AC 2007-998: FACULTY-FRIENDLY ASSESSMENT SYSTEMS FOR BIOMEDICAL ENGINEERING PROGRAMS

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Faculty-Friendly Assessment System for Biomedical Engineering Programs

Abstract

Many engineering programs have limited resources to create and operate an assessment system. Paramount to the success of a system is the system's ability to engage faculty without being an undue burden so that the faculty remains compliant and the system yields useful information. The assessment system design needs to ensure that: assessment data are collected consistently by the faculty, the faculty is involved in the analysis of these data, and any changes made in response to the data are implemented by the faculty.

At Western New England College, a program outcome assessment system has been designed to maximize faculty buy-in and participation by carefully defining the faculty interaction with the system. Most of the quantitative outcome data are delivered to the system from specific courses within the curriculum. The instructor of a course needs to be concerned with predefined outcome measures and deliver data to support that measure. This works well because instructors are centered on the day-to-day activity within their courses. This course-centered approach helps to measure outcomes consistently even when the course changes hands. Additionally, adjunct professors can easily provide data for assessment without the need for a broader interaction or understanding of the assessment system.

The data that are supplied to the system are ultimately analyzed by the faculty during specific, periodic departmental assessment meetings. The data that have been supplied to the system are inherently grouped and organized to facilitate meaningful discussion of outcomes, even though each outcome has several measures across the curriculum. This organization is designed into the system, needing only a small clerical effort to copy course data that has been provided by the faculty.

The system has been operating for three years and has recently generated data to support a formal ABET review that has led to an accredited status. The small size of our department and limited resource demand that the system provide a wealth of data without undue labor – this has been achieved.

Introduction

The ABET process has many facets that require significant effort and resource. Enderle, *et al.* have compiled a comprehensive review of all the necessary elements for accreditation that include eight separate criteria that must be satisfied in order to achieve an accredited status[1]. In this paper we focus on meeting the requirements of Criteria 3 and 8 with a quality improvement system that measures and assesses program outcomes while documenting and tracking any necessary feedback. Meeting Criterion 3 is perhaps the most challenging aspect of achieving ABET accreditation because it requires a true continuous improvement process that engages the entire undergraduate faculty[2].

Program Outcomes

This paper focuses on the assessment system that allows our program to assess Criterion 3, program outcomes and assessment, and Criterion 8, the program criteria as established by the Engineering Accreditation Commission (EAC) of ABET[3]. The outcomes for the Western New England College Biomedical Engineering Program were chosen so that graduates will be prepared to meet the Program Educational Objectives that are required by Criterion 2. The program outcomes include those required by Criterion 3 as well as bioengineering program criteria required by Criterion 8. We have chosen to assess both criteria in a similar manner and have included Criterion 8 in this assessment by adding additional program outcomes that address the program criteria specific for biomedical engineering. Thus, graduates of the Biomedical Engineering Program will have:

- (3a) an ability to apply knowledge of mathematics, science, and engineering,
- (3b) an ability to design and conduct experiments, as well as to analyze and interpret data,
- (3c) 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
- (3d) an ability to function on multi-disciplinary teams,
- (3e) an ability to identify, formulate, and solve engineering problems,
- (3f) an understanding of professional and ethical responsibility,
- (3g) an ability to communicate effectively,
- (3h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context,
- (3i) a recognition of the need for, and an ability to engage in life-long learning,
- (3j) a knowledge of contemporary issues,
- (3k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice,
- (8a) a knowledge of biology,
- (8b) a knowledge of physiology,
- (8c) an ability to apply advanced mathematics (including differential equations and statistics), science and engineering to solve problems at the interface of engineering and biology, and
- (8d) an ability to measure and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems.

Measuring Outcomes

Shuman, *et al.* provide detailed examples of specific strategies for measuring program outcomes that include physical portfolios, electronic portfolios, closed-form questionnaires, attitudinal surveys, open-ended surveys and structured student interviews, focus groups, competency measurements via surveys, student journals, concept maps, verbal protocol analysis, intellectual development, and authentic assessment[4]. Many of these measures require additional resources from the program to implement surveys and assess portfolios that are beyond the scope of the student's coursework. To simplify the process, we decided to utilize as many measures that already existed within our curriculum that provide a direct assessment of a particular outcome. These measures are therefore derived mainly from exams, quizzes, homework, and reports. An additional benefit to this approach is that the faculty is inherently directly involved in the assessment system. Moreover, we decided to rely on ***direct measures*** of outcomes and avoid more subjective surveys. Since a myriad of measurement possibilities have been written about previously, this paper focuses on the overall system used to track and assess the measures rather than detailing specific outcomes measures.

