An Evolving Capstone Course used in ABET Assessment

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Abstract
The Department of Engineering and Technology at Western Carolina University (WCU) has developed a capstone design course sequence that provides students with industry-relevant projects, while generating an excellent opportunity to assess many of the ABET (Accreditation Board for Engineering and Technology) student outcomes, commonly called "a through k." In its sixth year the two-semester course sequence sees a healthy list of projects that provide cross-functional opportunities for teams composed of undergraduate students in Engineering Technology (ET), Electrical and Computer Engineering Technology (ECET), and Electrical Engineering (EE).

Each of the capstone projects is assigned a faculty mentor, who acts as a resource to the team, providing guidance as well as technical expertise. The mentor is also integrally involved in project grading, as well as course-related program assessment. Each of the a-k student outcomes used in program assessment for ABET accreditation has been broken into multiple "performance indicators (PI)." Each of these PIs has its own related assessment task. Those assessments that are associated with the capstone sequence are part of a team effort, involving the faculty mentors and lead instructor.

This paper documents the system used to put the structure in place to provide consistency in assessment, as well as minimization of tedious effort. Faculty who are having increasing demands placed on their time need to have tools in place to facilitate data entry and report generation. A database that has been developed for assessment tracking is used as a vehicle to standardize and simplify the assessment process.

Introduction

Classified as an "engaged university" under the Carnegie Foundation, Western Carolina University strives to give its students meaningful experiences that can be translated into practice in the workplace and in their personal lives. WCU is a regional comprehensive university, serving over 9,600 students, graduate and undergraduate. The Department of Engineering and Technology has three ABET (Accreditation Board for Engineering and Technology) accredited undergraduate degrees: Engineering Technology, Electrical and Computer Engineering Technology, and Electrical Engineering with approximately 250 students in those majors. The EE program is accredited under the criteria specified by the Engineering Accreditation Commission (EAC), while the ECET and ET programs adhere to those criteria specified by the Engineering Technology Accreditation Commission (ETAC).[1] As is the case at most universities, the ABET assessment efforts are thorough and substantial with a significant effort being placed on the assessment of student outcomes, commonly known as "a through k," as detailed in the next section. The faculty in these three programs have subdivided each of these student outcomes into multiple components, referred to as "performance indicators (PI)." These PIs are defined in more detail in the *Performance Indicators and Student Outcomes Assessment* section that follows later. The PIs provide the granularity to assess each outcome, and since each outcome is typically divided into multiple PIs, it provides an opportunity to assess each outcome through several modes.

ABET Student Outcomes

Engineering and engineering technology programs that have gone through ABET accreditation have become very familiar with student outcomes, commonly known as "a through k." Engineering programs accredited through the Engineering Accreditation Commission of ABET must show that their programs assess the capabilities of their students for the following eleven student outcomes:

(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 life-long learning;

(j) a knowledge of contemporary issues; and

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

Similarly, engineering technology programs accredited through the Engineering Technology Accreditation Commission of ABET must show that their programs assess the capabilities of their students for the following eleven student outcomes:

(a) an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities;

(b) an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies;

(c) an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes;

(d) an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives;

(e) an ability to function effectively as a member or leader on a technical team;

(f) an ability to identify, analyze, and solve broadly-defined engineering technology problems;

(g) an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;

(h) an understanding of the need for and an ability to engage in self-directed continuing professional development;

(i) an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity;

(j) a knowledge of the impact of engineering technology solutions in a societal and global context; and

(k) a commitment to quality, timeliness, and continuous improvement.

Although these student outcomes have become the source of much assessment anxiety, they provide a critical structure for the assessment of an engineering or engineering technology program. The outcomes can be assessed by a number of different methods, such as alumni survey, course exam, project rubric, employer survey, amongst others.

Capstone Course Sequence

The capstone course sequence, commonly called "senior project," has developed into a substantial experience for the EE, ECET, and ET undergraduate students. The course is a two-semester sequence (ENGR 400 and ENGR 450), that students take during two consecutive semesters. The fall semester (ENGR 400) is dedicated to project requirements and system design. The spring semester (ENGR 450) is comprised of project fabrication and testing. This rough formula deviates slightly, as some projects vary in nature and complexity. Projects are typically sponsored by external industrial partners in the region surrounding the university; some projects are internally sponsored and some are sponsored by entities more distant than western North Carolina.

