1.7	1.8	1.7	1.9	1.8	1.8
g	1.9	1.5	1.7	1.8	1.8	1.7	1.7
h	1.6	1.6	1.7	1.7	1.6	1.6	1.6
i	2	1.6	1.7	1.9	1.8	1.8	1.8
j	1.5	1.4	1.6	1.6	1.5	1.5	1.5
k	2	1.6	1.7	1.8	1.6	1.6	1.7

After completing the senior exit survey, the graduating seniors are invited to a luncheon with the department head and the chairs of the curriculum and assessment committees. During the luncheon, students are invited to respond openly about strengths and weaknesses of the program, the curriculum and its prerequisite structure, labs and facilities, the instructors, technical support, and so on. Students are specifically asked about the 11 student outcomes. An administrative staff assistant is present to capture and type student responses.

The senior exit survey and interview provide valuable inputs to the assessment process. Often themes emerge that are taken back to the curriculum and assessment committees for further discussion. These themes are documented in the annual assessment report.

Outcome Assessment Results

Table 4-6 summarizes the results from Table 4-2, Table 4-4, and Table 4-5 for electrical engineering students. To two significant places, the averages are very similar.

Table 4-6. Summary Results for Outcome Assessment (0-1-2 scale)

	a	b	c	d	e	f	g	h	i	j	k
Faculty Course Assessments	1.7	1.7	1.7	1.8	1.7	1.9	1.8	1.8	1.8	1.8	1.7
Special Assessment	1.7	1.7	1.8	1.6	1.1	1.8	1.7	1.5	1.6	1.7	1.7
Senior Exit Interview	1.8	1.7	1.6	1.6	1.7	1.8	1.7	1.6	1.8	1.5	1.7
Average	1.7	1.7	1.7	1.7	1.5	1.8	1.7	1.6	1.7	1.7	1.7

We make the following observations:

- There is a high degree of correlation among the different types of measurements. There is an expectation that faculty might be assessing their courses high (since they are performing their

own assessments), seniors might assess outcomes as low (perhaps not having an appreciation yet of what they have learned), and the special assessment method is less biased (since it is a direct measure typically involving an objective evaluator). Yet there is surprisingly little variation.

- Given that a score of 1 corresponds to “satisfactory”, we observe that all of the outcomes were achieved. In fact, there appears to be a comfortable margin above merely “satisfactory” performance.
- We have been comfortable as a faculty with the more technical Student Outcomes. The (a), (b), and (e) type of outcomes are what we are trained best to teach. It is therefore gratifying that some of the professional, more human oriented outcomes are rated as well as the more technical ones. Multidisciplinary teams, communication, life-long learning, and contemporary issues all scored about equally. Professional and ethical responsibility (f) had the highest average score.
- The lowest average score is (e) having to do with identifying, formulating and solving engineering problems. As mentioned previously, this is due to the narrow interpretation used in the special assessment of this student outcome.

In summary, the data support the conclusion that all outcomes are achieved above the satisfactory level. The evidence that will be provided to the evaluation team will consist of the following:

- Completed special assessment forms are on file
- Faculty course assessment forms are on file
- Senior exit interview summaries
- Samples of student work

Alumni Survey

Each year surveys are sent to alumni five years after their graduation date. The survey contains approximately 20 questions designed to measure alumni perception of their attainment in areas related to the student outcomes and program objectives. Many questions require a response on a five-point scale where 5 corresponds to a strong positive response or agreement and 1 corresponds to a strong negative response or disagreement. Average scores are reported in Table 1-7.

Table 1-7. Summary Responses on Alumni Surveys

Electrical Engineering Program Alumni	
Question	Average
Did the technical courses at USU equip you with fundamentals in math and science appropriate for a professional engineering position?	4.5

A technical education can be viewed as consisting of two parts: An education in the foundational principles of math and science; and an immediately useful set of tools, which allows you to be effective and useful right out of the box, that is, immediately upon employment. To what extent do you feel like you had useful skills that your employers were able to use right out of the box?	3.7
If you have had to develop new skills or adapt to new technology, to what extent did your education prepare you for that?	4.2
Please indicate the degree to which your education at USU prepared you with the following engineering skills.	
Problem solving skills: an ability to formulate a problem, determine a direction of attack, and proceed toward a solution.	4.2
Requirements development: figuring out what you will need in order to approach and solve a problem.	3.9
Considering tradeoffs; employing creative ideas; making informed decision.	4.0
Implementation: Understanding how to actually build or manufacture your solution.	3.5
In addition to the technical classes, your education also had general education courses. To what extent have the general education courses you took, and the habits of self-education you may have acquired, helped you maintain an awareness of the world situation?	3.3
To what extent has your education generally contributed to your ability to "achieve your potential." That is, to what degree do you feel like your college education has helped you accomplish things in your professional and/or personal life that you would not have been able to accomplish without it?	4.2
To what extent has your education at USU prepared you for interaction with other people?	4.0
To what extent has your education at USU provided you with appropriate written and verbal communication skills?	3.8
To what extent has your education at USU provided you with an understanding of ethical issues?	3.6
What is the extent to which your engineering education at Utah State University has helped you make contributions to your profession and to society?	3.8

