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Planning and Implementing an Assessment Process with Performance Criteria for ABET Accreditation*

HAKAN GUROCAK
School of Engineering and Computer Science, Washington State University, Vancouver, WA, USA. E-mail: hgurocak@vancouver.wsu.edu

One of the most challenging criteria for engineering programs to meet for successful ABET accreditation is the Criterion 3 Program Outcomes. In this criterion, ABET requires the program to demonstrate the extent to which each outcome is met by the program. This requires a good mix of direct and indirect assessment of student performance, systematic data collection, assembly, analysis and evaluation. But the main challenge is the development of measurable learning outcomes. This paper presents an approach that defines a set of performance criteria for each program outcome to convert all program outcomes into measurable learning outcomes. The performance criteria create a middle layer between course outcomes and the program outcomes. Primary steps for planning such an assessment system as well as the analysis approach developed to assemble the data coming from various assessment tools are explained in detail. 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.

Keywords: ABET; accreditation; assessment; evaluation; performance criteria; outcomes; objectives

INTRODUCTION

IN THE UNITED STATES, accreditation is a non-governmental, peer review process that ensures educational quality. ABET, Inc., is responsible for the specialized accreditation of educational programs in applied science, computing, engineering, and technology. Educational institutions or programs volunteer to periodically undergo this review. ABET accreditation is assurance that a college or university program meets the quality standards established by the engineering profession for which it prepares its students.

ABET also evaluated programs outside the US by institutional request, in order to determine if they are "substantially equivalent" to ABET-accredited programs and to make recommendations for program improvement. In 2005, the ABET Board of Directors approved phasing out the substantial equivalency evaluations and started developing a plan for non-domestic accreditation. The first accreditation visits outside the United States were held in 2007.

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" [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. Supporting evidence must be presented and the process must also be well documented. 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. ABET does not prescribe any details on the assessment process. Instead, it is the program's responsibility to demonstrate to ABET that there is a robust assessment process in place which facilitates continuous improvement.

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. Portfolios [3] or faculty course assessment reports (FCAR)

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are used to measure and document the program outcomes. Typically, the FCARs use questions, project reports, and presentations to measure the outcomes. In some cases, each program outcome is mapped to a set of courses and the average student grades in these courses are used to indicate the level of achievement of the program outcomes [4, 5, 6]. Another approach involved course audits done by two program faculty using a set of rubrics to provide immediate feedback to the instructor of the course. Student and alumni surveys were used in combination with the course audits to assess the program outcomes [7]. A slightly different approach involves embedded indicators. The performance of all students is measured at different points in the curriculum using a set of indicators such as certain lab reports, design problems, capstone projects and essay questions. The indicators are linked to the program outcomes to assess the level of achievement [8, 9, 10]. Capstone courses are where culminating projects are given to the students. Therefore, sometimes these courses are used either to assess all of the program outcomes or a subset of them using rubrics for oral presentations, report writing and teamwork [11, 12, 13, 14].

The development of measurable learning outcomes is the most crucial aspect of any assessment process [15]. 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 [16, 17, 18]. 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. They identify the specific knowledge, skills, attitudes, and/or behavior students must demonstrate as indicators of achieving the outcome (Appendix). Defining the PCs is the most difficult part of an assessment process [19, 20]; hence there is some resistance by faculty to developing them in their programs [21]. The absence of the PCs generally leads to heavy workloads and unreasonable expectations of faculty, as they are required to collect anything that looks like the outcome. The PCs are not sufficient by themselves for program outcomes assessment. Ideally, the assessment strategy should have the ability to be coordinated across a program as a whole; provide feedback that is informative as well as easily organized and interpreted; and facilitate reflection and improvements on multiple levels.

We designed and implemented an assessment process with performance criteria as a new Mechanical Engineering program was established at Washington State University Vancouver. The performance criteria were used in a unique way to tie the program outcomes to course outcomes. The system helped demonstrate the degree to which each of the ABET program outcomes was attained in a continuous improvement effort.

ASSESSMENT PROCESS PLANNING

The main goal of our assessment process is to demonstrate the level of achievement of the program outcomes in ABET EAC Criterion 3 [1]. However, assessment is not, of course, the end goal. The end-goal is to use the data gathered from assessment to arrive at possible improvements in the program [22]. An assessment system must be carefully planned and implemented to generate the necessary data and to act on them to continuously improve the curriculum.