Tracking and Assessing Outcomes

The Biomedical Engineering Program has adopted an assessment process with a ***three-year cycle time***. Figure 1 shows that during the three year cycle, relevant data are gathered from specific measures of a particular outcome. Throughout the cycle, collection of these relevant data is performed using well defined measurement instruments within the curriculum (e.g. exam questions, homework problems, reports, etc.). Then, these data are gathered into a ***meta-analysis*** to determine that the outcome is being met. Since we are a relatively small program, it is necessary to combine data across the three years to increase the statistical significance of any conclusions drawn. The assessments occur during several predefined ABET meetings each semester; all faculty members participate in the review. Additionally, rubrics for each of the measures are included in the analysis. These rubrics help maintain a consistent evaluation of student performance across the years.

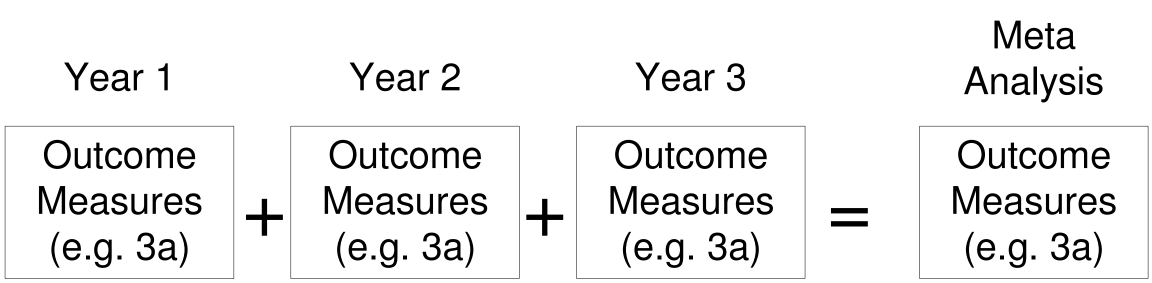

Figure 1 – A meta-analysis is performed on the summation of data from a three year period so that enough data is available to draw meaningful results. This periodic assessment occurs for each outcome on a specified schedule.

Table 1 shows the specific timing for gathering data and performing meta-analyses on each program outcome. Data are collected for each outcome every year within the curriculum and any major problems can be flagged by the instructor and brought to the attention of the faculty at one of several departmental assessment meetings throughout the year (2 meetings per semester). However, if there are no major problems, the data are stored until the meta-analysis is performed for that particular outcome. Notice that the meta-analyses are spread out across the three year cycle so that no more than six outcomes are analyzed in any given year, leading to a more thoughtful analysis. For example, during academic year 2004 – 2005 outcomes 3a, 3b, 3g, 3h, 8b, and 8c were analyzed. Each meta-analysis is documented and included in the outcome notebook for future reference. Recommended changes to the objectives, outcomes, curriculum, or assessment process will be derived from these analyses; changes are documented, implemented and assessed for effectiveness.

Table 1 - Schedule for the measurement and analysis of each program outcome

		AY 2004-2005		AY 2005-2006		AY 2006-2007	
	Year 0	Year 1		Year 2		Year 3	
		fall	spring	fall	spring	fall	spring
Develop outcomes	■						
Measure criteria 3 & 8 in courses		■	■	■	■	■	■
Flag any major issues		■	■	■	■	■	■
Outcome 3a meta-analysis		■					
Outcome 3b meta-analysis			■				
Outcome 3c meta-analysis				■			
Outcome 3d meta-analysis					■		
Outcome 3e meta-analysis						■	
Outcome 3f meta-analysis							■
Outcome 3g meta-analysis		■					
Outcome 3h meta-analysis			■				
Outcome 3i meta-analysis				■			
Outcome 3j meta-analysis					■		
Outcome 3k meta-analysis						■	
Outcome 8a meta-analysis							■
Outcome 8b meta-analysis		■					
Outcome 8c meta-analysis			■				
Outcome 8d meta-analysis				■			