This year 16 projects have been sponsored with 47 students enrolled in the cross-disciplinary course. Project teams are typically composed of two to four students with one faculty mentor assigned as a technical and managerial resource. The technical mix of students varies, depending on the project. Between the 16 projects there are 28 ET students, 11 ECET students, and eight EE students. The grading for the projects is a collaborative effort with input from the faculty mentor, project sponsor, and lead instructor with three milestone presentations each semester.

In the previous five years, 63 projects have been initiated. In order to frame and demonstrate the complexity and varied nature of the addressed problems, several are highlighted as follows: (1) *LED Lighting System to Assist Prostate Cancer Treatment*. Brachy therapy treats cancerous prostate tissue by implanting radioactive seeds into the prostate. A student team developed a disposable light-emitting diode (LED) lighting system and software to connect a physician treatment plan to seed implantation. A second team improved the design by making the system wireless and battery powered. A third team designed and developed an automatic pneumatic seed loading instrument and the device was patented. (2) *Total Knee Replacement Rehabilitation Device*. This project sought to develop a device for home use to assist the patient in achieving full range of motion following a total knee replacement operation. The knee device was subsequently submitted for a patent. (3) *Wake Forest Mannequin*. The purpose of this project was to design and build a prototype mannequin with appropriate mass, geometry, tissue stiffness, and joint stiffness properties to be used for weight shifting and patient transfer simulations. (4) *Medical Tool & Technologies*. The project sought to design, build, and test a head tracking system for use in proton radiation therapy for cancer treatment. (5) *U.S. Coast Guard*. The purpose of this project was to design and build a replacement structure and apparatus for the HU25 jet engines for display models to be placed at several bases. (6) *FLS Energy*. The purpose of this project was to design, build, and test a solar apparatus producing water temperatures at the mid-level (350°F) for use in industrial processes and food production.

Each year the departmental faculty assess courses in each respective program. The two-semester capstone course sequence was divided into six "gates," or milestone presentations. At each gate project team members and mentors enter data into an online tool called Comprehensive Assessment for Team-Member Effectiveness (CATME), which was developed with funding

from the National Science Foundation by a multidisciplinary team at multiple institutions. The website is housed at Purdue University and is free to use for educational purposes.[4] The CATME tool allows students and mentors to evaluate team members, including themselves. These CATME data and additional assessments detailed in the next section were used to formulate the information needed to document those student outcomes that were tied to the capstone course sequence.

Performance Indicators and Student Outcomes Assessment

ABET's student outcomes often specify multiple facets that translate into several capabilities for a student to demonstrate. For example, the ETAC student outcome *(k) a commitment to quality, timeliness, and continuous improvement* can be assessed to consider quality, timeliness and continuous improvement each individually. The faculty of the three programs chose to split these three components of this student outcome into three separate Performance Indicators (PI):

> (k.1) a commitment to quality;
> (k.2) a commitment to timeliness; and
> (k.3) a commitment to continuous improvement.

In this particular case, the PI (k.2) has been selected for assessment in the ENGR 400 course. The other two PIs were assessed in non-capstone courses. Each of the PIs selected for assessment in the capstone sequence required a separate evaluation activity by the project mentor or course lead instructor. Since the ET and ECET programs are both evaluated under the ETAC criteria, their student outcomes were mapped to the same PIs, but since the EE program is evaluated under the ETAC criteria, it was handled independently.

The nature of a capstone course lends itself naturally to program assessment activity. This is where the "rubber meets the road" for engineering and engineering technology students. For this reason, the following EAC and ETAC student outcomes were chosen for assessment in this capstone course sequence (ENGR 400 and 450):

EAC (EE) student outcomes:
(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;
(e) an ability to identify, formulate, and solve engineering problems;
(g) an ability to communicate effectively.

ETAC (ET and ECET) student outcomes:
(a) an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities;
(f) an ability to identify, analyze, and solve broadly-defined engineering technology problems;
(g) an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;
(k) a commitment to quality, timeliness, and continuous improvement.

