AC 2009-197: ASSESSMENT OF PROGRAM OUTCOMES FOR ABET ACCREDITATION

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ASSESSMENT OF PROGRAM OUTCOMES FOR ABET ACCREDITATION

Abstract
In EAC Criterion 3, ABET requires the degree program to demonstrate to the extent each program outcome is met. One of the main challenges is the development of measurable learning outcomes. This paper presents an overview of defining a set of performance criteria for each program outcome to convert the program outcomes into measurable learning outcomes. It then focuses on a weighted average approach to assemble assessment data for analysis. The assessment approach presented in the paper can be a good model for new institutions or programs seeking ABET accreditation. It can also provide ideas for existing programs that have already been through previous assessment cycles.

I. Introduction

The Engineering Accreditation Commission (EAC) publishes an accreditation criteria document annually[1]. The document lists nine criteria to be met by the program for successful accreditation. Criterion 3 “Program Outcomes” is one of the most challenging criteria. Recent statistics by ABET indicated that about 35% of the 59 programs evaluated at 20 institutions in 2007 had shortcomings in Criterion 3[2].

Program outcomes are statements that describe what students are expected to know and be able to do by the time of graduation. They relate to the skills, knowledge and behaviors that students acquire in their matriculation through the program. In this criterion, ABET requires the program to demonstrate “the degree to which the program outcomes are attained” by the program[1]. This is challenging because it requires a good mix of direct and indirect assessment of student performance, systematic data collection, assembly, analysis and evaluation. Furthermore, the program must demonstrate that there is a continuous improvement process in place. For new programs or existing programs, transition to this new outcomes-based approach can be difficult.

At many institutions the program outcomes are assessed using various rubrics. Course content is mapped directly to the program outcomes and student grades are used to show the level of achievement of the program outcomes. Faculty course assessment reports are used to measure and document the program outcomes[3,4,5]. Capstone courses are where culminating projects are given to the students. Therefore, sometimes these courses are used either to assess all program outcomes or a subset of them using rubrics for oral presentations, report writing and teamwork[6,7].

The development of measurable learning outcomes is the most crucial aspect of any assessment process[8]. Curriculum maps showing how the program outcomes are addressed across a curriculum or within given courses can demonstrate that certain types of materials are *presented* to the students. But these maps do not provide *evidence of student learning* of the desired skills. Furthermore, surveys and course grades are not, by themselves or collectively, acceptable methods for documenting achievement of outcomes since they provide evidence of either student opinions, or of generalized student achievement across potentially broad areas of study.

The ABET Criterion 3 program outcomes can be turned into measurable learning outcomes through the use of performance criteria (PC). The performance criteria are a set of measurable statements to define each learning outcome[9]. They identify the specific knowledge, skills, attitudes, and/or behavior students must demonstrate as indicators of achieving the outcome (Appendix).

We designed and implemented an assessment process with performance criteria as a new Mechanical Engineering program was established at Washington State University Vancouver. In this paper, we focus on the details of how we assemble the assessment data coming from various tools. The ultimate goal is to demonstrate "the degree to which the program outcomes are attained" as required by ABET Criterion 3. But first, we present an overview of the development of the performance criteria.

II. Overview of performance criteria

The program faculty decided to adopt the eleven ABET EAC Criteria "a" through "k" as the program outcomes for our new mechanical engineering program. Then, we developed a set of performance criteria (PC) for each of the 11 program outcomes. The goal was to measure and demonstrate how well the outcomes were met.

Our efforts were guided by a framework for EC 2000[10]. It provided Bloom and Krathwohl definitions of learning levels (knowledge, comprehension, application, analysis, synthesis, evaluation and valuation). For each ABET program outcome "a" through "k", the framework listed things students should be able to do at each level of learning.

Faculty members were provided with a copy of the framework. Each faculty member first looked at the list of outcomes "a" through "k" and decided which outcomes applied to a particular course they taught. Then, in each of the applicable outcomes, they decided which learning levels and action verbs were applicable. We went through this exercise for every course in the curriculum. After many faculty meetings, we were able to identify which of these action verbs appeared most frequently under each program outcome throughout the courses of the curriculum. Through some reduction, elimination and combinations we arrived at the performance criteria for each of the program outcomes (Appendix). To be measurable, each performance criteria had to start with an action verb, such as "apply", "choose", "analyze", "validate", corresponding to the levels of learning. The performance criteria were then presented to the Industry Advisory Board for their input and approval.

