AC 2007-878: A METHODOLOGY FOR DIRECT ASSESSMENT OF STUDENT ATTAINMENT OF PROGRAM OUTCOMES

Scott Danielson, Arizona State University

Bradley Rogers, Arizona State University

A Methodology for Direct Assessment of Student Attainment of Program Outcomes

Abstract

While not directly required in Criterion 3 of the ABET accreditation criteria for engineering technology programs, some form of direct assessment of student attainment of program outcomes is generally expected. Unfortunately, direct assessment can be overlooked by program faculty, often leading to an over reliance on indirect assessments such as surveys. This paper describes a successful methodology for faculty-driven, direct assessment of student attainment of program outcomes. The method does not require sophisticated technology or require students to create or maintain portfolios. The system provides student attainment of program outcome data by course, thus enabling curriculum improvement. Also, the system directly links examples of student work to program outcomes—a significant advantage as it melds the old and new accreditation requirements regarding student work samples. The method configures the materials used by the faculty each semester for their assessment of outcomes in the same format as viewed by ABET evaluators during a visit. Thus, the assessment process is institutionalized and last minute ABET visit preparation minimized.

Introduction

The assessment of student attainment of program outcomes as required by ABET accreditation criteria presents challenges for engineering education programs. Criterion 3 of the 2007/2008 criteria for accrediting engineering technology programs states that programs must demonstrate that student assessments are being used as part of a broad, documented continuous improvement process. In addition, multiple assessment methods are to be used to "triangulate" data to ensure that program outcomes and objectives are being met. The Criteria goes on to suggest possible assessment methods, including "student portfolios, student performance in project work and activity-based learning; results of integrated curricular experiences; relevant nationally-normed examinations; results of surveys to assess graduate and employer satisfaction with employment, career development, career mobility, and job title; and preparation for continuing education"[1]. The details of these assessment procedures are left to the discretion of each institution. Using data from employer and graduate surveys is convenient because the results can be quantified and someone other than the faculty does the work of completing the surveys.

However, while not directly required in Criterion 3, some form of direct assessment of student attainment of program outcomes is generally expected. Unfortunately, direct assessment can be overlooked by program faculty, often leading to an over reliance on survey information or other indirect measures. In 2004, Gloria Rogers stated in her "How are we doing?" article in the ABET *Communications Link*[2], "Most educational units are still depending on indirect methods such as surveys .... This is the most serious flaw in the current data collection methods observed ..." Anecdotal evidence gained from talking to individuals in various engineering technology programs indicates that direct versus indirect assessment is still a significant issue among engineering technology programs. The ABET web site provides information about assessment and assessment techniques. For example, there is information about indirect and direct assessment—the value and examples of each approach[3].

In short, the results of indirect assessment methods become much more meaningful when used along with a careful and ongoing direct assessment of student work. Also, ABET urges programs to work towards "triangulation," or assessing student attainment of outcomes via several different avenues. Thus, a combination of direct and indirect methods can improve a program's triangulation regarding the assessment of their student attainment of outcomes.

In addition to the ABET accreditation-related benefits, direct assessment may also improve student learning. In Stiggins'[4] article explaining the benefits of assessment for learning, it is clear that direct assessment is fundamental to the methodology.

However, while understanding that it needs to be done, designing an efficient methodology for direct assessment of student work can still present a challenge. Sanoff[5] describes Alverno College's approach to assessment using direct assessment of student performance as students progress though six levels of achievement towards mastery of outcomes. Morrell et al[6] describes an Alverno-inspired system being implemented in a multi-disciplinary engineering program.

In contrast, the approach taken by the Mechanical and Manufacturing Engineering Technology (MMET) Department at Arizona State University for faculty driven, direct assessment of student work is described below. It varies from the Alverno model in that it is not as structured, allowing individual faculty the freedom to incorporate direct assessment into their course activities as best fits their individual circumstances.

Continuous Improvement System

The MMET Department offers two ABET-accredited degrees at the baccalaureate level: manufacturing engineering technology and mechanical engineering technology. Within the mechanical engineering technology curriculum, three specialty concentration areas available to students aeronautical, automation, and automotive. The Department has an enrollment of just under 200 students and teaches over 55 courses per year.