The PIs for these student outcomes are spelled out in detail in Table 1 for the two courses (ENGR 400 and 450) and the three programs (EE, ET, and ECET).

Table 1: Performance Indicators for EE, ET, and ECET in ENGR 400 and 450

Course/Term	EE Performance Criteria	ET and ECET Performance Criteria
ENGR 400 Fall 2012	(c.1) - An ability to design a system, component, or process to meet desired needs (c.2) – An ability to apply realistic constraints within a system, component, or process design (c.3) – An ability to identify and use appropriate technical literature (e.1) - An ability to identify engineering problems (e.2) - An ability to formulate engineering problems (e.3) - An ability to solve engineering problems	(f.1) - An ability to identify broadly-defined engineering technology problems (f.2) - An ability to analyze broadly-defined engineering technology problems (f.3) - An ability to solve broadly-defined engineering technology problems (k.2) - A commitment to timeliness
ENGR 450 Spring 2013	(g.1) - An ability to produce written technical reports (g.2) - An ability to present oral reports (g.3) - An ability to apply graphical communication techniques	(a.1) - An ability to select and apply the knowledge of the discipline to broadly-defined engineering technology activities (a.2) - An ability to select and apply the techniques of the discipline to broadly-defined engineering technology activities (a.3) - An ability to select and apply the skills of the discipline to broadly-defined engineering technology activities (a.4) - An ability to select and apply the modern tools of the discipline to broadly-defined engineering technology activities (g.1) - An ability to produce written technical reports (g.2) - An ability to present oral reports (g.3) - An ability to apply graphical communications techniques (g.4) - An ability to identify and use appropriate technical literature

Each of the performance indicators in Table 1 were translated into a rubric used by each faculty mentor. The rubric spells out the typical performance level that would be characterized as excellent, satisfactory, marginal, and unsatisfactory. Each student was evaluated to this rubric, as noted by example in Table 2 that follows. This particular rubric was applied to student outcome (f), which was subdivided into three PIs for the ET and ECET program assessment. This particular project team had three ET students on the team, as noted beneath their "generic names." In each case of an applied rubric there are additional supporting data that project mentors maintain, such as project notebooks, 3D solid models, design calculations, etc.

Table 2: Rubric used for PIs (f.1), (f.2), and (f.3) for ET:

| | | Stone | | | | Mentor Name: | | |
| | | Rotor Core Assembly | | | | Project Name: | | |

ENGR 400 ETAC Rubric

f. an ability to identify, analyze, and solve broadly-defined engineering technology problems

Performance Criteria (f.1) - An ability to identify broadly-defined engineering technology problems

Performance Criteria (f.2) - An ability to analyze broadly-defined engineering technology problems

Performance Criteria (f.3) - An ability to solve broadly-defined engineering technology problems