Source of Outcome Measures

In order to measure the effectiveness of the program, each program outcome is measured at least three times throughout the curriculum using a variety of direct assessment instruments such as in class exams, laboratory reports, and homework. A summary of the courses in which each program outcome is assessed is given in Table 2. Notice that we only measure outcomes in core engineering and BME courses that all students will be taking, simplifying the assessment process. Also, there can be a tendency to try to measure every possible outcome that is relevant for a particular course, but this approach is overly cumbersome[5]. Meaningful conclusions regarding student attainment of program outcomes can be drawn with a focused set of measures. To keep the system simple and manageable by our small faculty, we aim to assess (measure) student ability for each outcome three times during the student's curriculum; there is a longitudinal progression for the measurements and performance expectations. Each assessment point (measurement) is chosen because of its place in the curriculum and its relevance to the outcome. The expected performance level for each outcome is defined as a given percentage of students receiving a grade of 70% or better on the assessment instrument. Because it is expected that students will mature in their abilities as they progress through the curriculum, the percentage of students that must receive a grade of 70% or better is higher for upper-level courses. Thus, the expected performance for freshman (100-level courses) and sophomore (200-level courses) classes is that 70% of students will receive a grade of 70% or better on the assessment instrument. The expected performance level rises to 80% and 90% of students receiving a grade of 70% or better on assessment instruments in junior (300-level courses) and senior (400-level courses) classes, respectively. Performance below the expected performance level may trigger a recommendation for corrective action either during a meta-analysis or between meta-analyses when an instructor brings forward a concern.

Example Assessment Measure

The system uses a variety of assessment measures including exam questions, exam sections, homework problems, laboratory reports, or other measures that are typically used within courses. The specific measures have been agreed upon by the BME faculty. Each outcome measure remains the same from year to year, although minor modifications can occur as long as the measure continues to provide relevant information that students are meeting the specified performance.

Consider the outcome 3i, *a recognition of the need for, and an ability to engage in life-long learning*. This outcome is measured in three courses (Table 2). In the sophomore year, students in BME 201, Foundation of BME, are assessed on their ability to research and summarize a current topic in BME. In the junior year, students in BME 331, Bioinstrumentation, are assessed on their ability to read, summarize, and orally present a technical journal article. Finally, in the senior year, students in BME 451, Biomechanics, are assessed on their ability to perform a literature search of peer-reviewed publications and interpret technical papers. Notice the progression of sophistication needed for each measure as the students move through the curriculum. It is important to note that we address this outcome in other places in the curriculum; we only choose to measure it three times. The ABET reviewer is aware of the entire curricular context of the outcome as well as the specific measures.

Assessment Documentation

In order to make this assessment system easy to follow, the instructor's responsibility is straightforward each semester. Figure 2 shows the assessment notebooks that are kept up to date throughout the academic year. The instructor must be familiar with the list of specific predefined measurements that are to be used in the appropriate course; this list is stored in the course assessment notebook (red binders). The data from these measurements are to be collected, summarized using a standardized ***outcome assessment form***, and placed into the course assessment notebook (red binders) with pertinent examples of student work and any rubrics used. Engineering support staff then copy these results once per year into the outcome assessment notebooks (blue binders). This simple system allows the outcomes to be reviewed either by course topic or by outcome number. Results of the outcome meta-analysis are documented and stored in the blue outcome assessment notebooks.

Table 2 - Assessment of specific program outcomes within the BME curriculum – each blue box indicates that a particular outcome is measured within the specified course using a predefined assessment instrument.

Biomedical Engineering ABET Criterion 3 & 8 Assessment Summary

		Criterion 3											Criterion 8			
Semester	Course	3a	3b	3c	3d	3e	3f	3g	3h	3i	3j	3k	8a	8b	8c	8d
Freshmen Year																
Fall Semester																
ENGL 132	English Composition I (GCR/ER/MR)															
ENGR 102	First Year Engineering Seminar (GCR/ER/MR)															
ENGR 103	Introduction to Engineering (ER/MR)			X	X	X	X				X					
MATH 133	Calculus I (ER/MR)															
PEHR 151	Personal Health and Wellness (GCR)															
PHYS 133	Mechanics (GCR/ER/MR)															
Spring Semester																
ENGL 133	English Composition II (GCR/ER/MR)															
ENGR 110	Engineering Problem Solving (ER/MR)											X				
ENGR 105	Computer Programming (ER/MR)															
MATH 134	Calculus II (GCR/ER/MR)															
PEHR 151	Lifetime Activities Series (GCR)															
PHYS 134	Electricity and Magnetism (GCR/ER/MR)															
Sophomore Year																
Fall Semester																
BIO 107	General Biology I (MR)															
BME 201	Foundations of Biomedical Engineering (MR)		X				X	X	X	X	X		X	X		
CHEM 105	General Chemistry I (ER/MR)															
ENGR 208	Fundamentals of Electrical Engineering (MR)															
MATH 236	Differential Equations(ER/MR)															
Spring Semester																
BME 202	Biomedical Systems (MR)	X										X			X	
CHEM 106	General Chemistry II (MR)															
ENGR 206	Engineering Mechanics (MR)															
ENGR 212	Probability and Statistics (ER/MR)															
MATH 235	Calculus III (ER/MR)															
Junior Year																
Fall Semester																
BME 301	Engineering Physiology I (MR)												X	X		
BME 305	BME Laboratory I (MR)		X				X	X				X				X
BME 331	Bioinstrumentation (MR)						X	X		X						
MATH 350	Engineering Analysis I (ER/MR)															
	Sequence Elective (MR)															
	College Wide Requirement (GCR)								X							
Spring Semester																
BME 302	Engineering Physiology II (MR)	X												X	X	
BME 306	BME Laboratory II (MR)			X	X						X	X				X
BME 340	Biomaterials (MR)												X			
BME 350	Biomedical Thermal Systems (MR)	X													X	
	Sequence Elective (MR)															
	College Wide Requirement (GCR)								X							
Senior Year																
Fall Semester																
BME 405	BME Senior Laboratory (MR)		X		X											X
BME 437	BME Senior Design Project I (MR)			X		X			X							
BME 451	Biomechanics (MR)									X						
	Sequence Elective (MR)															
	BME Technical Elective (MR)															
	College Wide Requirement (GCR)								X							
Spring Semester																
BME 440	BME Senior Design Project II (MR)					X										
	Technical Elective (MR)															
	Sequence Elective (MR)															
	College Wide Requirement (GCR)								X							
	College Wide Requirement (GCR)								X							
		3a	3b	3c	3d	3e	3f	3g	3h	3i	3j	3k	8a	8b	8c	8d