An ABET accreditation process was conducted in the 2004/2005 academic year under the new outcomes-based TAC of ABET criteria, and the programs were accredited (an initial accreditation for the mechanical engineering technology program). The continuous improvement system used for several years before the visit was based on an educational version of the Define-Measure-Analyze-Improve-Control (DMAIC) paradigm. The overall process of assessment and continuous improvement is shown below in Figure 1. Originally, faculty and the Industrial Advisory Board (representing industry) worked together defining the expected program outcomes that graduates would meet. Courses and the curriculum were also analyzed to ensure their fit within the overall plan. Faculty then developed course-learning objectives for their courses over the course of several semesters. These elements defined the target educational process to be measured, analyzed, and improved.

As seen in Figure 1 below, each MMET course has established course-learning objectives and the faculty member is responsible for gathering assessment data about student learning during

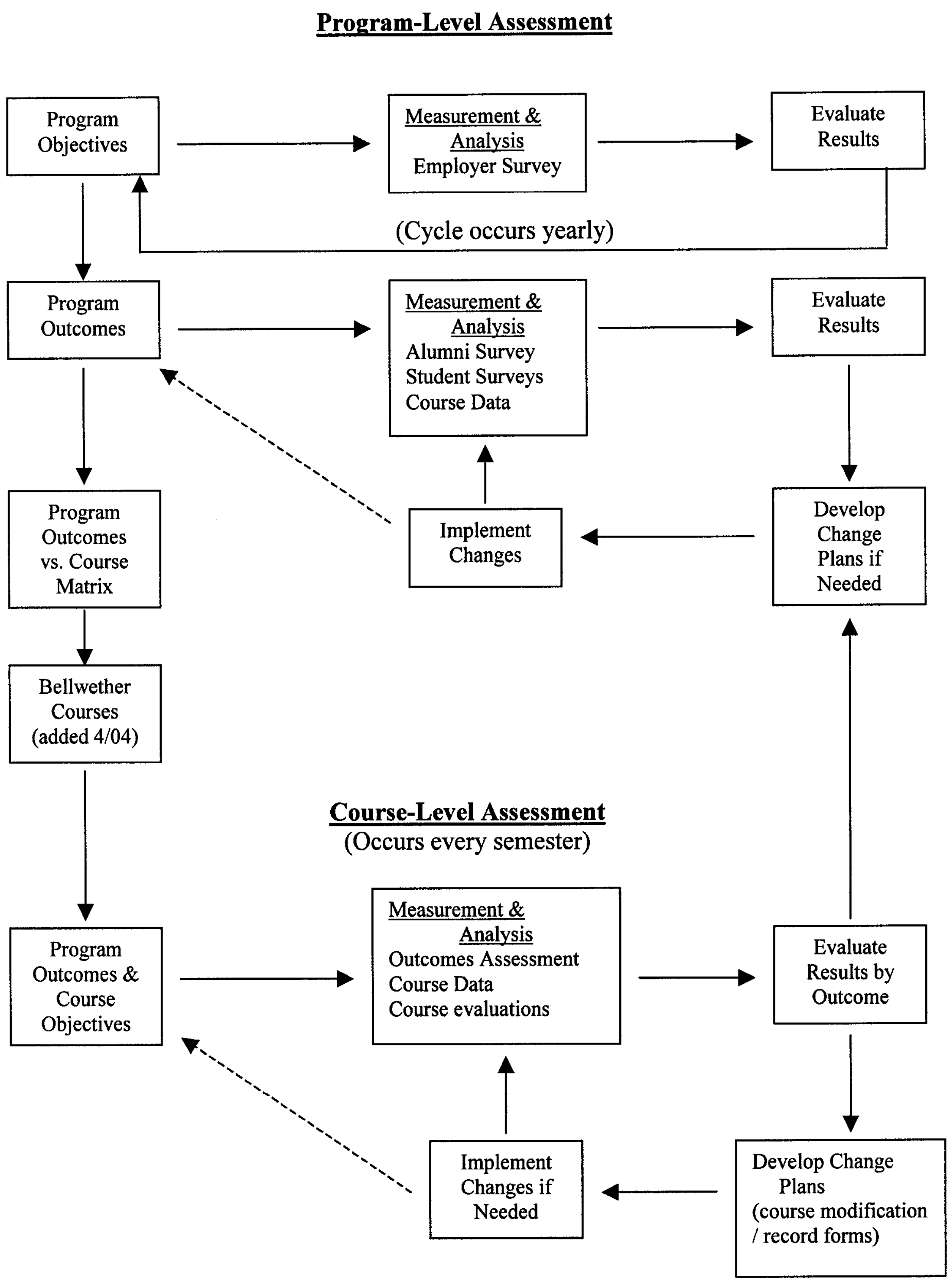

Figure 1. MMET Department continuous improvement process overview

the course term. Also, survey data are used to assess attainment of program objectives and student outcomes. Whenever possible, varying methods of assessment are used to “triangulate” results. The discussion below will focus on the faculty’s direct assessment of student work—which is only a part of the overall continuous improvement process.