We developed 38 performance criteria for the 11 program outcomes. In the next step the PCs were mapped to the curriculum (Figure 1).

Course	A1	A2	A3	A4	A5	A6	A7	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	E1	E2	E3	F1
MECH 101 Intro to Mech Eng			x												x							x
MECH 103 Engr. Graphics													x									
MECH 211 Statics	x	x	x	x																		
MECH 212 Dynamics	x	x	x	x																		
MECH 215 Mechanics of Materials	x	x	x	x																		x
MATH 360 Probability & Statistics	x	x			x	x			x	x										x	x	
MECH 303 Fluid Mechanics	x	x	x	x			x		x		x								x	x	x	
MECH 304 Instru. & Measurement		x	x						x		x										x	
MECH 309 Intro to Engineering Materials			x	x				x	x	x	x										x	
MECH 313 Engineering Analysis	x																				x	
MECH 301 Thermodynamics	x	x	x	x															x	x	x	
MECH 310 Intro to Design & Manufacturing			x	x					x	x	x			x	x						x	
MECH 314 Design Process			x	x				x				x	x	x	x	x	x	x				x
MECH 348 Dynamic Systems & Control	x	x	x	x			x													x	x	
MECH 405 Intro to Microcontrollers													x	x	x	x	x	x				
MECH 425 Intro to Manufacturing Systems			x	x	x	x													x	x	x	x
MECH 431 Semiconductor Devices	x		x	x			x														x	
MECH 404 Heat Transfer	x		x	x			x					x	x	x					x		x	

Figure 1. A portion of the Courses-to-PC matrix. "X" shows performance criteria that appear in a given course. The boxes show where assessment data samples are taken for program assessment.

We interpreted the applicable performance criteria in the context of each course to develop course outcomes[11]. This way, activities in the courses would be linked to the program outcomes through the performance criteria. Table 1 provides examples of how A-2 at the program level was interpreted in each of the courses where it appeared.

Table 1
A Performance Criterion Interpreted In the Context of Courses

At the program level "A-2" reads:

A-2. Chooses appropriate mathematical model for a system or process

Course	**"A-2" Interpreted in the context of courses**
	Students will
Mech 211 Statics	Choose appropriate mathematical models for bodies at rest
Mech 212 Dynamics	Choose appropriate mathematical models to write equations of motion for particles and rigid bodies
Math 360 Statistics	Choose appropriate mathematical models such as student's t-test and F-test to analyze sample data to interpret and draw conclusions for population data
Mech 303 Fluid Mechanics	Choose the integral or differential form of equations to solve for the mass, momentum and energy balance of the systems
Mech 467 Automation	Choose appropriate transfer function models based on the dynamic response of a system

Table 2 shows the course outcomes of Mech 467 "Automation" course as an example.

Table 2
Course Outcomes for Mech 467 “Automation”

Students will be able to:	
A-2.	Choose appropriate transfer function models based on the dynamic response of a system.
A-7.	Analyze system response using mathematical models.
B-4.	Validate control theory with experimental results.
E-3.	Design controllers using the root-locus method.
G-1.	Produce lab reports explaining lab activities and results.
K-3.	Write PLC programs or simulate system response.
K-4.	Use MATLAB software for analysis.

In the next section, we briefly describe how we assess the achievement of the course outcomes by the students.

III. Assessment of course outcomes

All scores in our assessment system use the standard 1 to 5 Likert scale as the rubric (5: Consistently exceeds expectations, 4: Exceeds expectations, 3: Meets minimum expectations, 2: Seldomly meets expectations, and 1: Never meets expectations). At the end of the semester, each student gets a “score” on the scale of 1 to 5 indicating how well he/she achieved each course outcome. So, if there are 7 course outcomes as in the case of the Mech 467 Automation course, then each student gets 7 scores indicating how well he/she achieved each outcome. Along with the scores, each student also receives a regular letter grade for the course (A, B+, C-, etc.).

The instructors arrive at these scores by assigning specific problems in homework and exams designed to target the course outcomes throughout the semester. For example, if there are 10 questions on an exam, the first two may target course outcome A-2, next 3 may target course outcome E-3 and the last five may target course outcome B-2. The instructors have detailed spreadsheets where they accumulate the grades each student gets towards a given course outcome throughout the assignments and exams of the semester. At the end, they have a cumulative grade for each student for each course outcome. These grades are then converted into a standard scale of 1 to 5 outcome “scores”. A detailed coverage of this course outcomes assessment process can be found in[12].