On a 1 to 5 scale, there are four intervals: [1,2], [2,3], [3,4], and [4,5]. Scores in the interval from 3 to 5 indicate a positive perception and scores in the interval from 1 to 3 indicate a negative perception. Scores near 3 are “neutral”. The data in Table 1 show that alumni recognize positive lasting impacts of their education in the Electrical Engineering program five years after graduation. We make the following observations.

- The strongest positive scores (in the range 4 to 5) are in the following areas.

- Education in the fundamentals of math and science appropriate for a professional engineering position (score 4.5). This indicates that alumni feel they are able to apply technical knowledge gain in this program in their work as practicing engineers, which provides evidence on the attainment of student outcome (a).
- An ability to develop new skills or adapt to new technology (score 4.2). Alumni perceive that their education prepared them to continue learning and adapting after graduation. This relates directly to life-long learning in student outcome (i) and PEO 2.
- Problem solving skills (score 4.2). Alumni perceive that their education prepared them to formulate problems and solve engineering problems, which relates to student outcome (e).
- Consider tradeoffs, thinking creatively, and making informed decisions (score 4.0). These skills relate to engineering design in the presence of constraints as described in student outcome (c). Alumni indicate a strong positive perception that their education developed in them these important design skills.
- Life achievements and accomplishments (score 4.2). Alumni perceive that their education has enabled them to succeed in achieving their potential. This relates to PEO 1.
- Interaction with other people (score 4.0). Since interaction is the basis for working effectively with other people as a team, strong positive response from alumni response indicates attainment of student outcome (d).
- Positive scores (in the range 3 to 4) are in the following areas.
 - Skills immediately useful upon graduation (score 3.7). Alumni felt that they were able to apply in their first job skills that they developed during their education. This relates to the attainment of student outcome (k) and PEO 2.
 - Develop requirements to help formulate engineering problems (score 3.9). This relates to the attainment of student outcome (c).
 - An understanding of world situations through general education courses (score 3.3). This relates to student outcome (h).
 - Verbal and written communication skills (score 3.8). This is a fairly strong positive indication that alumni felt their education developed in them needed communication skills. This corresponds to student outcome (g).
 - An understanding of ethical issues (score 3.6). Alumni perceived that the program produced in them an ability to recognize ethical issues and their responsibility with respect to these issues. This relates to student outcome (f).
 - Contribute to their profession and to society (score 3.8). Recognizing contributions requires knowledge of contemporary issues (student outcome (j)) as well as understanding the impact of engineering solutions (student outcome (h)). Making contributions also relates to achieving career success (PEO 1).

B. Continuous Improvement

Describe how the results of evaluation processes for the student outcomes and any other available information have been systematically used as input in the continuous improvement of the program. Describe the results of any changes (whether or not effective) in those cases where

re-assessment of the results has been completed. Indicate any significant future program improvement plans based upon recent evaluations. Provide a brief rationale for each of these planned changes.

Since the last ABET review of the department, several changes have been made to improve the programs at all levels of the curriculum. These changes include strengthening the core of math and English, modifications to the senior project process, updating the curriculum to track changes in technology, updating lab equipment, modifying key assessment documents, and working to improve retention. This section describes examples of the continuous improvement process in the department. Because many of these examples relate to changes in the core curriculum, these affect both programs in the department: the Electrical Engineering Program and the Computer Engineering Program. Each case described below lists (1) the indicators suggesting what change was needed, (2) the changes that were implemented, and (3) the results of re-assessment where available.

Changes in Core Technical Requirements

Math Requirements

We received feedback from three sources that the students' preparation in linear algebra and differential equations was inadequate, without sufficient depth or applicability. Sources of feedback included the alumni survey (2011, 2013 "more math"), senior exit interviews (e.g., Senior exit survey minutes, April 2010), and faculty course assessments in core classes such as Electrical Circuits (ECE 2250) and Continuous-Time Systems and Signals (ECE 3620). This was discussed among the faculty in the department and with the IAC. The faculty voted to change the math requirement. Instead of taking a single 4 credit hour class covering both subjects (Linear Algebra & Differential Equations – Math 2250), students are now required to take two separate courses (Linear Algebra – Math 2270, 3 credit hours; and Differential Equations – Math 2280, 3 credit hours) on each of these subjects. The IAC was supportive of this change. Appropriate paperwork was completed to make this change to the prerequisite structure. Feedback on faculty course assessments indicates that students are better prepared with the needed mathematical concepts, and in senior exit interviews and senior exit surveys students have expressed greater comfort with these concepts.

