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Implementation and Results of a Revised ABET Assessment Process

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Implementation and Results of a Revised ABET Assessment Process

Abstract

The electrical and computer engineering programs at Iowa State University were reviewed by the Engineering Accreditation Commission of ABET during fall 2012. The department revised its process of assessing student outcomes since the last visit in light of the current criteria for accrediting engineering programs and in the interests of efficiency and sustainability. Several faculty committees and course instructors have specific responsibilities for student outcomes assessment. The revised process takes a multilevel approach that leverages existing assessment tools and best practices. The multilevel approach supports efficient data collection while also providing sufficient data to make decisions. This paper describes the process and provides assessment examples and observations at each level.

Introduction

The electrical and computer engineering programs at Iowa State University were reviewed by the Engineering Accreditation Commission of ABET during fall 2012. This paper presents the department's revisions to its process of assessing student outcomes since the last visit in light of the current criteria for accrediting engineering programs and in the interests of efficiency and sustainability. The revised process involves a larger number of faculty members in specific ways. The revised process also takes a multilevel approach that leverages existing assessment tools and best practices. These two aspects were keys to a successful accreditation review.

Faculty Involvement in the Assessment Process

Having a critical mass of faculty involved ensures that the expectations of ABET Engineering Criterion 6 are met, which states, in part, that faculty must be qualified to develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives and outcomes[1]. At least two faculty members in a program were deeply involved in the assessment process. These core faculty either attended ABET workshops to enhance their knowledge or were trained as program evaluators. Expanding the core group builds a foundation on which to sustain assessment and improvement efforts over time. In addition to the core expert group, other faculty members were enlisted for specific assessment and evaluation tasks. This had multiple benefits, including spreading the workload among the faculty, sharing the responsibility for program improvement, and creating greater awareness of how to assess student learning.

Two faculty committees have primary involvement with student outcomes attainment and assessment: the curriculum committee and the ABET committee. The ABET committee is responsible for creating, maintaining, administering and monitoring assessment and evaluation procedures used by the department. The ABET committee makes recommendations for process and program improvements. The curriculum committee manages the curriculum and oversees consistency with ABET Engineering Criteria, student outcomes, and program objectives in concert with the ABET committee. In particular, the curriculum committee incorporates assessment and evaluation results to make program revisions and decisions. The chairs of these committees serve on the respective college-level committees, which facilitates important coordination with college-level and/or college-wide assessment procedures as well as sharing of practices among departments.

Two special faculty groups have a formal involvement in student outcomes assessment. The use of these groups is specific to the multilevel assessment approach described later in the paper. One group is the senior design committee. This is a small group of faculty, in addition to faculty and staff instructor(s), who manage all aspects of the senior design course sequence that serves computer, electrical and software engineering students. In addition to its management function, it conducts frequent informal assessment of the senior design program as well as formal assessment pertinent to ABET student outcomes assessment. The other group is the portfolio review committee. This is a small group of faculty, in addition to academic advising staff instructors, who implement and use rubrics to review student portfolios. All students in the department submit a portfolio of student work in a 1-credit senior course, Portfolio Assessment. Portfolios are introduced in a 1-credit first-year course, Professional Program Orientation. Development begins in a sophomore course, Program Discovery, and is continued in a junior course, Program Exploration. Portfolios are a means to document and communicate student work for faculty review and student outcomes assessment. The process of creating a portfolio also gives students the opportunity to reflect on their academic program. The portfolio is submitted electronically, typically as a link to a web site designed by the student. The main elements of a portfolio used for assessment by the portfolio review committee are:

1. Career objective and resume
2. General education component and reflection
3. Examples of prior work
4. Technical work experience
5. Senior design project
6. Cumulative reflection

The general education reflection and cumulative reflection elements include specific questions to gather information relevant to particular student outcomes.

The effective use of faculty committees and groups involved over 40% of the faculty in targeted ways in student outcomes assessment. There are 55 faculty members in the department at tenured, tenure-track, and lecturer ranks. The curriculum committee and ABET committee each has seven faculty members. The senior design committee has seven faculty members. The portfolio review committee has eight faculty members. While there is some overlap among the 29 members, more than 20 faculty members participated in these committees. Not only does this lead to reasonable workloads and efficiencies, the division of responsibility is aligned well with the scope of each committee. In addition, the faculty members involved create a community of practice around student outcomes assessment that enhances teaching and learning in the department.[14] In turn, these faculty members support several faculty instructors who are asked to conduct course-level outcomes assessment as described later. In addition, faculty advisors of senior design projects provide input about the attainment of particular student outcomes assessed in the second senior design course. One of the challenges of broader faculty involvement is consistency and uniformity in reviewing and scoring student work using the rubrics. By monitoring the results of the process with continued use, guidelines and norms will be developed to alleviate this. Overall the faculty as a whole is better positioned to understand, support and use the assessment process.

Multilevel Assessment Approach

The revised process takes a multilevel approach that involves various faculty as described above and incorporates various proven assessment tools and practices[3,4,5,6,7,8,9,10,11,12,13]. Although the tools are not new, their integrated and coordinated use by the faculty committees represents a creative approach to department-wide student outcomes assessment across multiple programs.