The department provides each instructor with a standard spreadsheet. They enter the final scores into that spreadsheet and send it back to the department. The standard spreadsheet computes class averages and distributions for each course outcome (Figure 2).

Course Outcome	Average	Distribution				
		5	4	3	2	1
A-2	4.5	47%	53%	0%	0%	0%
A-7	4.8	76%	24%	0%	0%	0%
B-4	4.5	47%	53%	0%	0%	0%
E-3	4.5	65%	24%	12%	0%	0%
G-1	5.0	100%	0%	0%	0%	0%
K-3	4.7	71%	29%	0%	0%	0%
K-4	4.5	53%	41%	6%	0%	0%

Figure 2. Instructor's assessment scores for the course outcomes in Mech 467.

The data as well as sample student work are placed in a course portfolio for each course. Now, we will describe how the data are combined to analyze and evaluate the achievement of each program outcome.

IV. Analysis of assessment data

Assessment data for each performance criteria are collected using various tools such as exit surveys, design panel[13], focus group study, student course surveys, etc. For example, for A-2 the data come from the course portfolios of the courses where A-2 appears, from exit surveys, from alumni surveys and from student course surveys.

Immediately after the Spring semester ends, the curriculum assessment committee starts working on the assessment data. The ultimate goal is to write a program assessment report. This report contains data and trend charts showing how well each program outcome was achieved in the current academic year. It also summarizes recommendations by the faculty for changes to improve the performance in the next academic year.

The assembly of the data is a fairly complex process. The main idea is to assemble the data using a weighted average approach. We use A-2 as an example in the rest of this section to explain the details.

We built 11 separate Excel spreadsheets, one for each program outcome "a" through "k" to process the data. In each spreadsheet there are tabs for each performance criterion. For example, the spreadsheet for outcome "A" contains seven tabs (A-1 through A-7). Furthermore, each spreadsheet has a tab where the overall achievement of the outcome is computed. Figure 3 shows the tabs for A-2 and for overall outcome "A".

A-2. Chooses appropriate mathematical model for a system or process.

Instructor Assessment from Course Portfolio

Course	Ave.	5	4	3	2	1	Weight
Math 360	3.80	20%	44%	28%	8%	0%	3
Mech 211	4.62	62%	38%	0%	0%	0%	3
Mech 215	4.10	27%	53%	20%	0%	0%	3
Mech 303	4.20	0%	73%	18%	9%	0%	5
Mech 348	4.00	14%	76%	10%	0%	0%	5
Total Weighted	4.13	21%	61%	15%	4%	0%	19
Assessment Tool Weight							5

Student Course Survey

Course	Ave.	5	4	3	2	1	Weight
Math 360	3.78	20%	46%	27%	7%	0%	3
Mech 211	4.23	46%	38%	8%	8%	0%	3
Mech 215	4.08	23%	62%	15%	0%	0%	3
Mech 303	4.04	17%	71%	13%	0%	0%	5
Mech 348	4.08	27%	54%	19%	0%	0%	5
Total Weighted	4.05	26%	56%	16%	2%	0%	19
Assessment Tool Weight							4

Exit Survey	4.24	29%	65%	6%	0%	0%	
Assessment Tool Weight							3
Alumni Survey	4.33	44%	44%	11%	0%	0%	
Assessment Tool Weight							3
Overall	**4.17**	**28%**	**57%**	**13%**	**2%**	**0%**	

(a)

A. Knowledge of mathematics, science, and engineering and the ability to apply this knowledge in solving problems

		Category					Criterion
Performance Criterion	Average	5	4	3	2	1	Weight
A-1	4.20	32%	55%	11%	2%	0%	4
A-2	4.17	28%	57%	13%	2%	0%	3
A-3	4.32	33%	57%	10%	1%	1%	5
A-4	4.21	28%	56%	13%	3%	0%	5
A-5	4.23	36%	51%	13%	0%	0%	1
A-6	4.09	25%	59%	16%	1%	0%	2
A-7	4.22	32%	50%	14%	4%	0%	3
Outcome A	**4.22**	**30%**	**55%**	**12%**	**2%**	**0%**	**23**

(b)

Figure 3. (a) Computations on the A-2 tab, (b) Computations on the outcome "A" tab.

Course weights - Faculty decided that each course contributing to a particular performance criterion does so at varying levels depending on the emphasis of the course. As a result, the faculty assigned weights, on the scale of 1 to 5, describing how each course contributes to a particular performance criterion. Using these weights and scores from each course portfolio for A-2, we compute the overall weighted average from course portfolio data. Similarly, the student survey data and the exit survey data are used to compute their respective weighted averages.