						Stone Rotor Core Assembly	Stone Rotor Core Assembly	Stone Rotor Core Assembly
						92xxxxxx	92yyyyyy	92zzzzzzz
						Student A	Student B	Student C
REF	Performance Indicator	Excellent (4)	Satisfactory (3)	Marginal (2)	Unsatisfactory (1)	ET	ET	ET
f.1.	*CPI #1 : Through preliminary investigation, the student shall be able to identify a design problem for a model, prototype, or process*	Able to interpret technical knowledge without assistance in problem selection; articulates how his/her particular skills or knowledge is suitable and applicable to problem selected; able to see the whole as well as parts of the problem; able to interpret without assistance prescribed criteria.	With limited instructor assistance, able to interpret technical knowledge in problem selection; can articulate how his/her particular skills or knowledge is suitable and applicable to problem selected; needs some instructor assistance with seeing problem as whole and parts of the problem and interpreting prescribed criteria.	Needs instructor assistance in interpreting technical knowledge in problem selection; difficulty determining how his/her prior skills and knowledge apply to problem solution; difficulty with stating the overall problem and identifying parts within the problem; needs assistance in interpreting prescribed criteria.	Lacks ability in interpreting technical knowledge in problem selection; unable to determine how prior skills and knowledge apply to problem selection or solution; unable to articulate the problem as a whole; needs assistance in interpreting prescribed criteria	4	4	3
f.2.	*CPI #1 : The student shall be able to recognize elements and constraints of a problem and formulate a design to satisfy prescribed criteria.*	Able to see the problem as a whole as well as parts of the problem; identifies constraints within problem without assistance; able to articulate and discuss how constraints affect problem design and solution; ability to articulate an initial experimental design procedure for problem solution; uses appropriate literature where necessary.	Able to see the problem as a whole as well as parts of the problem; identifies at least one constraint within problem; with some assistance able to articulate and discuss how constraints affect problem design and solution; ability to articulate an initial experimental design procedure where problem solution; uses appropriate literature where necessary.	Difficulty seeing the problem as a whole as well as parts of the problem; difficulty in determining constraints; needs significant assistance to articulate and discuss how constraints affect problem design and solution; poor initial experimental design procedure for problem solution ; not familiar with how to apply appropriate literature.	Difficulty seeing the problem as a whole as well as parts of the problem; cannot identify or apply constraints; needs significant assistance to articulate and discuss how constraints affect problem design and solution; poor initial experimental design procedure for problem solution ; not familiar with how to apply appropriate literature.	3	3	3
f.3.	*CPI #1 : The student shall be able to apply logical problem solution methods to develop a solution for a proposed model, prototype, or process.*	Develops a design strategy, including a plan of attack, details work into subtasks, development of a timetable; develops several potential solutions and determines optimum; demonstrates ability to integrate prior knowledge into new problem; uses computer tools and engineering resources effectively; supports design procedure with documentation and references; applies engineering and/or scientific principles correctly; recognizes practical significance of design outcome/answer.	Develops a solid basic design process, timetable included; relies primarily on a single design solution; is able to integrate prior knowledge into design process; generally sees the overall concept of the problem; uses computer tools and engineering resources effectively; supports design procedure with documentation and references; applies engineering and/or scientific principles correctly; recognizes practical significance of design outcome/answer.	Exhibits limited knowledge with regard to what constitutes a design process; design tends to be sketchy; minimal research is evident with regard to developing a solution to the design problem; documentation and references are weak and incomplete; lacks confidence in applying engineering and/or scientific principles; weak understanding of practical significance of design outcome/answer.	No design strategy; cannot develop a design without significant assistance; focuses on only one solution; much difficulty with relating prior knowledge into design process; difficulty applying computer tools and engineering resources; no references included; no application of engineering and/or scientific principles; no specific outcome or answer in evident.	3	3	3

Student 92#

Student Name

Major (ECET,ET)

Once each faculty mentor evaluated each student on each team for each PI, the data were sent to the assessment coordinator to be aggregated. These rubrics were developed in a Microsoft Excel spreadsheet. Prior to sending the rubrics to individual mentors, the spreadsheets were standardized with most fields in protected mode. This ensured the highest chances of success in combining the data from all mentors for the 16 projects. If these fields had not been protected, there is a high likelihood that well-meaning faculty members would insert rows, add extraneous data, and complicate the process for the assessment coordinator. The aggregated responses for the Fall 2012 PIs (ENGR 400) and the Spring 2013 PIs (ENGR 450) will form the backbone of the assessment data for all three programs. The 2012-13 academic year is being used as a pilot to form the methodology for assessment with the 2013-14 academic year being the assessment year for the next ABET self study. Accreditation visits are scheduled for 2014-15 for ECET and ET, and 2016-17 for EE.

Conclusions and Future Work

Every ABET accredited engineering and engineering technology program undergoes periodic review. Most programs go through assessment development that advances its programs toward higher success in achieving their student outcomes. Following the most recent ABET reviews, the EE, ECET, and ET programs at Western Carolina University have adopted an approach to split each student outcome into multiple performance indicators. Those PIs have been mapped into assessment modes with many of them falling into the capstone course sequence. This paper documents the process employed to map those PIs and assess each through the use of a rubric by a project faculty mentor. The results of this assessment will become more clear upon the next ABET review.

In addition to the efforts presented here, a department-maintained assessment database (Microsoft Access), piloted during the 2011-12 academic year is being utilized.[5] The database is expected to play a significant role in providing an electronic repository for WCU faculty to organize assessment data and for ABET visitors to find information.

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