The faculty developed an approach to the assessment and continuous improvement at the course level with the intent of linking the assessment to existing faculty processes and measuring learning without extensive acquisition of new data. The process is based on their course learning objectives (that are linked to program objectives). Once the initial development and initial implementation was accomplished, the typical faculty workload to implement the continuous improvement process varied between 10 – 20 hours per semester, depending on the number of classes and specific assessment methodologies adopted by the faculty member.

Individual instructors select exam problems, laboratory work or homework, or other graded work that probes specific learning objectives for their direct assessment vehicle. After grading the item, individual student performance measures for these items are logged, often in a spreadsheet. These performance measures are based on a standard that indicates whether a student substantially understands the topic area. For instance, a faculty member might decide that a grade of 75% or higher on an exam problem indicates a substantial or acceptable ability with the topic or related learning objective.

Then as a meta-analysis for the class, the faculty member determines the percentage of students in the class achieving the learning objective. An example of an Excel-based criteria sheets as applied to a class exam is shown in Figure 2 below.

Assessment Criteria Summary

Semester **Fall**
Instructor **R. B**

MET 300
Test 3

Number of questions/Criteria: 8
Number of students: 11

Test No. or Proj. Criteria	Point Value	STUDENTS																				Average	% correct	Prog. Outcom	ABET Outcom
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20				
3	3	2	1	3	2	3	3	2	2	3	3	3										2.5	81.8	2.1	7.Par2
4	6	4	6	4	6	6	3	6	6	6	6	5										5.3	87.9	1.3	C
7	4	1	2	4	4	4	4	0	4	4	4	4										3.2	79.5	1.3	C
11	4	4	4	2	4	4	4	2	3	2	3	4										3.3	81.8	2.1	7.Par2
14	8	4	4	8	8	8	8	5	8	8	4	8										6.6	83.0	2.1	7.Par2
16	4	3	0	2	3	4	2	0	1	2	2	2										1.9	47.7	2.1	7.Par2
20	4	4	1	4	4	4	4	4	4	1	4	4										3.5	86.4	2.1	7.Par2
23	2	1	1	1	1	1	1	1	2	2	2	2										1.4	68.2	2.1	7.Par2

Evaluation and Corrective Action:
The students performed above 80% on all the questions except for question 7 (79.5%), question 16 (47.7%) and question 23 (68.2%). Since the performance relating to question 16 and question 23 were extremely low, a separate lecture session will be added to the sylabus in MET 300. Also, more emphasis in lecture will be placed in material relating to question 7.

Figure 2. Sample assessment record sheet

These criteria sheets are first used in his grading process, recording the student marks in each aspect of the work examined. Of importance to this discussion, is the embedded linking of these specific student work criteria to both the program and ABET student outcomes. These criteria sheets are later analyzed to provide data on student attainment (as a group) of both course and program outcomes. Note that the instructor includes both an evaluation of the results and suggests follow-up action as needed. Since implementing this scheme for purposes of program assessment, the instructor has also realized that it helps him provide a more even grading of project materials. This point serves as a reminder that continuous improvement takes multiple forms.

The course level assessments are stored in a set of notebooks—arranged by program outcome—and stored in the department office. Each notebook has the assessment data (instructor summaries attached to examples of student work) for all the classes that impact that outcome. These notebooks now provide two things—evidence of faculty doing direct assessment of the student attainment of program outcomes (and thus the ABET a-k outcomes) and samples of student work addressing those outcomes. (As these notebooks are updated every semester, a large component of the program's ABET documentation is in perpetual readiness for an ABET visit. The Department views this as a hallmark of a true continuous improvement process.)

However, it is important to note that the assessment process does not stop at the course level. At the end of each semester, a small group of faculty (usually three individuals) does an overall assessment of these direct assessment data generated by instructors from the student work. For instance, the faculty team will "pull" an outcome notebook and evaluate all the evidence of student attainment of that outcome presented from the multiple classes. These faculty teams make judgments about student attainment of each outcomes based on the direct assessments by the faculty of the student work, as described above, and record their judgments.