Tool weights - Just like each course contributes to the performance criteria at varying levels, each assessment tool can have a varying degree of reliability in assessing a particular performance criterion. In general, direct measurement tools, such as the course portfolio (instructor scores as described in Section III), are more reliable. Hence, the faculty decided to assign weights to each assessment tool.

Criterion weights – Using the same reasoning, faculty decided that each performance criterion contributes to the achievement of outcome A at a varying degree. The program puts more emphasis on some criteria than others. Therefore, each criterion was assigned weights. By computing the weighted sum of all performance criteria we arrive at the overall score for outcome A at the program level.

V. Evaluation

The spreadsheets used in the analysis produce three charts annually for each of the 11 program outcomes (Figure 4).

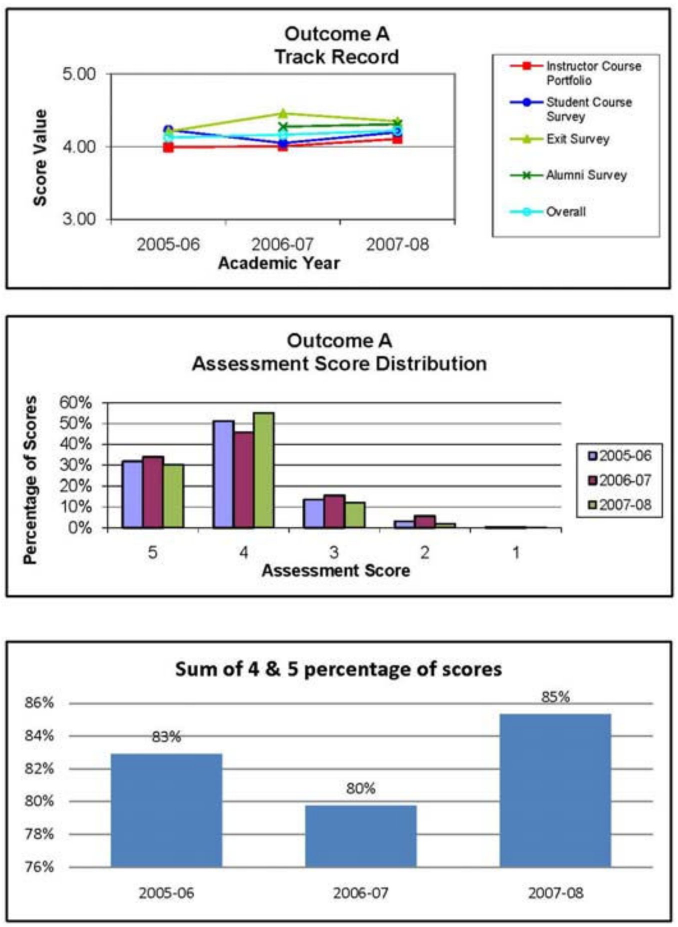

Figure 4. Track record for program outcome A.

The top chart shows the average scores on the scale of 1 to 5 indicating how well the program achieved the outcome in each academic year. The chart also shows assessment results coming from each tool. The middle chart is a distribution of scores on the scale of 1 to 5. The bottom chart shows the summation of percentages of 5 and 4 scores in each academic year.

The evaluation process involves reviewing the results of the assessment data to make decisions leading to changes in the program. For this purpose the faculty defined the following program target to provide metric goals for each outcome:

> *In each program outcome, 80% or more of our students will achieve that outcome with a score of 4.0 or higher.*

In other words, when the percentage of students in the 4 and 5 scores in the distribution chart (Figure 4) are combined, the result should be at least 80% for that outcome to be successfully achieved at the program level. If this level is not achieved, we look for ways to improve the performance.

The assessment report prepared by the curriculum assessment committee, these charts and the faculty recommendations are used in the "closing the loop" faculty meeting shortly after the end of each Spring semester. In this meeting the program faculty evaluates the results and approves changes to the curriculum.

VI. Conclusions

ABET EAC Criterion 3, requires the program to demonstrate "the degree to which the program outcomes are attained" by the program. We turned our program outcomes into measurable learning outcomes through the use of performance criteria. These criteria identify the specific knowledge, skills, attitudes, and/or behavior students must demonstrate as indicators of achieving the outcome.