While informal feedback is routinely obtained from student surveys, student forums, and comments by faculty and students, this paper addresses four sources of direct, formal measurements: senior design, the required portfolio class, a small number of required courses before the senior year, and surveys administered every semester by the college and completed by employers of students on internships. Data are collected from different types of measurements at three different levels. The levels provide a range of information. Level 1 assessment uses high-level information from a cross-section of students in the program that can be used to identify trends and potential problems. It is done frequently, automatically, and with little overhead. Level 2 assessment uses senior-level information from all students in the culminating capstone courses. Students demonstrate attainment of outcomes through senior design projects and other summative information in portfolios. Level 3 assessment uses sophomore- and junior-level information from students in selected required courses. Student learning is assessed using rubrics and assignments that focus on specific outcomes of interest. This is finer grained and more specific than the other levels. It is done less frequently. It provides more in-depth examination of a student outcome earlier in the program at the time the student is learning about it. The multilevel approach supports efficient data collection while also providing sufficient data to make decisions. The approach is similar to model refinement: Level 1 assessment provides the most abstract assessment model, with each level refining it further.

Aspects of this approach, though developed independently, are similar to a process reported by Auburn University.[8] Auburn was very selective in courses used for assessment. Using a couple of core courses, they focused on using student projects and writing exercises for assessment. The approach presented in this paper also uses senior design and laboratory projects, and writing exercises in senior design and portfolio courses. In other related work, the United States Military Academy describes a process also motivated by efficiency and faculty involvement.[11,12]

The student outcomes for Iowa State's electrical and computer engineering programs are identical to the ABET *a*-*k* outcomes of the ABET 2012-2013 accreditation cycle as listed below.[1]

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in lifelong learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The table below lists the tools used to assess the student outcomes in the computer engineering program. Similar tables apply to the electrical and software engineering programs.

Table 1. Student outcomes assessment tools for the computer engineering program.

Direct Assessment Tool	**ABET Student Outcomes[1]**										
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
Level 1: Employer survey from internships	√	√	√	√	√	√	√	√	√	√	√
Level 2: Senior design scoring by industry panel			√		√		√				√
Level 2: Senior design rubric scoring by faculty advisor	√		√	√	√	√	√				√
Level 2: Senior design rubric scoring by instructor			√			√	√				
Level 2: Portfolio rubric scoring by faculty								√	√	√	√
Level 3: Course-based rubric scoring by instructor											
CPRE 281: Digital Logic		√									
EE 230: Electronic Circuits and Systems		√			√						
CPRE 288: Embedded Systems			√								
CPRE 381: Computer Organization					√						√
CPRE 310: Theoretical Foundations of Comp. Eng.	√										
CPRE 394: Program Exploration						√					

The assessment plan is devised such that each student outcome (column) is assessed by at least one tool from each of the three levels, with the exception of the professional skills found in outcomes g, h, i, and j. Most course-based assessments focus on only one or two outcomes to provide a detailed learning level view from an appropriate course. The direct measurements are set up to provide both breadth of coverage (all of outcomes a-k) as well as depth of coverage (multiple measurements for each outcome).

At level one, the employer survey results provide a high level indication of how well our students are meeting the outcomes. Since the survey is not tied directly back to a curricular learning experience, potential problems identified using this tool may be difficult to attribute to a course. At level two, the senior design and portfolio courses are used. These courses provide an opportunity to evaluate student work that encompasses multiple outcomes. While these courses do not necessarily teach content that supports an outcome, the work produced by the students is reviewed to determine whether they have attained the outcome. If a potential problem is indicated, the results will lead to an examination of student learning in prior courses. The third level is designed to provide additional granularity. This is done by measuring an outcome in a course where that outcome is taught. There may be cases where one or more of the three levels of direct measures indicate a potential problem that cannot be pinpointed to a specific learning experience in a course. In such cases, additional courses and rubrics may be added to the process.

Rubrics form the basis for assessment at levels two and three. A rubric defines characteristics on which student performance is judged. Using a common scale for rubrics provides a consistent framework for assessment, especially when there are multiple faculty members involved in scoring student work. The ABET committee reviewed the guidance provided by ABET and other educational literature on rubrics when implementing the current rubrics-based approach to outcomes assessment.[9,10,3,13] This knowledge was shared with faculty groups responsible for developing and using the rubrics. The committee agreed to use analytic (vs. holistic) rubrics, which provide specific feedback about the strengths and weaknesses of student performance. Each student outcome is assessed based on measuring one or more analytic categories, or performance indicators, which focus on important aspects of student performance related to the outcome. Examples of performance indicators are given in the assessment examples below; see Table 4 and Table 5. Each indicator is rated individually using points assigned to the performance levels. The committee agreed to use a four-point performance scale. Common terms used for the levels are shown below.

Table 2. Four-point performance scale and respective terms used in the rubrics.

1	2	3	4
• Beginning • Unsatisfactory	• Developing • Partly Satisfactory	• Accomplished • Competent • Satisfactory	• Exemplary • Exceptional • Beyond Satisfactory

The descriptions of performance were developed using this scale and an understanding of the relative performance expected. The terms at a particular level are interchangeable. For example, “Accomplished” and “Competent” represent the same level of performance in the rubrics presented for student outcomes assessment in this paper.