This change has impacted students' ability to apply knowledge of math to solve engineering problems (Student Outcome (a)) and their ability to identify, formulate, and solve engineering problems (Student Outcome (e)). Since improved core fundamental skills facilitates the ability to adapt to new areas of technical specialty, this also impacts students' ability to engage in life-long learning (Student outcome (i)).

Numerical Methods

In the past, students took Introduction to Computer Science I & II (C++ programming) during the two semesters of their freshman year. In the sophomore year, there were no required programming courses and no courses in the prerequisite structure required programming in the sophomore year. When students encountered programming again during their junior year, many students had lost much of their programming skill. Faculty instructors expected students to be able to program from the start in junior level classes. This issue surfaced in faculty course

assessments. In senior exit surveys, students were uniformly supportive that this would be important (Senior Exit Survey December 2010.)

Another deficiency noted in junior and senior level courses was related to the type of programming experience they were getting in the CS courses. They were being taught the syntax of the C++ language and object oriented programming concepts, but not developing the programming skills that many engineers need: applying programming to solve engineering and scientific problems numerically.

To address these problems, the faculty voted unanimously to require students to take a course during the sophomore year that applies computer programming to solve engineering problems numerically. With the encouragement of the College of Engineering, the course Numerical Methods for Engineers (ENGR 2450) was added as a requirement to the curriculum. The content of this course agreed with our goals for a rigorous programming experience, and we added the requirement that students take this course during the sophomore year. This change was made in 2012, and there has not been sufficient time to observe the results of this change.

This change has impacted students' ability to apply knowledge of math to solve engineering problems (Student Outcome (a)) and their ability to identify, formulate, and solve engineering problems (Student Outcome (e)). Since the ability to try things out using computers (e.g., programming to understand a new concept) is enhanced by this course, this change also impacts students' abilities to engage in life-long learning (Student Outcome (i)).

Circuits Courses and Signals & Systems Courses

When USU switched from quarters to semesters around 1998, two quarters of basic circuits were squeezed into one very full, semester-length course Electrical Circuits (ECE 2250). Inevitably there was insufficient time to cover all the necessary topics in one semester. Some instructors were able to cover more material than others in a semester, but the left-over uncovered topics were always pushed into and taught during the first few weeks of the follow-on course Circuits and Signals (ECE 3620). In ECE 3620 this created an unnatural break a few weeks into the semester and stole time away from the topics that need to be covered in that class. Leftover topics from ECE 3620 got pushed deeper into the curriculum and were covered in the second semester of Signals and Systems (ECE 3640). Two semesters of Signals and Systems adequately absorbed the slippage that occurred in the introductory circuits course, but students found it awkward to be conceptually bridging between textbooks and topics. This problem and possible solutions have been the subject of debate among the faculty for about ten years.

Another factor driving the need for change was the observation that there was too much overlap between the second Signals and Systems course (ECE 3640) and the technical elective Introduction to Digital Signal Processing (ECE 5630). Students complained about the significant overlap in course evaluations and in senior exit surveys, and ECE 5630 instructors expressed the desire to recover time to introduce additional topics.

Based on these inputs, the faculty in the areas of circuits and signals and systems organized an ad hoc committee to review the entire curriculum spanning the basic circuits course (sophomore year), the junior-level signals and systems courses, and the senior-level DSP course. These courses were torn apart and rebuilt from the ground up.

The committee proposed to introduce a second semester of circuits by taking 1 credit hour away from the first semester of circuits and taking 2 credits of technical electives. This change spreads the basic circuits concepts across a two-semester course sequence (3 credit hours each) in the sophomore year. The additional time provides the opportunity for greater depth of coverage and more time for practice to allow the concepts to sink in.

The re-designed signals and systems courses carry the same course numbers but the course titles and emphases have been adjusted, with the first semester focusing on continuous-time signals and system concepts and the second semester focusing on discrete-time signals and systems concepts. The overlap in the senior-level digital signal processing course was eliminated leaving open time to introduce concepts in two-dimensional/image processing. The newly designed course sequence is summarized below.

- ECE 2250 – Electrical Circuits I (3 credit hours)
- ECE 2290 – Electrical Circuits II (3 credit hours)
- ECE 3620 – Continuous-Time Signals and Systems (3 credit hours)
- ECE 3640 – Discrete-Time Signals and Systems (3 credit hours)
- ECE 5630 – Digital Signal and Image Processing (3 credit hours)

This change was implemented in the 2012-2013 school year when the new circuits sequence (ECE 2250 & 2290) was taught for the first time. To accommodate students who had taken the old courses, the old format for ECE 3620, ECE 3640 had to continue to be taught for one year, and the old format ECE 5630 had to continue to be taught for two years. The new signals and systems courses were taught for the first time in 2013-2014. The transformation will be complete in 2014-2015 when the new digital signal and image processing course will be taught. These changes to the undergraduate course structure have also impacted courses at the graduate level.