Design and implementation of an assessment process must engage program faculty from the very first step. But most faculty members don't know much about assessment or are not engaged in the accreditation process. Furthermore, they don't have time to come up to speed with the details. In our case, the department chair started engaging the faculty in the assessment process by offering two short workshops. The materials for these workshops were compiled and summarized by the department chair after an extensive literature search and after he attended workshops offered by ABET. Our first departmental workshop, ABET 101, was about the assessment process and the criteria. The second workshop, ABET 102, examined some of the ideas and implementations found in the literature that addressed specific parts of the process.

Planning our assessment system involved several steps as shown in Table 1. The first step, development of the program outcomes, was relatively easy since the faculty decided to adopt the ABET program outcomes Criterion 3 "a" through "k" (Appendix). The second step, development of the performance criteria, was much more involved as explained later. Next, the performance criteria had to be mapped to the courses and all course syllabi had to be updated with new course outcomes. This process essentially realigned the curriculum with the desired program outcomes. Various assessment tools were selected and mapped to the performance criteria to measure the level of achievement of the program outcomes. On the analysis side, we had to decide how to process, assemble and analyze the incoming assessment data. The approach we developed is explained in detail below. Forms had to be developed to evaluate the results and to create action items to change the curriculum. We planned how to handle the documentation of the entire effort. Finally, the timeline of events in the assessment cycle and responsibilities of individual faculty and/or committees had to be defined clearly.

Performance criteria applied to the curriculum

We decided to develop a set of performance criteria (PC) for each of the 11 program outcomes ("a" through "k") so that we could measure and demonstrate that the outcomes were met. Our efforts were guided by a framework developed by funding from the National Science Foundation [24]. 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. For example, for outcome "A", applying knowledge of mathematics, students should be able to describe mathematical and physical significance of functions, derivatives of functions and integrals of functions at the "knowledge" level of learning (lowest level). But at a higher level of learning such as "synthesis", the same outcome would mean that the students should be able to combine mathematics principles to formulate models of physical processes and systems. In this framework, verbs such as "describe" and "combine" are called McBeath action verbs.

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 criterion 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. The next step was to make a complete mapping of the performance criteria to the courses in the curriculum. The outcome of this effort was a Course-to-PC matrix (Figure 1).

The success of the program in each of these PCs is based on the success of various activities that take place in many courses across the curriculum. For instance, the faculty identified that the performance criterion "A-2" would be achieved if the

Table 1. Assessment planning steps and the outcomes in each step

	Assessment planning steps	In our program	Result
1	Develop program outcomes	Faculty decided to adopt ABET EAC Criterion 3 "a"—"k" as the program outcomes. Additional outcomes are possible.	• List of program outcomes
2	Develop performance criteria (PC)	Developed by faculty with input from industry advisory board	• List of performance criteria for each program outcome (Appendix)
3	Map each PC to courses	Faculty decided in which courses students gained the skills/knowledge described by each PC	• Courses-to-PC matrix
4	Develop course master syllabi	Each instructor interpreted the PCs assigned to his/her course in the context of the course. He/she described the PCs with more specificity. This created the course outcomes	• Master syllabus for each course in the curriculum [23]
5	Map assessment tools to each PC	Faculty decided which tools should be used to assess each PC. We made sure that the use of direct and indirect assessment tools for each outcome was balanced	• Assessment tools chart
6	Analysis of assessment data	Designed the approach to process and analyze assessment data	• Spreadsheets (one for each program outcome), and • Track record charts
7	Evaluation of data	Decided how to review the data and recommend actions for change	• Action form
8	Documentation	Planned how to document the assessment data, evidence, student work samples, analysis, faculty meeting minutes, program reports, etc.	• Program outcome portfolios, and • Course portfolios
9	Timeline and reponsibilities	Planned what will be done when and by who	• Assessment calendar

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	

Fig. 1. A segment 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.

corresponding activities in Mech 211, Mech 212, Mech 215, Math 360, Mech 303, Mech 304, Mech 301, Mech 348, Mech 438 and Mech 467 are successful. In other words, each PC at the program level flows to the course level where it is interpreted in the context of particular courses. Table 2 lists some of these interpretations.