In general, the descriptions were written so that 3 points represents an expected level of performance. Thus, for ABET purposes, a program seeks the attainment of student outcomes with a score of at least 3 points. The ABET committee decided that the percentage of students achieving a score of 3 or better should not be less than 75% when using the rubrics developed for senior design, portfolios, and course-based assessment.

The remainder of the paper presents assessment examples at each level. All assessment instruments and rubrics are available online.[2]

Level 1 Assessment Example

The college implemented a constituent-created, competency-based, ABET-aligned assessment tool for the engineering experiential education workplace using commercial software created by a provider of competency-based performance assessment, development, coaching and learning tools.[4] Via this tool, student outcomes are each multi-dimensional and represent some collection of workplace competencies necessary for the practice of engineering at the professional level. Fifteen competencies are measured by the online tool as shown in Table 3.

Table 3. Core competencies in engineering at Iowa State.

Analysis and Judgment	Engineering Knowledge	Planning
Communication	General Knowledge	Professional Impact
Continuous Learning	Initiative	Quality Orientation
Cultural Adaptability	Innovation	Safety Awareness
Customer Focus	Integrity	Teamwork

The definition of each competency is clear, concise and independent of all others. Specific to each definition is a set of observable and measurable key actions that a student may take that demonstrates their development of that competency. For example, the Initiative competency has the following definition and key actions:

- Initiative: Taking prompt action to accomplish objectives; taking action to achieve goals beyond what is required; being proactive.
- Key Actions
    - Responds quickly. Takes immediate action when confronted with a problem or when made aware of a situation.
    - Takes independent action. Implements new ideas or potential solutions without prompting; does not wait for others to take action or to request action.

- Goes above and beyond. Takes action that goes beyond job requirements in order to achieve objectives.

There is a mapping of the competencies to the ABET (a-k) student outcomes. For example, the Initiative competency is associated to varying extents with student outcomes (a), (b), (c), (d), (e), (g), (i), and (k). Other competencies are associated with fewer outcomes; e.g., Professional Impact is associated with only (d) and (g).

Each supervisor (employer) of a student intern (usually a sophomore or junior) provides an assessment of the student's demonstration of each key action in the workplace. Employers are aware of the college's core competencies, and supervisors know their opinions will be surveyed at the end of an internship. Supervisors are asked to respond to this question for each of the key actions: "When given the opportunity, how often does the student perform the key action?" (5 = always or almost always; 4 – often; 3 – usually; 2 – sometimes; and 1 – never or almost never.) To receive academic credit for their work experience, each student is required to complete the standard self-assessment and to ask that their supervisor complete the same assessment of the student. The supervisor response rate has been between 85 and 95% over the past ten years. A value for student demonstration of each competency is computed as the average of the supervisor's assessment of the associated key actions. A program average for each competency is computed by averaging all the supervisor competency values. A score for "demonstrated achievement" of a student outcome is calculated using the mapping. A "percent demonstrated achievement" is calculated relative to a perfect score of five for each competency.

The results for surveys administered every semester from 2006 through 2011 are shown in Figure 1 below. There were 134 responses from computer engineering intern/co-op students and 84 responses from their supervisors. We use a threshold of 85% (shown as a dashed line in the figure) below which an outcome may represent an area for improvement.

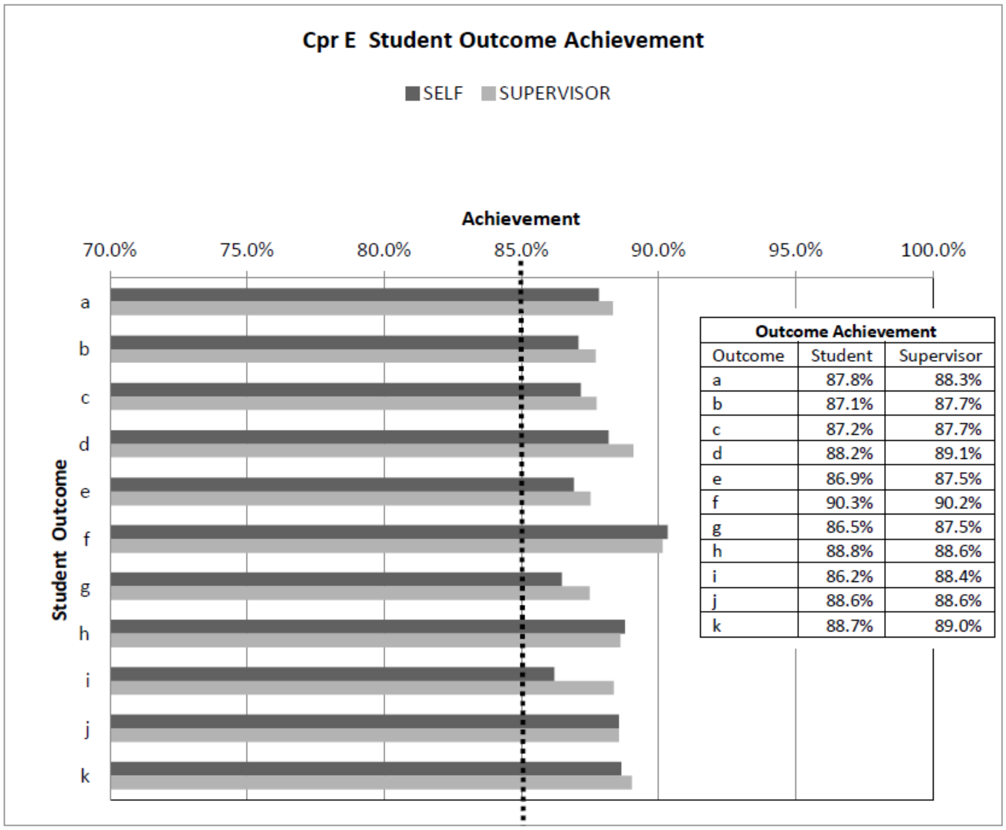


Figure 1. Student outcomes assessment achievement demonstrated through internships.