Students have not yet graduated from the revised curriculum, so no assessment from the senior exit surveys is available. However, students in the revised ECE 3640 have expressed enthusiasm for the revised curriculum. The instructor for the course provided the following feedback:

It was obvious that the students had studied circuit analysis techniques, but were not fully comfortable with them. Their ability improved during ECE 2290. They had learned SPICE as an analysis tool sufficiently to be able to use it without further help. The students were able to complete the labs without great difficulty. Overall students felt more comfortable with circuit analysis and were better ready to go on to ECE 3620. Several topics were covered that had been part of ECE 3620 (RLC circuits, three-phase power, and filter circuits) were covered in the new ECE 2290, which allowed more time in ECE 3620 for signals. Time will tell if students actually do better in ECE 3620, but for now the students seem to be more confident in their circuit analysis abilities.

This change has impacted students' ability to apply knowledge of math to solve engineering problems (Student Outcome (a)) and their ability to design and conduct experiments, as well as

to analyze and interpret data (Student Outcome (b)) and their ability to identify, formulate, and solve engineering problems (Student Outcome (e)).

Changes in Written and Verbal Communication

Written and Verbal Communication

Written and verbal communication was flagged as an issue over multiple years in the alumni survey. The alumni that were surveyed had been out long enough to appreciate the need for effective communication in the work place and expressed the opinion that education in written and verbal communication could be improved. (See Alumni Survey 2013, “Technical writing ... could be added” “strengthen verbal communication” “do realistic writing” “require technical writing courses”; Alumni Survey 2011 “how to present technical info to non-technical people...technical writing”; Alumni Survey 2012 “technical writing.”) The IAC commented on the need to strengthen communication skills (IAC Minutes October 2008). At the time, students were required to take Research Writing in a Persuasive Mode (ENGL 2010), followed by a writing experience associated with the senior project. Another factor driving the need for change is that the faculty felt the quality of the writing in the senior project reports needed to improve. Students have also commented on English instruction (see for example Senior Exit Survey minutes, April 2010.)

To address this issue, the ECE and English Departments discussed ways to strengthen technical communication skills for students in this program. It was determined that undergraduate students would be required to take Introduction to Technical Communication (ENGL 3080). ENGL 3080 is a 3 credit hour class. To compensate for the increase in credit hours, the writing requirements in Engineering Communications II (ECE 4850) were reduced and the credit hour allocation was reduced from 2 to 1 credit hours.

Feedback from students over time in senior exit surveys and senior exit interviews indicated that students appreciated having education targeted to written communication and oral presentation skills. Still, the faculty were not entirely satisfied by the quality of written senior project design documents. Graduating seniors reported mixed experiences in the ENGL 3080 class, with the quality of the education being highly dependent on which instructor taught the class. The ECE Department continues to work with the English Department to achieve consistency across all sections of ENGL 3080.

The issue of written and verbal communication was raised to the college level. To benefit all the engineering programs administered within the college, and to have more direct control over the instruction and the course content, the College of Engineering created a new course entitled Introduction to Technical Communication (ENGR 3080), which is patterned after ENGL 3080. The college hired a full-time instructor to teach multiple sections of this course each semester. Students are encouraged to take the College of Engineering technical writing course, but the technical writing course offered by the English Department still satisfies the requirement. ENGR 3080 was offered for the first time in Spring 2014.

This change has impacted students’ ability to communicate effectively (Student Outcome (g)). Evaluation in Senior Exit Surveys has indicated that the class has had a positive effect (“Very

good class. Best English class” (Senior Exit Survey minutes, April 2010), although the effectiveness did depend on the instructor.

Engineering Communication

Written and verbal communication is an important element in the Electrical Engineering Program. Inputs related to this are described above. Student outcome (g) deals exclusively with effective communication. Over the last six years, extensive changes have been made with respect to the writing requirements in the program. As described above, students are now required to take either ENGR 3080 or ENGL3080 on technical communication. In addition, when the senior project course sequence was redesigned, the writing components were separated out to help formalize students’ understanding of project reporting and presentation requirements. We now hire a PhD student from the Technical Writing Program in the English Department to work closely with all the senior projects. This person reads and provides feedback comments on student reports. Students revise their reports and submit them for additional reviews. The responses we have had so far from graduating seniors is uniformly positive.

Dr. Don Cripps, who teaches both Engineering Professionalism (ECE 3810) and senior design has made the following observation regarding the effectiveness of the engineering communication course, “I can see a difference in writing ability from what I get in Professionalism to what I see in Senior Design.”