By interpreting program level performance criteria in the context of each course, we developed the course outcomes. For example, in Mech 467 "Automation" course, the course outcomes were derived as shown in Table 3. Using this approach, a master syllabus with appropriate course outcomes was prepared for each course of the curriculum [23]. In each course, we assess the level of achievement of every course outcome. The data are then combined to analyze and evaluate the program level achievement of each program outcome.

Assessment tools

Assessment tools can be classified as direct and indirect measures. The direct measurements are most familiar to faculty. They provide for the direct examination or observation of student knowledge or skills against measurable learning outcomes. Faculty conduct direct assessment of student learning throughout a course using exams, demonstrations, reports, etc. However, the key issue here is to make sure that the measurable outcomes, such as the course outcomes on the master syllabi, are assessed in these assignments and exams. Portfolios are another example of direct measurements.

Indirect assessment involves surveys. They provide information about student perception of their learning. Exit surveys given to graduating seniors is a good example of indirect assessment of program outcomes. Another popular method is the focus groups.

All assessment methods have their limitations. Therefore, a mix of three different assessment methods for each outcome, called triangulation, is recommended [25]. In our implementation shown in Figure 2, we mapped at least three assessment tools to each program outcome.

The Design Panel tool is used to assess courses with substantial project components. The design panel consists of alumni, industry representatives, graduate students and faculty. The panel assesses the students' design and realization ability, professional and ethical responsibility and communication skills. The panel is provided with design project final reports, streaming video files of the students' final presentations and the digital pictures of the design project prototypes [26].

Documentation

The ABET accreditation involves an on-site visit to the institution requesting an evaluation. It is the

Table 3. 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.

Table 2. Performance criterion interpreted in course context

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

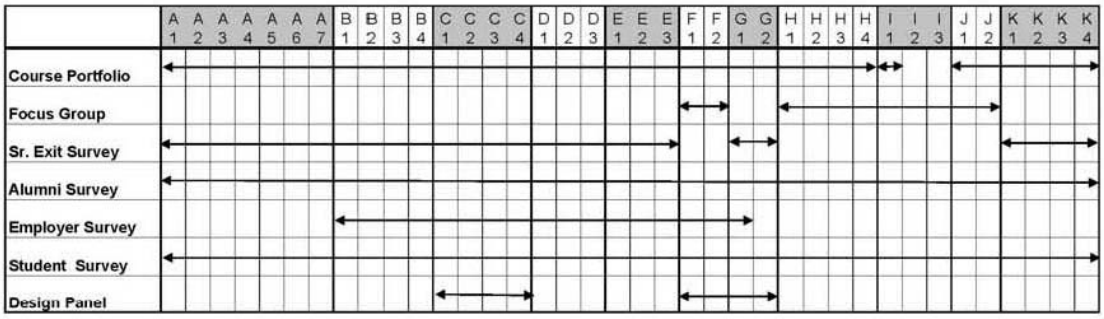

Fig. 2. Assessment tools chart.

institution's responsibility to demonstrate with evidence that a continuous improvement process is in place.

We organized our on-site documentation into three levels similar to a pyramid:

1) Program self-study report,
2) Program outcome portfolios,
3) Course outcome portfolios.

At the highest level is the self-study report submitted to ABET and the members of the visiting team before the accreditation visit. It follows the format provided by ABET and addresses all criteria to be met for successful accreditation.

Program outcome portfolios are at the mid level. There are 11 portfolios, one for each outcome. The portfolios are 3-ring binders with section dividers. Each binder contains the following sections:

- Educational strategies
- Track record
- Recommendations/Actions
- Student work samples (evidence).

The primary goal of the program outcome portfolios is to present convincing evidence for each program outcome ("a" through "k") to the visiting team that there is a continuous improvement process in place and that the outcomes are achieved. Ideally, the team should be able to find all the information they need for criterion 3 in these 11 portfolios.