The supervisor and student data from in the figure indicate that no outcomes have scores lower than the 85% threshold. The student data (student self-assessment of their own actions in the workplace) indicate that the scores for the following outcomes are closest to the threshold: (e) an ability to identify, formulate, and solve engineering problems; (g) an ability to communicate effectively; and (i) a recognition of the need for, and ability to engage in, life-long learning. In addition to (e) and (g), the supervisor data show these as the next lowest scores: (b) an ability to design and conduct experiments, as well as to analyze and interpret data; and (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. Relatively speaking, these outcomes represent areas to assess in more detail and consider for improvement. For example, through an inspection of survey results in more detail, competencies significantly affecting the outcome scores can be identified. The lower score by students on outcome (e) can be traced to a lower rating of their own actions related to the initiative competency. The score for outcome (e) is also affected by the innovation and customer focus competencies, which have the lowest scores of all competencies by both students and supervisors.

Worth noting, however, is that many students take internships in their second and third years. Thus the survey data describe the student experience of some students who are still relatively early in their disciplinary studies. This may affect students' actual knowledge, skills, and abilities in relation to engineering problem-solving, and/or their perception of them. It may also affect the job duties assigned to a student intern. For example, a student may not yet have significant design experience, or there may be limitations on the innovation involved in internship activities compared to what the student sees other engineers working on. The ABET committee considers such factors when interpreting survey results.

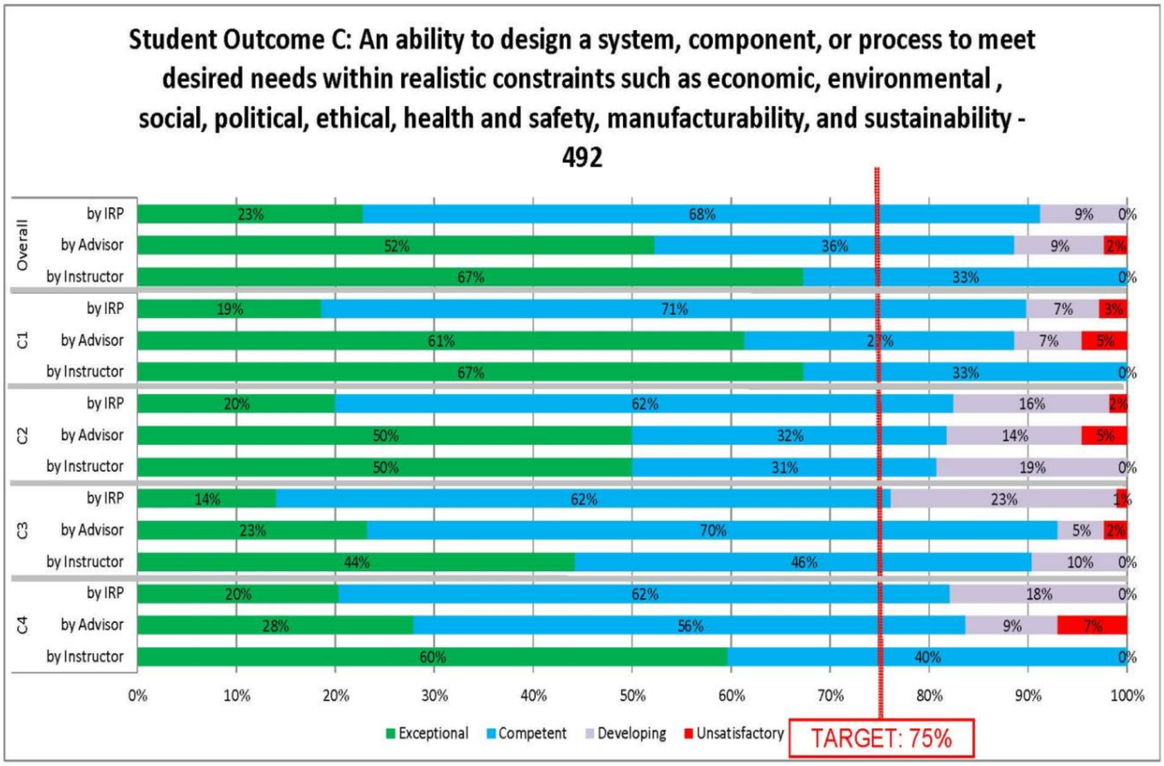
Level 2 Assessment Example: Senior Design

In senior design, the instructor, the project advisor and an industry panel review design work using rubrics. For example, the rubric for student outcome (c) is given in Table 4 below.