This change has impacted students’ ability to communicate effectively (Student Outcome (g)).

Changes in the Senior Project Process

Senior Project Course Sequence

Based on inputs from faculty and students, the senior project course sequence has been redesigned. Previously, students were expected to complete their senior project in a single semester. Students repeatedly expressed the desire for more time to complete their projects (for example, during the Senior Exit Survey --- see e.g. Senior Exit Survey minutes April 2012, April 2013). The single-semester approach also played a role in the poor quality of the written design documents described above. Faculty who advised student projects also expressed frustration with the short time-frame to complete project work.

Based on these inputs, it was decided to re-design the senior project course sequence. The Mechanical and Aerospace Engineering (MAE) Department had a two-semester course sequence. To be compatible with MAE and enable more cross-disciplinary team projects, it was decided to change to a two-semester senior project sequence. The new proposal was presented to the IAC who agreed that students would have a better design experience if given two semesters to complete their projects.

The current senior project course sequence is described in detail under curriculum in Criterion 5. In summary, the new sequence consists of four courses:

- ECE 3810 – Engineering Professionalism (1 credit hour)
- ECE 4820 - Engineering Design I (1 credit hour)
- ECE 4830 - Engineering Communications I (1 credit hour)

- ECE 4840 - Engineering Design II (2 credit hours)
- ECE 4850 - Engineering Communications II (1 credit hour)

Normally students take ECE 3810 in the junior year and the ECE 48xx courses during the two semesters of the senior year. ECE 4820 & 4830 are taken concurrently as are ECE 4840 & 4850. We note that the writing components of senior design are also impacted by the re-design of the course sequence. This course sequence was put in place starting in 2013. We are collecting data to assess the impact of this change.

This change has impacted students' ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, health and safety, manufacturability, and sustainability (Student Outcome (c)).

Capstone Courses

In the past, students expressed an interest in doing a senior project closely tied to one of the technical elective courses. The faculty viewed this as an opportunity to raise the technical level of senior projects. This was also discussed in IAC meetings (see, e.g., IAC Meetings minutes, February 2009.) In response to these inputs the faculty have designated certain elective courses as capstone courses. These courses have strong design and project elements. The capstone courses are listed on in Table 5-3 on page **Error! Bookmark not defined.**6. Because of the strong emphasis on engineering design, capstone courses can be substituted for Engineering Design I (ECE 4820). There is a formal process that students must follow to make this substitution. Students are required to fill out a form that is kept in their file in the department office. Students involved in Capstone courses are still required to take other aspects of the Senior Design courses, including Engineering Communications II (ECE 4850).

Feedback in senior exit interviews and the senior exit survey indicate that students appreciate the opportunity to take capstone courses. Faculty and other senior project evaluators have observed an increase in the technical depth and quality of the senior projects.

This change has impacted students' ability to design a system (Student Outcome (c)).

Changes in Digital Design and Microprocessor Systems

Digital Circuits

Digital circuits is an area where course content must evolve over time to keep up with innovations occurring in industry. Where once combinational logic was wired up at the gate and flip-flop level, programming FPGAs and CPLDs have become standard. To keep abreast of technology developments, the Industrial Advisory Committee suggested that lab work in Digital Circuits (ECE 2700) should emphasize programming logic devices using Verilog. This change was implemented. Surveyed graduating seniors report a high degree of confidence with Verilog programming.

This change has impacted students' ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (Student Outcome (k)), their ability to design a system (Student Outcome (c)), and their ability to identify, formulate, and solve engineering problems (Student Outcome (e)).

Digital Design Sequence

In the past, Digital System Design (ECE 5530) was the follow-on course to Digital Circuits (ECE 2700). Over a period of several years, graduating seniors observed in the exit survey and in exit interviews that only 20-30% of ECE 5530 was new material. (See, for example December 2010, May 2011 and April 2013 Senior Exit Survey minutes.) The backtracking in ECE 5530 was traced to the desire to provide remedial instruction to incoming graduate students who had not previously taken the equivalent of ECE 2700 as a prerequisite course with its HDL-oriented approach to digital design. A group of faculty were appointed to an ad hoc committee to examine ways to solve the problem of significant overlap between ECE 2700 and ECE 5530. The committee determined that ECE 5530 could be eliminated from the curriculum and the small amount of new material could be absorbed into other courses in the curriculum. The faculty voted to approve this recommendation. Since this change was implemented, complaints about overlap have stopped and no concerns have surfaced.

This change has impacted students' ability to use the techniques, skills and modern engineering tools (Student Outcome (k)), in a way that is expected to be neutral.