The educational strategies section contains a summary of all educational activities that took place in each course with this outcome to provide an opportunity for the students to demonstrate their achievement of that outcome. The track record section starts with charts showing trends in the achievement of the outcome over the years (Figure 6). Data analysis that led to the trend charts is also provided (Figure 5).

The Recommendations/Actions section below contains a table listing all instructor recommendations compiled from the individual course portfolios supporting this outcome and all approved actions for change. The student work samples section below provides sample assignments, projects, exams selected from various courses providing evidence that the outcome is assessed throughout the curriculum.

Course portfolios are compiled for each course every semester. For the purpose of the on-site visit, the course portfolios are considered to be back-up materials to provide more detail and evidence than is available in the program outcome portfolios, if required by the evaluation team. In each academic year there are 29 course portfolios. These are also 3-ring binders with the following section dividers:

- Master syllabus
- Instructor's course syllabus
- Assessment
  - Course assessment report
  - Action Form (Appendix)
- Major handouts prepared by faculty
- Sample student work.

At the beginning of each semester, every faculty receives an empty course portfolio from the department. Throughout the semester, they collect student work samples in this portfolio. At the end of the semester, the instructor fills out the course assessment report. This is a standard form where

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%

(a) Instructor's assessment scores

Course Outcome	Average	Distribution				
		5	4	3	2	1
A-2	4.9	88%	12%	0%	0%	0%
A-7	3.9	41%	18%	35%	6%	0%
B-4	4.4	41%	53%	6%	0%	0%
E-3	4.3	29%	71%	0%	0%	0%
G-1	4.8	76%	24%	0%	0%	0%
K-3	4.5	53%	41%	6%	0%	0%
K-4	4.5	71%	18%	6%	6%	0%

(b) Student course survey scores

Fig. 3. Assessment data for Mech 467 Automation course. (a) Instructor's assessment scores as tabulated automatically by the standard spreadsheet. (b) Student course survey results automatically tabulated by the bubble sheet reader machine.

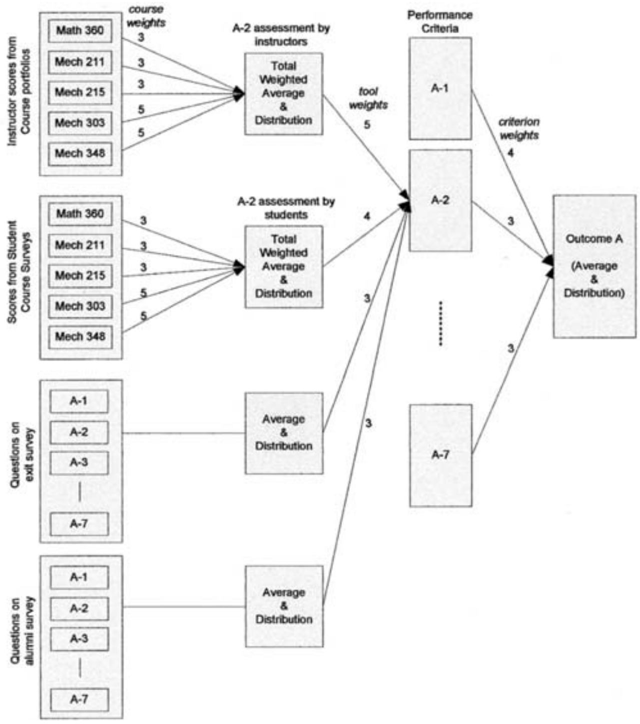

Fig. 4. Weighted average approach used in the assembly of the assessment data. This approach leads to a score and distribution indicating the extent to which each program outcome is achieved. Only A-2 is shown as an example. The same approach is applied to all performance criteria and the program outcomes.

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

	Ave.	5	4	3	2	1	Weight
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

Performance Criterion	Average	Category 5	4	3	2	1	Criterion 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)

Fig. 5. Spreadsheets are used to assemble and analyze the data following the approach shown in Figure 4. (a) Computations on the A-2 tab, (b) Computations on the outcome "A" tab.