Table 4. Rubric for outcome (c) applied to senior design projects.

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				
Performance Indicators	**1: Unsatisfactory**	**2: Developing**	**3: Competent**	**4: Exceptional**
(C1) Develops a design strategy based on project and client needs and constraints.	Lacks design strategy. Does not recognize client needs and constraints.	Has some design strategy. Haphazard approach. Cannot design processes or individual pieces of equipment without significant amounts of help.	Develops a design strategy. Comes up with a reasonable solution.	Develops a design strategy, including project plan and requirements. Suggests new approaches and improves on what has been done before.
(C2) Thinks holistically: sees the whole as well as the parts	Has no knowledge of the design process. No holistic thinking.	Has some knowledge of the design process. Has no concept of the process as a sum of its parts.	Understands the design process. Makes an attempt to think holistically.	Articulates the design process and how areas interrelate. Thinks holistically: Sees the whole as well as the parts.
(C3) Supports design procedure with documentation and references	No documentation	Design is done incompletely without the proper justification. Lacks documentation.	Provides reasonable design procedure with documentation and references.	Clearly lays out the design procedure with supporting analysis. Document relevant information. Provides market/literature survey.
(C4) Considers all the relevant technical, nontechnical constraints and design tradeoffs.	Missing all relevant constraints.	Considered technical constraints. Nontechnical constraints and design tradeoffs are missing.	Design strategy includes relevant technical constraints and design tradeoffs. Some relevant nontechnical constraints are missing.	Design strategy includes all the relevant technical and nontechnical constraints. Clearly shows the design tradeoffs.

Figure 2 below presents the results for outcome (c) as measured in the senior design course.



C1 - Develops a design strategy based on project and client needs and constraints.
C2 - Thinks holistically: sees the whole as well as the parts
C3 - Supports design procedure with documentation and references
C4 - Considers all the relevant technical, nontechnical constraints and design tradeoffs.

Figure 2. Assessment results for student outcome (c) in senior design.

The bar colors of green, blue, gray and red correspond to performance/proficiency levels: exceptional, competent, developing and unsatisfactory, respectively. The x-axis represents the percentage of students achieving each of the proficiency levels. The performance indicators measured for outcome (c) are enumerated along the y-axis. Each performance indicator for senior design is shown with scores by the instructor, the project advisor, and the industry review panel. The top set of bars on the y-axis gives the average over all indicators. The label in each bar segment indicates the percentage of students achieving a specific proficiency. For example, for performance indicator C4 as rated by the industry review panel, 82% of the students were competent or exceptional. The red vertical line represents the target percentage to have 75% achieve a score of 3 (competent) or better. Achieving this target percentage is illustrated graphically when the green and blue bars extend past the red line. The results show that the target is met or exceeded for all indicators and by all raters for this particular measurement of student outcome (c).

Level 2 Assessment Example: Portfolios

Portfolios were introduced earlier in the paper. They are collected every semester and graded by an academic advising staff instructor. A portfolio consists of the following required elements (RE).

RE1. Name
RE2. Front page that describes purpose of portfolio
RE3. Career objective paragraph
RE4. General Educational Reflection and General Education Component
RE5. Examples of prior work
- Minimum of 3 individual or group projects from classes/labs
- Exams, major homework examples, or class presentations/final reports
- Resources used outside of the classroom to complete prior work and problem solving (e.g., specific professional journals, experts in field, other students, library resources)

RE6. Internship/co-op/technical work experience
- Duties and project definitions
- Skills learned
- Evaluations
- Final presentations to managers

RE7. Senior design project
- i. Project definition and role on team
- ii. Individual contribution and skills contributed and learned
- iii. Link to supporting documents such as team website, project plan, project poster
- iv. Specific ways that project may contribute to the solution of a regional, national or global problem

RE8. Résumé
- Undergraduate research, published papers
- Awards/activities

RE9. Cumulative Reflection

The General Education Reflection (element RE4) is expected to answer these questions:

GE1. What are your current short/long term goals?
GE2. How do general education classes help you to think about an engineering problem?
GE3. What have you learned in your general education classes that help you think beyond the technical aspects in engineering problem solving to understand the impact of engineering solutions in a global, economic, environmental, or societal context?

The Cumulative Reflection (element RE9) is expected to address:

CR1. Preparation to:
- design systems or processes,
- formulate and solve engineering problems,
- understand the impact of engineering solutions in a global/societal context,
- work in groups,
- recognize contemporary issues,
- understand professional and ethical responsibilities.

CR2. Information, research or experiences from outside of the classroom that supported completion of class projects or other coursework. Students are asked to identify resources used and how they helped (e.g., library resources, specific professional journals, experts in field, other students).
CR3. Co-curricular or extra-curricular learning activities beyond the required curriculum that served as examples of lifelong learning (e.g., student organizations, career or study abroad fairs, undergraduate research experiences, or other university programs).
CR4. Activities to advance one's ability to apply knowledge and skills to new problems and to develop confidence in taking risks.

With the department's transition to a rubric-based assessment process, student outcomes (h), (i), (j), and (k) are assessed periodically by faculty using rubrics applied to a subset of student portfolios. For example, results for outcome (i), a recognition of the need for, and an ability to engage in life-long learning, are summarized below.