Microcontroller Hardware & Software

For many years, the Microcontroller Hardware and Software (ECE 3710) was designed around the 8086 microprocessor. The department moved to use the 8051 microprocessor. Then the Industrial Advisory Committee observed that the ARM processor had supplanted the 8051 as the dominant embedded microprocessor/microcontroller in the marketplace. It was suggested that a corresponding shift be made in the curriculum to better prepare students to work with the tools and hardware common in the industry. (See IAC Meeting Minutes, February 2009.) Students also commented on a desire to move to the ARM processor (Senior Exist Survey Minutes, December 2010, May 2011.) In response to this input, a change was made in the course ECE 3710. Dr. Ryan Gerdes developed a whole new set of labs around the ARM processor, and new ARM-based hardware was acquired. The new labs were implemented during the 2012-2013 academic year. The first crop of students to take the new class are graduating in the 2013-2014 year. The re-design is having a positive impact as reported by graduating seniors during exit interviews.

Of the students interviewed, it was uniformly agreed that the labs were extremely time-consuming and also extremely educational. Students learned both hardware and software debugging skills. Students commented that this course solidified their programming skills. Debugging and programming skills are essential skills needed for engineering practice. Thus, this change has impacted Student Outcome (k).

The IAC was updated about the change in the IAC meeting held November 2012, and were very supportive of the changes.

Successful completion of the labs required that students read product manuals and technical data sheets. This experience built students' confidence in themselves and their ability to find needed information and use it to solve their problems. One student commented, "In this class, I learned how to learn." The ability to use new hardware as it is developed is an important professional skill for electrical engineers. The skills students develop in this course in reading data sheets thus impacts Student Outcome (j), the ability to engage in life-long learning.

Computer Architecture

Based on inputs from students and faculty, it was decided to remove ECE 3720 from the curriculum and to move the material into Computer Systems Programming and Architecture (ECE 5720). This change was made to help prepare students for a graduate program in computer engineering. Feedback from students in exit interviews was very positive. One student commented that this course convinced him/her to pursue a degree in computer engineering. In the process of making this change, Dr. Koushik Chakraborty modernized the content of ECE 5720 to address issues relating to multicore parallel architectures.

This change primarily affects the computer engineering students, since ECE 5720 is a required course in their program. It also affects electrical engineering students who choose to take ECE 5720 as a technical elective.

This change impacts students' ability to design a system to meet constraints (Student Outcome (c)); and the ability to identify, formulate, and solve engineering problems (Student Outcome (e)), and the ability to use modern engineering tools (Student Outcome (k)).

New Courses and Emphases

Power Courses

The alumni survey (e.g., 2013) and senior exit survey ask for feedback about what is missing from the curriculum. A response that has emerged is “power electronics”. It has been a long-range goal for the department to develop a teaching and research program in the area of power systems. There is growing industrial demand for engineers with training in power, and there was no power program (as such) in the entire state of Utah. Seniors have also requested power classes, and responded well to them (Senior Exit Survey, May 2011. April 2013.)

With an infusion of funding from the State of Utah's USTAR program, the ECE Department was able to officially begin a power program by hiring a new faculty in this area, Dr. Regan Zane. Dr. Zane brought with him a strong power research program, and classroom and laboratory-based power electronics courses began to be offered at the undergraduate and graduate level. To our knowledge, this is the only fully-fledged power program anywhere in the State of Utah. In Fall 2013 an open position in the power area was filled by the arrival of Dr. Zeljko Pantic. The department now offers the following power courses.

- ECE 5930 – Introduction to Power Electronics (3 credits)¹
- ECE 5140 – Electrical Energy (3 credits)
- ECE 5930 – Electric Vehicle Design (3 credits)¹
- ECE 6140 – Advanced Electrical Energy (3 credits)

Undergraduate students may take 5000-level courses as technical electives. Graduating seniors have had very positive comments about the power courses. The Power Electronics class has garnered the “best class” rating from students during senior exit interviews.

¹ When new courses are taught, the general rule is to teach them under an ECE 5930 “special topics” number, before assigning them a permanent number. This allows the course to be debugged before a permanent course is established in the catalog. This course is new enough that it still has the 5930 course number.

This change impacts students' ability to use modern engineering tools (Student Outcome (k)), ability to design a system with constraints such as environmental constraints (Student Outcome (b)), and introduces abilities to solve new classes of engineering problems (Student Outcome (e)).

Radio Transceivers Capstone Course

Several of the signal processing faculty observed that there was a gap in the curriculum. Courses on digital signal processing and communications dealt with processing signals after being digitized by an A/D converter. Courses on microwaves and antennas dealt with high-frequency electronics and fields and waves. However, there was no course dealing with the system between the antenna and the A/D converter. With approval from the department head, a new course was created to fill this gap. At its heart, this is really a systems engineering course that uses radio frequency systems for radios, radars, and the like as an area to apply systems engineering principles. An industrial sponsor donated over \$10,000 in cash and equipment for this course. Because the course includes an extensive design project, this is offered as a capstone course. This course is taught every other year and alternates with Real-Time Digital Signal Processors (ECE 5640), another capstone course. Feedback from student evaluations have led to improvements in this course over time.