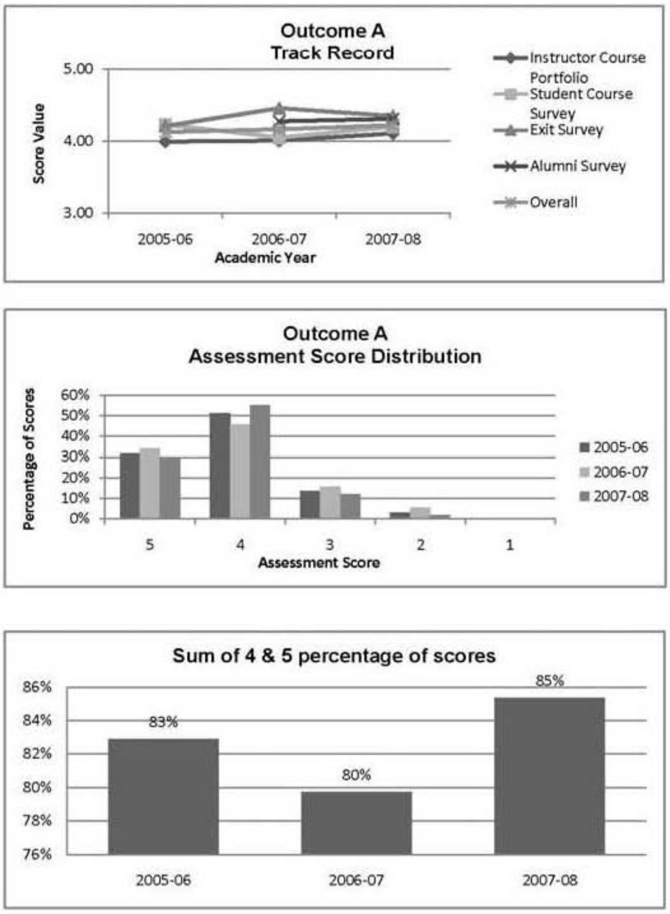

Fig. 6. Track record for program outcome A.

the instructor briefly describes all educational activities in the course and how they enabled the students to achieve course outcomes. The action form is where the instructor makes recommendations for improvement in the course based on the assessment data. These forms are later processed by the curriculum assessment committee to compile recommendations for the entire program. The instructor returns the portfolio to the department at the end of the semester.

Table 4. Assessment calendar and responsibilities

	Fall semester			**Spring semester**			**Responsibility of**
	Aug.	Oct.	Dec.	Jan.	Apr.	May	
Distribute course portfolios to faculty	×			×			Program admin. assistant
Send Alumni and Employer surveys	×						Program admin. assistant
Receive/process Alumni and Employer surveys			×				Program admin. assistant
Industry Advisory Board meeting		×					Department Chair
Exit survey of graduating seniors			×			×	Department Chair
Focus group					×		Consultant (Business faculty)
Distribute Student Course Surveys			×			×	Faculty
Process student course surveys			×				Program admin. assistant
Submit complete course portfolios to department			×			×	Faculty
Update Program Outcome portfolios						×	Curriculum assessment committee
Assessment report						×	Curriculum assessment committee
"Closing the loop" meeting						×	All faculty meeting led by the curriculum assessment committee

Timeline

The program outcomes assessment cycle starts with the distribution of the course portfolios to faculty in the Fall (Table 4). Student course surveys are administered in early December. During the final exams week (mid-December) they are processed using a machine. The data are provided to the faculty who complete their course portfolios and submit them to the department at the end of December. The same steps are followed in the Spring semester. In the week after the final exams, the curriculum assessment committee updates all program outcome portfolios and generates the assessment report. The "closing the loop" meeting is held to discuss the assessment findings and approve actions for change in the curriculum. By the middle of May all assessment work is completed and the faculty knows what may need changing in the next offering of their classes.

ANALYSIS AND EVALUATION OF ASSESSMENT DATA

Analysis

The assessment data collected from various tools and in each course need to be assembled to arrive at the extent to which each program outcome is achieved. Due to the complexity of the assembly process, the following sections are provided.

Data collection

Assessment data for each performance criteria are collected using various tools as shown in Figure 2. For example, for A-2, data come from the course portfolios of the courses where A-2 appears, from exit surveys, from alumni surveys and from student course surveys. Each year, the assessment data are collected in the Fall and Spring semester. Shortly after the Spring semester ends, the data for the entire program are analyzed. In order to keep the process manageable, the data are collected only from those courses with a "box" (Figure 1).