Using various assessment tools, we can gather data on how well students are achieving each of the performance criteria, hence the program outcomes. One of the challenges is the assembly of the data for analysis. In this paper, we focused on the details of the weighted average approach we developed.

The assessment approach leads to track record charts for each of the 11 program outcomes. These charts allowed us to document "the degree to which the program outcomes are attained" as required by Criterion 3.

Our new program was visited by an ABET team in 2007 for its first evaluation. We received full term accreditation. The assessment approach presented in this paper can be a good model for new institutions or programs seeking ABET accreditation. It can also provide ideas for existing programs that have already been through previous assessment cycles.

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APPENDIX

Performance Criteria

And Program Outcomes

A. Knowledge of mathematics, science, and engineering and the ability to apply this knowledge in solving problems.

- A-1. Applies mathematics (multivariate calculus, differential equation, and/or linear algebra) to obtain analytical or numerical solutions.
- A-2. Chooses appropriate mathematical model for a system or process.
- A-3. Demonstrates knowledge of fundamental scientific (chemistry, physics) and/or engineering principles.
- A-4. Applies scientific (chemistry, physics) and/or engineering principles toward solving engineering problems.
- A-5. Demonstrates knowledge of basic principles of statistics.
- A-6. Applies statistical methods in analyzing data.
- A-7. Analyzes modeling results of systems or processes using fundamental scientific and engineering principles.

B. An ability to design and conduct experiments, as well as to analyze and interpret data.

- B-1. Identifies the constraints, assumptions, and models for the experiment.
- B-2. Uses appropriate equipment and techniques for data collection.
- B-3. Analyzes experimental data using appropriate tools and/or statistical tools.
- B-4. Validates experimental results with respect to assumptions, constraints, and theory.

C. Ability to design and realize thermal and mechanical components, systems, or processes to meet desired needs and realistic constraints such as economical, environmental, social, political, ethical, health and safety, manufacturability and sustainability.

- C-1. Analyzes needs to produce problem definition for thermal or mechanical systems.
- C-2. Carries out design process (such as concept generation, modeling, evaluation, iteration) to satisfy project requirements for thermal or mechanical systems.
- C-3. Can work within realistic constraints, (such as economical, environmental, social, political, manufacturability, health and safety, ethical, and sustainability) in realizing systems.
- C-4. Can build prototypes that meet design specifications.

D. Ability to function on multi-disciplinary teams.

- D-1. Shares responsibilities and information on schedule with others on the team.
- D-2. Participates in the development and selection of ideas.
- D-3. Demonstrates good interpersonal skills on a team.

E. Ability to identify, formulate, and solve problems encountered in the practice of mechanical engineering.

- E-1. Classifies information to identify engineering problems.
- E-2. Examines alternatives using mathematical, scientific, and engineering knowledge to formulate solutions.

Continued on next page.

E-3. Uses analytical, computational, and/or experimental methods to obtain solutions.

F. Understanding of professional and ethical responsibility.

F-1. Evaluates ethical issues (such as safety intellectual property, reporting data, etc.) that may occur in professional practice using professional code of ethics.

F-2. Interacts with industry, project sponsors, professional societies, and/or community in a professional manner.

G. Ability to communicate effectively.

G-1. Produces a variety of documents, such as lab or project reports, using appropriate formats and grammar with discipline-specific conventions including citations.

G-2. Delivers well-organized, logical oral presentations, including good explanations when questioned.

H. Ability to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

H-1. Aware of the impact of engineering solutions in a global context.

H-2. Able to explain how engineering solutions impact society.

H-3. Able to evaluate the impact of engineering solutions on the environment.

H-4. Aware of the impact of engineering solutions in an economic context.

I. Recognition of the need for, and an ability to engage in life-long learning.

I-1. Able to use resources to learn new material not taught in class.

I-2. Able to list sources for continuing education opportunities.

I-3. Recognizes the need to accept personal responsibility for learning and the importance of life-long learning.

J. Knowledge of contemporary issues

J-1. Describes the impact of contemporary issues (such as environmental, global trade, economic, health, safety tradeoffs, and emerging technologies).

J-2. Describes impact of engineering decisions on energy resources.

K. Ability to use the techniques, skills, and modern engineering tools necessary for mechanical engineering practice.

K-1. Able to set-up and/or operate engineering equipment for projects.

K-2. Able to establish interfaces among systems.

K-3. Writes high-level programs to simulate systems, to control systems, and for numerical solutions of engineering problems.

K-4. Uses software for analysis, synthesis and presentation.

Continued from previous page.