The performance indicators, iA-iC, for the rubric are defined as follows:

(i.A): Description / discussion of use of external sources of information to complete class projects and other problem-solving tasks.

(i.B): Awareness of learning activities outside of the classroom, including participation in professional and technical societies, learning communities, industry experiences, etc.

(i.C): Acknowledgement of how the college experience contributes to understanding the need to continuously update professional skills to solve new problems.

The complete rubric is given in Table 5 below.

Table 5. Rubric for outcome (i) applied to senior portfolios.

Student outcome (i): a recognition of the need for, and an ability to engage in life-long learning				
Performance Indicators	**Proficiency/Performance Scale**			
	1: Beginning	**2: Developing**	**3: Accomplished**	**4: Exemplary**
(i.A) **Description / discussion of use of external sources of information to complete class projects and other problem-solving tasks**	Cannot use materials outside of what is explained in class. Assumes that all learning takes place within the confines of the classroom.	Seldom brings information from outside sources to assignments. Completes only what is required.	Multiple examples of use of external sources of information, including library resources, professional journals, experts in field, and other students.	Demonstrates ability to learn independently – goes beyond what is required in completing an assignment.
(i.B) **Awareness of learning activities outside of the classroom, including participation in professional and technical societies, learning communities, industry experiences, etc.**	Shows little or no interest in outside learning resources, including professional and/or technical societies, learning communities, internships, etc.	Co-curricular and/or extra-curricular learning experience. Occasionally participates in the activities of local learning opportunities.	Multiple co-curricular and/or extra-curricular learning experiences. Active participation in local learning activities.	Participates and takes a leadership role in learning opportunities available to the student body.
(i.C) **Acknowledgement of how the college experience contributes to understanding the need to continuously update professional skills to solve new problems**	Has difficulty in recognizing own shortcomings.	Acknowledges the need to take responsibility for own learning.	Demonstrates connection between short/long term goals and life-long learning.	Demonstrates responsibility for creating one's own learning opportunities.

Selected elements of the portfolio (from the list of required elements above) are examined to determine scores for the rubric. For outcome (i), the following specific elements are reviewed.

Indicators	Cumulative Reflection	General Education Reflection	Senior Design	Other
i.A	CR2	-	RE7.ii, iii	RE5, RE6
i.B	CR3	-	-	RE5, RE6, RE8
i.C	CR4	GE1	RE7.ii, iv	-

The chart in Figure 3 below summarizes the rubric scores for a sample of computer engineering students completing the portfolio course during fall 2011.

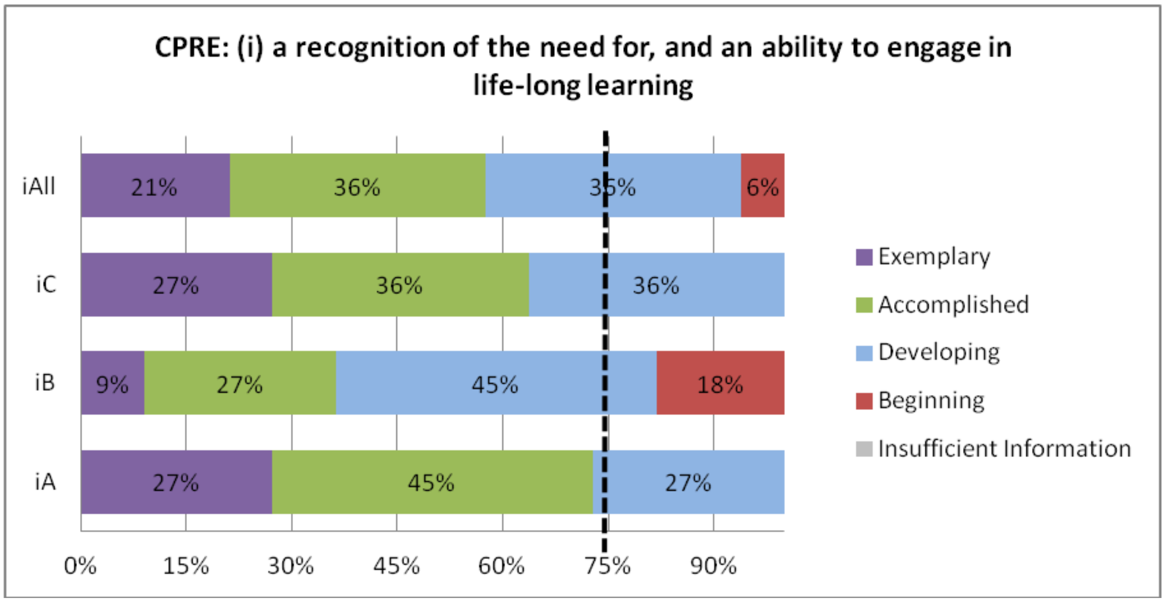


Figure 3. Assessment results for student outcome (i) using senior portfolios.