Course portfolios contain instructor's assessments of how well each course outcome was met. The data consist of an average score on the scale of 1–5 for each course outcome. It also contains a distribution of student scores on each outcome. The instructors arrive at these scores by assigning specific problems in homework and exams designed to assess how well each student achieves course outcomes. These are the direct measures. For example, if there are 10 questions on an exam, the first two may target course outcome 1, the next 3 may target course outcome 4 and the last five may target course outcome 5. 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". All scores used 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: Seldom meets expectations, and 1: Never meets expectations). At the end of the semester, each student gets a "score" on the scale of 1–5 indicating how well he/she achieved each course outcome. So, if there are five course outcomes, each student gets five 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.). A detailed coverage of this course outcomes assessment process can be found in [27]. Each instructor uses a standard Excel spreadsheet to provide their course outcome scores to the department (student scores are cut-and-pasted from their own grade spreadsheet into the standard spreadsheet). The standard spreadsheet computes the averages and distributions as shown in Figure 3a. The instructor uses these tables in the course assessment report section of their course portfolio at the end of the semester. The department receives the standard spreadsheet with data for further processing.

Student course survey is one of the indirect measures we use. These surveys are printed on bubble-sheets for quick processing by a machine. They list the outcomes of the course in which they were distributed. Therefore, each course has its own customized bubble sheet. The surveys are administered and processed by the program administrative assistant. The students are asked to rate themselves on how well they think they achieved the course outcomes on a scale of 1 to 5.

Exit surveys are given to the graduating seniors at the end of the Spring semester. The survey lists all performance criteria and asks the student to rate each one on the scale of 1 to 5. We also use alumni surveys, employer surveys, focus group studies and design panel reviews [26] to collect more assessment data.

Data analysis

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

Assembly of the data is a fairly complex process. The main idea is to assemble the data using a weighted average approach. Using A-2 as an example, it can be seen in Figure 4 that there are five courses contributing to the achievement of A-2 at the program level.

Course weights: The faculty concluded that each course contributing to a particular performance criterion does so at varying levels. Although a particular performance criterion may appear in a course, depending on the emphasis of the course, that performance criterion may or may not be the central activity in that 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 as 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, 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 the outcome A at a varying degree. The program puts more emphasis on some criteria than others. Therefore, the faculty assigned weights to each criterion. By computing the weighted sum of all performance criteria we arrive at the overall score for outcome A at the program level.

To process the data, we built 11 separate Excel spreadsheets, one for each program outcome "a" through "k". 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 (last two columns in Figure 4). Figure 6 shows the tabs for A-2 and for overall outcome "A".

The spreadsheets produce three charts annually for each of the 11 program outcomes (Figure 6).

The top chart in Figure 6 shows the average scores on the scale of 1 to 5 indicating how well the program achieved the outcome in each academic year (such as the Outcome A average score of 4.22 in Figure 6b in 2005–06). On this chart we also plot assessment results coming from each tool, such as exit survey, course portfolio, etc. 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. As explained in the next section, the program target is minimum 80%.

The curriculum assessment committee also copies student work samples from course portfolios into outcome portfolios to build the evidence section of those portfolios. The ME-CAC generates two outcomes:

1) Assessment report for the program faculty,
2) Completion of the documentation by updating the program outcome portfolios with new track record charts, recommendations for change, and evidence from student work samples.

EVALUATION

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 6) 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 ME-CAC is used in the "closing the loop" meeting shortly after the end of each Spring semester. In this meeting the program faculty evaluates the results and approves changes to the curriculum. Faculty is given the task of implementing the changes in the next offering of their courses. At the beginning of each semester of the following academic year, the ME-CAC chair checks with each faculty to make sure that the changes were implemented. In the Fall semester, a slightly modified version of the assessment report is presented to the industry advisory board (ME-IAB) for discussion and input.

The overall process results in improvements in three categories:

1) Program outcomes
2) Program of study
3) Assessment process itself.