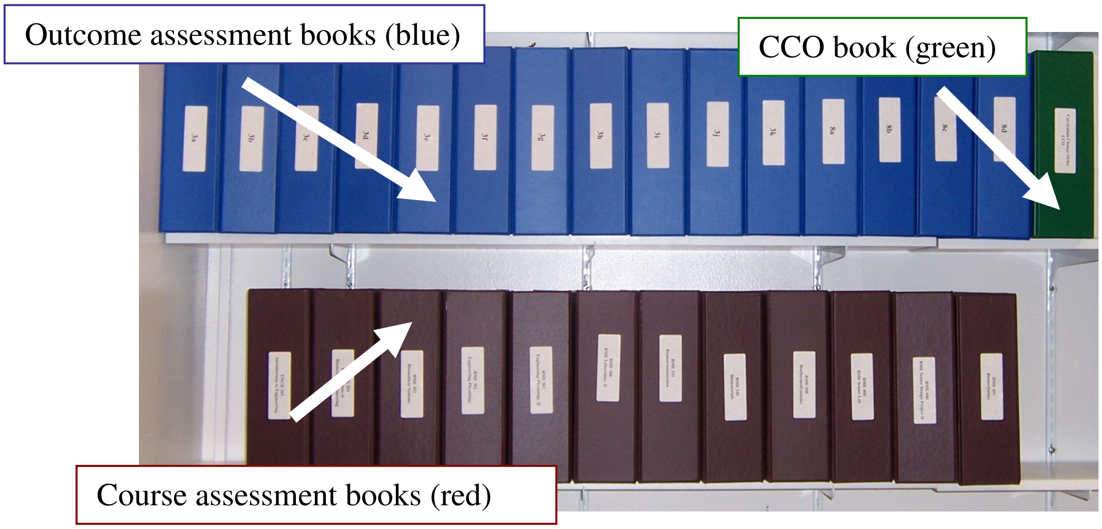

Figure 2 – Assessment notebooks that are used to help manage the system. The instructors only need to enter information into the course assessment books (red binders on the lower shelf). Information is copied from the course assessment books into the appropriate outcome assessment books (blue binders on the upper shelf). Curriculum change orders (CCOs) are kept in the green binder on the upper shelf.

Course Review

In addition to the analysis of each program outcome, each required biomedical engineering course is analyzed on a three year cycle during regularly scheduled departmental assessment meetings. The course objectives, topics and outcomes, as well as student assessment (grading policies) are reviewed. Course objectives are assessed through a student survey (indirect method) each time the course is offered; these surveys are also considered during the course review. Recommended changes to the objectives, outcomes, curriculum, or assessment process will be derived from these course reviews; changes are documented, implemented and assessed for effectiveness. It is important to note that even though only a limited number of formal outcome measures may be made for a specific course, all courses in the curriculum serve to strengthen the background of students to achieve the program outcomes. The course's relationship to all outcomes is also documented, but there is no attempt to specifically measure all possible outcomes.