In this chart, the purple and green bars illustrate proficiencies at levels 4 and 3, respectively; here named exemplary and accomplished. 73% of the students performed at a level of 3 (accomplished) or higher on performance indicator iA, which addresses their use of external information as part of engineering problem formulation and solution. However, only 36% of the students performed at a level of 3 or higher on indicator iB, which addresses their awareness of and participation in learning activities outside of the classroom. Indicator B also shows students with "Beginning" proficiency. 64% of the students performed at a level of 3 or higher on indicator iC, which requires students to recognize needs and opportunities for new learning. The faculty who scored this rubric made the following observations:

1. The scores are highly dependent on the extent to which the student followed the instructions for completing the portfolio.
2. It is likely that interviewing a student would result in higher scores because relevant information would be obtained directly.
3. The portfolio content related to senior design is typically only partially complete because the students take the portfolio course concurrent with the first semester of senior design. Thus the more intensive design work done in the second semester of senior design is not incorporated.

A target threshold of 75% of the students achieving a level of 3 or higher is marked on the chart. These results show that improvement is needed for indicators iB and iC.

Level 3 Assessment Example

Course-based assessment of student outcomes also uses rubrics, which are developed by the ABET committee in collaboration with instructors who teach selected courses. In consultation with an ABET committee member, the instructor selects the student work to review and does the scoring.

For example, outcome (b) is assessed in a 200-level computer engineering course, with results shown in Figure 4 below.

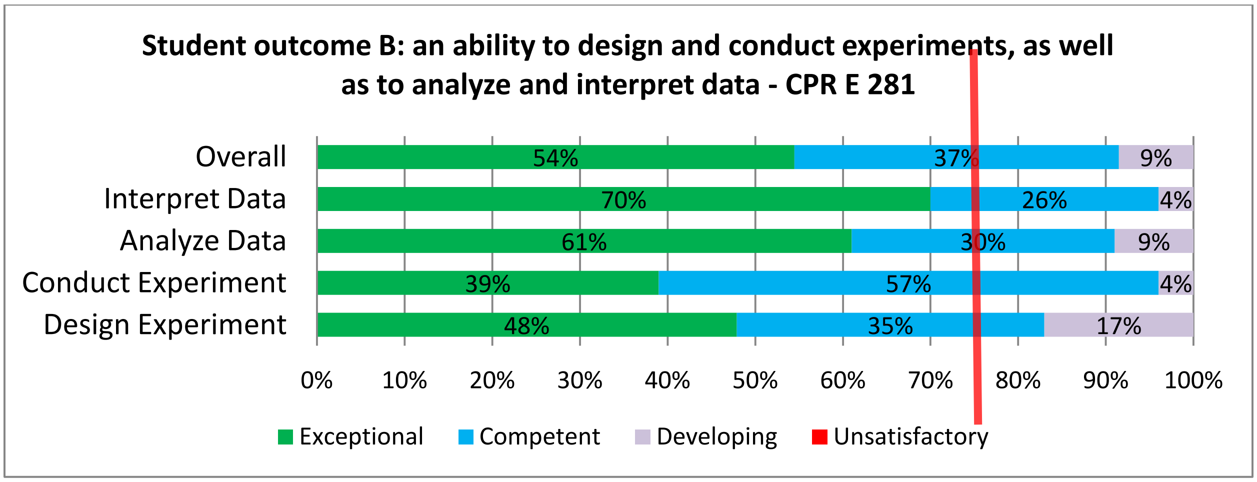


Figure 4. Assessment results for student outcome (b) in CPRE 281.

A specific laboratory experiment (programming the DE2 board to perform binary addition) was chosen since it primarily focuses on experimenting with the board, data collection and analysis. More than 80% of the students achieved levels 4 (exceptional) and 3 (competent) in all four performance indicators, which exceeds the target attainment level of 75%. The area in which most students were not able to perform at the highest level is conducting the experiment, where 39% performed at an exceptional level. For the other three performance indicators, half or more than half of the students performed at an exceptional level. Overall, 91% of the students attained outcome (b) at an exceptional or competent level based on assessment in this course.

It is worth noting that the course-based outcomes assessment is implemented as orthogonal to the primary grading assessment in a course. A specific component of the course, which otherwise may not have been graded separately, is chosen to emphasize the attributes highlighted in the performance indicators of an outcome. For instance, outcome (c) was assessed in CPR E 288, Embedded Systems. Students programmed a robot to navigate a specified race course. Their project grade was based on a rubric emphasizing the degree to which the end-goals were met. The outcome (c) assessment rubric however was applied to a design document that included attributes of the project relevant to the outcome. An outcome rubric score is focused on specific aspects of student learning, whereas a course grade reflects comprehensive learning in a course.

Evaluation of the Assessment Results

All of the assessment results are compiled and reviewed by the ABET committee. Table 6 below refers to the overall assessment of student outcomes. A cell is marked if the committee concluded that the overall assessment result does not meet an expected attainment level.

Table 6. ABET committee evaluation of student outcomes for each assessment method.

Assessment Method	Student Outcomes X: Student outcome does not meet expectations based on assessment results.										
	a	b	c	d	e	f	g	h	i	j	k
Survey of Interns/Employers											
Senior Design Rubrics											
Portfolio Rubrics								X	X		
Course-based Rubrics					X						

Specific performance indicators within rubrics were also reviewed. Table 7 below lists performance indicators that did not meet expectations. There may be cases where one or more performance indicators of a certain rubric that is used to assess a student outcome do not meet expectations, but the overall assessment still meets expectations. For example, performance indicator b4 does not meet expectations when applied to EE 230 (Table 7), but the overall assessment of student outcome (b) meets expectations (Table 6).