This change impacts students' ability to apply knowledge of mathematics (e.g., signal processing) (Student Outcome (a)); the ability to design and conduct experiments (Student Outcome (b)); the ability to design a system to meet constraints (Student Outcome (c)); and the ability to identify, formulate, and solve engineering problems (Student Outcome (e)).

Significant Changes in Laboratory Infrastructure

Networking Laboratory

The course on computer networking, which is a technical elective for electrical engineers and a core requirement for computer engineers, has grown in popularity over the last ten years. The increase in demand for this course required a corresponding increase in educational laboratory space. This issue became apparent when both students and the faculty instructor complained about the inadequacy of the lab space in EL 212 (see for example, Senior Exit Survey minutes, April 2013). Room EL 103 was converted from a research laboratory into an educational laboratory for computer networking. The new lab (over 850 square feet) is well equipped with 20 new workstations. Dr. Rose Hu has been modernizing the curriculum to stay abreast of modern wireless networking concepts. The new laboratory has addressed the concern about insufficient lab space.

This change impacts an ability to use modern engineering tools (Student Outcome (k)), and an ability to solve engineering problems (Student Outcome (e)).

Electromagnetics Lab Equipment

Old equipment in the EM lab was starting to become unreliable. This was having a negative impact on student experiences in the labs associated with the EM courses. Two new network analyzers were acquired with one being specifically purposed for classroom and laboratory use.

The instructor reports that the new equipment is excellent and fills the need for an educational laboratory.

This change impacts students' ability to do design and conduct experiments (Student Outcome (b)) and the ability to use modern engineering tools (Student Outcome (k)).

Other changes

Robotics

Mobile Robots (ECE 5340), a capstone course, has been very popular for many years. In this class students apply feedback control system principles to build and control wheeled robots. Both students and faculty have expressed an interest to transition from ground robots to flying robots (i.e. UAVs/drones). The greater sophistication required for controlling UAVs has been matched by adding (Linear) Control Systems (ECE 5310) as a prerequisite. This change is being implemented currently (with the course to be taught first spring 2015), and feedback is not available yet.

When implemented, this change will impact student's ability to apply knowledge (Student Outcome (a)), to design systems (Student Outcome (c)), and to identify and solve engineering problems (Student Outcome (e)).

Freshman Orientation

Enrollment rates in the Electrical Engineering and Computer Engineering Programs have been fairly flat over the last five years, while enrollment in other technical majors such as Mechanical Engineering and Computer Science have seen increases. As a move toward recruiting and retention, the ECE Department has instituted a freshman orientation program that gets faculty to sit down face-to-face with groups of freshman and talk over pizza for lunch. This gives the students contact with faculty before showing up in sophomore-level classes. During these exchanges, faculty talk about careers in engineering, talk about the major, ask and answer questions, and so forth. Freshman Orientation is new enough that no assessment data is currently available.

Increased Lab Access

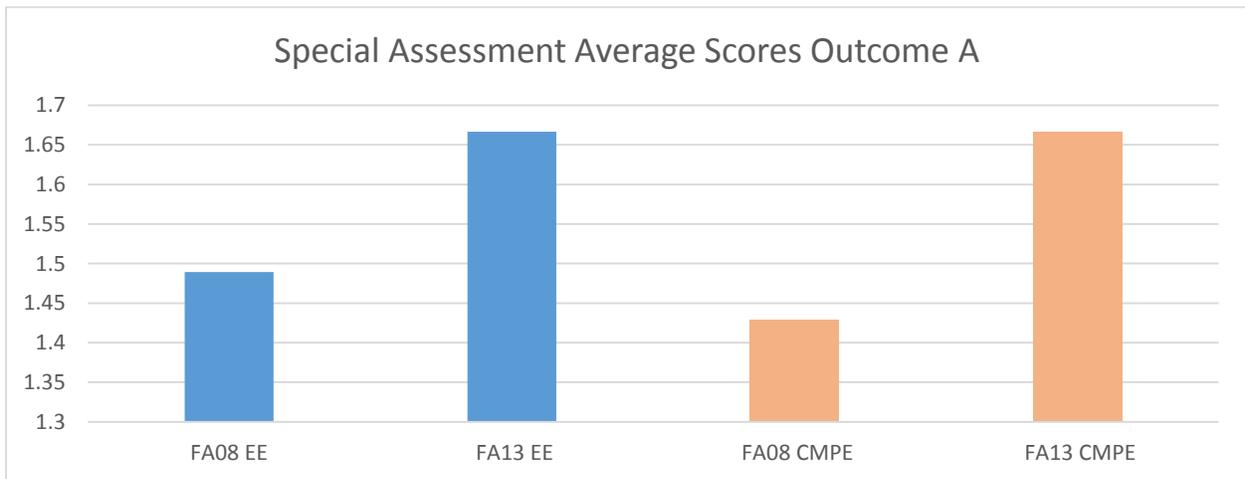
In the past, access to labs required a physical key after regular working hours. For students working on laboratory projects, this hampered student work. In 2013, Campus Facilities replaced locks on the lab doors with electronic locks which allow keycard access. This change increases security and also increases the available hours for students to use the labs.