In the case of the program outcomes, examples include changes in the particular performance criteria and addition or removal of certain performance criteria from individual courses. In case of outcome "J" (contemporary issues), we identified the need for a professional development workshop for our faculty so that they could improve their course materials. Examples of improvements in the program of study include changing the sequence of courses in the curriculum and adding a weekly lab component to the fluid mechanics course. Finally, the assessment process itself received some changes including removing the "design panel" as an assessment tool for outcome "D" and changes in the action form in the course portfolios so that minor and major changes can more readily be identified on the form.

DISCUSSION

It took about a year of preparation and planning before "turning on" this assessment system in our program. Therefore, it is essential to start as early as possible. It is beneficial to have at least two cycles of assessment data before the ABET team visits the program. Since the planning takes about a year, the effort of implementing such an assessment process should be started at least three years before the actual ABET team visit. It is important to engage the constituencies of the program in the planning process. In our case we worked with the program industry advisory board, as well as students to get their input throughout the development of the process.

As in any assessment process, the data collection requires significant amount of careful planning and tracking. We had to create many standardized forms, surveys, spreadsheets to manage the data collection and analysis. Personnel had to be carefully assigned to key roles to make the system work. Sustainability of the development process is important. We recommend working with small committees and giving responsibility to individual faculty to lead certain efforts, such as development of PCs for outcome "J", initial draft of the alumni survey, etc.

Engage faculty early on in the process to start developing faculty buy-in. Educating the faculty about the basics of assessment and how it differs from grading (assessing outcomes versus grading assignments) is an important starting point. Make sure the assessment system is not a burden on the faculty. The assessment system should not interfere with how faculty members teach their classes. In our system, the interface between the classes and the assessment system is through the course outcomes. The only requirement from a faculty member is the delivery of assessment scores at the end of the semester for each course outcome in his/her course syllabus. As long as these scores are delivered to the department, how they cover the course content, the assignments they give, grade spreadsheets they use, etc. are all up to them. The department provides a standard spreadsheet to each faculty to receive the scores at the end of the semester. In addition, they fill out short forms, such as the action form and place copies of student work samples into the course portfolio. In most courses, teaching assistants handle the sample collection.

The assessment process brought faculty together to plan the program and to decide on the changes collectively as a team. This gave a sense of ownership of the program to each faculty member. The faculty developed a good understanding of the interconnections between courses and how each course served to fulfill the program outcomes. They understood how their courses fit the "big picture". Therefore, they could design the course materials accordingly to serve the higher level purpose of helping the program achieve its outcomes.

The process also eliminated random changes that took place over time in a course as a result of different instructors offering the same course. In the past, depending on who offered a given course, the course content would somewhat randomly change based on the decisions of the instructor. Under the new process, each course has to deliver a set of course outcomes that were determined collectively by the program faculty. Instructors are still free to adjust the course content to their style. But at the end of the semester, they must demonstrate successful delivery of the course outcomes. Therefore, the process prevents random changes in the curriculum.

CONCLUSIONS

In this paper an assessment system for ABET accreditation in the United States has been presented. The assessment system uses performance criteria in a unique way to tie the program outcomes to course outcomes. It produces results to demonstrate to the extent each program outcome is met by the program as required in the ABET EAC Criterion 3. For new programs or existing programs, transition to the outcomes-based approach can be difficult. One of the goals of the paper was to explain all the steps we went through to design and implement this system. 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. Our new program was visited by an ABET team in 2007 for its first evaluation. We received full term accreditation.

Finally, ABET offers annual workshops. If a program is planning to apply for ABET accreditation, it is highly recommended to attend these workshops. Several of our faculty attended the workshops which were extremely useful to come up to speed quickly on the details of what was expected by ABET for a successful accreditation visit.

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Hakan Gurocak is the founding director of the School of Engineering and Computer Science (ENCS) at Washington State University Vancouver. His research interests include haptic interfaces for virtual reality, robotics, fuzzy logic controllers and technology-assisted delivery of laboratory courses at a distance. His research has been supported by grants from NSF, SME and the M.J. Murdock Charitable Trust. He is the winner of two best paper awards and the 2001 WSU Vancouver Faculty Research Excellence Award. Dr. Gurocak is a member of the, ASEE, ASME and the IEEE Robotics and Automation Society. He is an ABET Program Evaluator for mechanical engineering.

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.

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.