Table 7. Summary of performance areas that need attention.

Assessment Method	Student Outcomes Non-blank: Specified performance indicator does not meet expectations.										
	a	b	c	d	e	f	g	h	i	j	k
Survey of Interns/Employers											
Senior Design Rubrics				d1			g1 g6				
Portfolio Rubrics								hB	iA iB iC	jB2 jC	kB
Course-based Rubrics											
CPRE 281: Digital Logic											
EE 230: Electronic Circuits and Systems		b4			e1 e2 e3						
CPRE 288: Embedded Systems											
CPRE 381: Computer Organization					eC						kC
CPRE 310: Theoretical Foundations of Comp. Eng.											
CPRE 394: Program Exploration						fC					

List of performance indicators:
b4: interpreting data
d1: team participation, as assessed by senior design team faculty advisor
e1: identifying key points of the project and an approach to its solution
e2: analyze and solve
e3: prototype, test, evaluate and validate
eC: system integration, testing, and verification; demonstration of correctness
fC: analysis of a complex situation involving ethical interests or principles to support an appropriate course of action
g1: verbal communication organization, as assessed by industry panel
g6: written communications such as use of graphs and tables, as assessed by industry panel

The committee discussed all available results, and made several observations, decisions and recommendations.

For example, the senior design assessment rubrics for its outcomes (a,c,d,e,f,g and k) all met overall expectations. However, several performance metrics for outcome d and outcome g are below expectations. Under outcome d, the performance indicator d1 (team participation) was at 66% level, which is below the 75% threshold. Under outcome g, performance indicators g1 (related to organization in oral presentation) and g6 (related to use of graphs and tables in written communication) were at 71% and 65%, respectively, according to the industry panel. These scores are below the 75% threshold. However the advisor and the instructor scores for g1 and g6 are well above 75%. The ABET committee will work with the senior design committee to understand the communication expectations of the industry panel and develop appropriate action items to improve communications skills. Similarly, the senior design committee will pursue improvements in team participation among students. These actions are consistent with ongoing improvements and other observations in senior design.

As noted earlier, the overall assessment result for outcome (i) using portfolios was below the expected attainment level (55% vs. 75%). Since it is not measured in other courses, there is not a comparison at levels two or three in the multilevel assessment process. This is one of the challenges of outcomes assessment associated with professional (versus technical) skills. However, it can be cross-checked with the employer survey, where it exceeds the target. It's worth noting that it is among the lower rated outcomes, especially by students, on the employer survey. Looking more closely, performance indicator iA, using external information as part of engineering problem solving, was at 73%, and is considered acceptable by the ABET committee. However, the other two performance indicators did not meet expectations. The result for iB, awareness of and participation in learning activities outside the classroom, was unusually low at 36%. Indicator iC, recognition of learning needs and opportunities, was better at 64% but still lower than expected. The faculty who scored the rubric attributed this to portfolio content, i.e., what work students decided to collect, document, or reflect on. However these two performance indicators are also aspects of professional development focused on in newly introduced courses, Program Discovery and Program Exploration. These courses were in response to previous feedback that suggested more attention should be given to these topics. They were first offered in 2010-11 and 2011-12, respectively, and thus were not taken by the fall 2011 students whose portfolios were assessed. Thus, as a result of these courses, portfolio content and outcome (i) are expected to improve. The ABET committee shared this conclusion with the curriculum committee. The ABET committee also observed that improvements in outcome (i) should better prepare graduates to recognize and pursue professional development and continuous learning activities early in their careers, which is one of the educational objectives for the program.

Conclusions

The results, recommendations and ongoing/expected improvements from the assessment and evaluation process contributed to a successful accreditation review for all programs managed by the department.

A number of lessons were learned through this accreditation cycle. Some lessons reinforced previous observations and decisions, whereas others provided new information and insights. In relation to the key objectives of efficiency and faculty involvement for the revised process, the following conclusions are drawn:

- Having a small committee of faculty knowledgeable about the accreditation process adds significantly to the quality of assessment results. For example, a committee member was assigned to shepherd the outcomes assessment procedure for each course. Despite departmental information sessions for faculty on assessment practices, it is challenging

for course instructors to correctly and consistently interpret information and apply the practices in their courses. Using knowledgeable committee members as shepherds is an important and efficient way to involve other faculty.
- The hierarchical/layered assessment approach, exemplified by the Level 1, 2, and 3 assessments, is effective and reduces assessment effort. A higher level view can guide what needs to be assessed more critically at lower levels.

These procedural details are also noted:

- Professional skills outcomes such as (g), (i), and (j) are more effectively assessed later in a student's program, such as in a senior design course or using senior portfolios.
- Although rubrics were discussed and tested to increase understanding and reliability by different scorers, more attention to calibration is needed for course-based outcomes assessment, especially when a rubric is used by different instructors for the same course.

Throughout the assessment and evaluation process, faculty engaged in meaningful conversation and work about teaching and learning. Many faculty participated in assessment in some manner. Discussions about assessment results addressed both the value and the limitations of the process. Faculty generally perceived the process as reasonable in terms of time and effort. Faculty engagement is a key factor to implement and sustain the improvements.

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