This change will enable students to spend more time on lab work, which will impact their ability to design and conduct experiments (Student Outcome (b)) and their ability to design systems (Student Outcome (c)).

How well has this worked?

While improvements have been made to make the evaluation process more systematic, the existing process was in place for years, and has been a driver behind many improvements made to the program.

An example of this is shown in the following data, obtain from the special assessment scores for Outcome A. To put this in context, prior to 2012, a single semester of circuits was taught, followed by a two-semester sequence of circuits, signals, and systems. Starting in 2012, a new Circuits II course was introduced as a core requirement (with appropriate changes in the following courses). The Outcome A assessment information before (in FA08) and after the change (in FA 13) are shown in the table below (with separate scores for electrical engineering and computer engineering students):



It is seen that the Outcome A scores improved as a result of the change. (The change was most evident for the computer engineering students). This is evidence that the evaluation process provides valuable input to driving change.

This plot also motivates the changes in the assessment process that have been described above. The information in the graph was obtained when the assessment data was collected was ranked on a 0-2 scale (instead of the 1-5 scale now used). On this short scale, there is a tendency for scores to be compressed together. (Very few students get 0, so this really becomes almost a binary 1-2 scale). Also, there was no specific threshold set for attainment of an outcome. If a threshold had been set (at 1.5, say, which would have been reasonable on a 0-2 scale), then the need for improvement would have been clearly identified. As it was, the need for improvement was identified from other data sources: the senior exit survey, IAC meetings, and faculty meetings. For this change, these sources of information are identified below:

Sr. Exit Survey May 2011: “Circuits was a lot of information taught too fast in one semester. There was not enough time to get proficient in it” “I was overwhelmed in circuits” “One of the most important classes to have”

Fac mtg May 2011: Discussion of 2250 (circuits I) curriculum. Discussion of putting some material in ECE 1000. Discussion about pushing students so fast they can't competently learn the material (if we cover too many chapters, have they learned anything?)

Sr. Exit Survey May 2012: "Add 3-phase power" (that is one of the topics included in the 2nd semester of circuits that was previously getting short shrift). From students who had not benefited from the change.

Fac mtg Aug 2011: Discussion of changes to core, including give students more exposure to circuits and systems; eliminate orphaned topics currently in 3620; reduce overlap between undergraduate and graduate classes; eliminate ECE 1000.

IAC Nov 2011: Second circuits course to be added. Removed freshman course.

Proposed course addition: add a course (tentatively numbered 2260) for Circuits II.

Sr. Exit Survey Dec. 2013: "It's a good idea to have another semester of circuits in ECE 2290" (That is, when asked if they had the second semester of circuits, the students felt like it would be important, but they had not had it themselves yet even though the change had been made.)

The graphical data presented above was not, in the heat of the moment, presented to the ABET reviewers. It was present (numerically) among the data available for review, but we did not specifically call it out. It is presented here to show that the process in place was, in fact, effective at identifying need for change based on multiple data sources.

Recent Results

In accordance with the procedures described above, the ECE department assessment committee met on February 2, 2014 to consider assessment data and to discuss the assessment process. The minutes from that meeting include the following: "We are pleased to report that the average score for Outcome (e) for the Fall 2014 cohort rose to 4.02 (on a 1-5 scale), a significant increase over recent years." By contrast, the score reported in the department ECE ABET Report (July, 2014) was that the score was 3.2 (adjusted to the new 1-5 scale). On a more detailed scale, out of 40 students, 34 had scores ≥ 3 (85%) and 26 had scores ≥ 4 (65%). These are clearly within the thresholds specified by the departmental evaluation requirement. The need for a change was identified due to the low score reported in the last ABET report. This is a score, like the others, that we will be watching, to see if it remains strong.

Summary:

In summary, the ECE program has had in place a strong program of assessment for many years. The assessment process has been modified to make its analysis and consideration more straightforward. In addition, the process of evaluation and action, leading to recommendations for change, has been strengthened and occurs on a more regular basis, with definite evaluation scores established. We have shown that the previously existing process did use data to drive changes. With the changes in place, it is expected that this process will be even better.