Through the process of course reviews all biomedical engineering faculty members become familiar with the material covered in all of the required biomedical engineering courses. These reviews have already proved to be very beneficial in helping to coordinate delivery of material within the curriculum. The schedule for the course review during the three-year assessment cycle is shown in Table 3. Notice that no more than six courses are reviewed in any one academic year. The results of a course review are documented and stored in the red course assessment notebooks (Figure 3). Additionally, the foundational engineering courses ENGR 103, *Introduction to Engineering*, and ENGR 110, *Engineering Problem Solving*, are reviewed because the BME Program derives specific outcome assessment measures from these courses.

Table 3 Schedule for the Course Review

		AY 2004-2005		AY 2005-2006		AY 2006-2007	
	Year 0	Year 1		Year 2		Year 3	
		fall	spring	fall	spring	fall	spring
Develop outcomes and map to courses	■						
BME 301 BME 302 BME 350		■					
ENGR 103 BME 451			■				
BME 437 BME 440 BME 340				■			
BME 305 BME 306 BME 405					■		
ENGR 110 BME 331 GCRs						■	
BME 201 BME 202							■

Closing the Loop with Corrective Actions

Data generated by each assessment tool are collected, analyzed, and stored each year by the faculty member teaching the course in which the measurement is made. If any major issues are revealed by analysis of these data, the faculty member may recommend changes during one of the departmental assessment meetings that are scheduled throughout the year. Additionally corrective action may be taken as a result of an outcome meta-analysis or course review. If the recommended changes are approved by the program faculty, the responsible faculty member will submit a standardized ***curriculum change order (CCO)*** form. The use of the curriculum change form provides a method by which alterations in the curriculum or assessment can be tracked over time for proper implementation and effectiveness. Curriculum change orders are kept with the assessment books in a green binder (Figure 3).

A recent example of closing the loop within the assessment system comes from assessing outcome 3a, *an ability to apply knowledge of mathematics, science, and engineering*. Students are given an exam question regarding a mathematical model of the circulatory system (Windkessel). In 2005, during the meta-analysis of outcome 3a, the faculty identified that this specific measure could be strengthened. Although the question asked descriptive questions about the model, it did not probe the understanding of the model under varying physiological conditions. By assessing the students' ability to generalize their knowledge to a new physiological situation, the faculty is more confident that the students are learning to *apply* their knowledge as required by the outcome. In this case, the students were asked to indicate how the model parameters would change under increased sympathetic stimulation. After agreeing that the assessment should be changed, a CCO was created and the course instructor modified the assessment.

Use of Web-based Software

Many institutions are constrained by resource issues and we are no exception. The interface with the system is predefined and not cumbersome so that an instructor can provide the appropriate data without clerical assistance. Although the system is based on printed material and all assessment material is ultimately stored in the assessment notebooks, we do use a web-based file system to promote easy communication between instructors. We use a commercial vender (Pro Softnet Corporation's IDrive backup software and service) to provide basic file sharing ability and secure backup of the outcome assessment forms, course assessment information, syllabi, and reports. When a faculty member is assigned a course they have not taught before, all relevant assessment documentation is available to them without the need for direct communication with previous instructors.

Adjuncts and Course Responsibility

The initial effort to specifically define outcome measures was well worth it: we have had good system compliance, even when hiring adjuncts or passing courses between faculty members. Although the specific measures vary throughout the curriculum, the forms and responsibilities are the same for each course that is used for assessment. Thus the faculty has adopted a rhythm and routine of consulting the documentation prior to the start of a semester when planning a course. Specific measures are therefore made correctly and reported into the system at the end of the semester. It is important to note that this system relies on faculty cooperating with the specific measures that have been defined. Although there is some room for creativity in measuring outcomes, consistency in making the measurements makes the meta analysis easier. Since we have intentionally kept the number of measures for each course relatively small (typically 1-3 per course), instructors are not overly constrained in how they assess the course objectives.

Adjuncts need only be informed of the specific measures expected – the ABET coordinator (in our case the department chair) discusses the outcome measures with the adjunct prior to the course beginning. A gentle reminder or two are sent during the semester and then a final request for documentation at the end of the course is made. The need to follow ABET responsibilities is written into all adjunct contracts.

Conclusions

This paper presents a framework for assessing outcomes as a means for meeting the requirements of ABET Criteria 3 and 8. The success of this system lies with the system's ability to engage faculty without being an undue burden so that the faculty remains compliant and the system yields useful information. The design of the assessment system ensures that: assessment data are collected consistently by the faculty, the faculty is involved in the analysis of these data, and any changes made in response to the data are implemented by the faculty. The system's course-centered approach aids in keeping the faculty engaged in the process and helps to measure outcomes consistently even when the course changes hands. The system has been operating for three years and has recently generated data to support a formal ABET review that has led to an accredited status.

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