Then, each fall and spring, before the semester starts, a meeting of the department faculty is held. As a part of that meeting, the faculty as a whole looks at the higher level direct assessment data (done by the faculty teams) and any appropriate indirect assessment data (e.g., survey) to make judgments on how program outcomes and objectives are being met by students and graduates. As the process continues, specific outcomes or content areas that appear "weak" in these analyses become the focus of the faculty in both their courses and for deciding any broader curriculum changes.

This system proved successful during the ABET on-site evaluation visit in 2004. Program evaluators for both the mechanical and manufacturing programs were complementary about the direct assessment data and the manner in which they were presented. The system has also helped the program faculty identify various curriculum and course improvements.

However, because of the large number of courses and volume of work produced by the students, involving all the courses within a program in this assessment process was recognized as unwieldy. After the 2004 ABET visit, MMET faculty decided to concentrate the detailed direct assessment of student outcomes to specific courses, denoted as "bellwether" courses.

Use of Bellwether Courses

In most cases, multiple courses address programs outcomes and virtually every course taught within the engineering technology program will impact at least one of the outcomes. The purpose of bellwether courses is to identify a representative subset of courses from the program that will be used in the direct assessment process. These bellwether courses were chosen by their relevance to the program outcomes (and thus the TAC of ABET a-k outcomes) and the two different program criteria. The bellwether courses assessments are in place to form the foundation of the global assessment of the program outcomes using direct assessment of the student work.

This is not meant to imply that assessment is limited to the bellwether courses—each faculty member is still responsible for continuous improvement in all courses for which they are responsible. Thus, they must have an assessment process in place to ensure this is accomplished. In the MMET Department, the faculty have adopted a "course change form" methodology, where each semester the faculty record a snapshot of each course that they teach. This snapshot includes what went well in the course, what didn't go well, and, most importantly, what they recommend be tried next time the course is taught to improve the outcomes of the course.

In identifying bellwether courses, it is necessary to map the course outcomes to the ABET outcomes so that courses can be identified that meet both the general and specific program outcomes. These results across the curriculum will result in a complete mapping identifying how each course contributes to both program outcomes and the ABET criteria. As examples, in this paper four courses identified as bellwether courses and their mappings onto the ABET a-k criteria, will be discussed. These representative bellwether courses are at the sophomore, junior and senior levels, and are listed below, along with their catalog descriptions.

AET 210, Measurements and Testing (3 credits). Measurement systems, components, system response, and the characteristics of experimental data. Prerequisites: Calculus II and Physics II.

MET 331, Machine Design I (3 credits). Applies engineering mechanics to the design of machine elements and structures. Stress analysis techniques, failure modes, tolerances, cylindrical fits, and shaft design. Prerequisite: Mechanics of Materials.

MET 460/461, Capstone Design Project (6 credits – two semester sequence) Group project designing, evaluating and analyzing components, assemblies and systems. Develop products and manufacturing techniques demonstrating state of the art technology. Prerequisites: Machine Design I and Advanced Manufacturing Processes.

The sophomore course, AET 210, is an integrated lecture/laboratory course. Included in this course are six laboratory experiences requiring students to write formal laboratory reports. These reports are graded both for technical content and the quality of the written presentation. Therefore, this course is an opportunity to assess both the analytical and writing skills of students at the sophomore level. The MMET faculty have identified this course as a bellwether course supporting five ABET outcomes, a, b, c, g and k. It is worthwhile to point out that an advantage to identifying a bellwether course at the sophomore level is that it serves not only to support the program outcomes, but is also an "early warning" of student deficiencies, so that appropriate corrective action may be taken. With this in mind, efforts have been made at Arizona State University to identify bellwether courses through the curriculum to ensure that identified deficiencies have been addressed before the students graduate.

The junior course in machine design, MET 331, is also a lecture course building on the foundations developed in statics and mechanics of materials. This course was chosen specifically to assess student achievement in these topics. In terms of the ABET criterion, the faculty identified this course as addressing outcomes c, e and k.

The senior courses, MET 460/461, form the two semester capstone experience for the students. The capstone experience is a cornerstone of the curriculum, forming the transition between academic study and the practice of engineering, and is designed to integrate the knowledge acquired throughout the curriculum. This is accomplished by working in a team environment to complete an engineering project of interest to industry. The experience involves technical design and evaluation as well as project management, scheduling, written and oral presentations, and marketing of the products. Consequently, the capstone sequence is an obvious bellwether course choice. While individual projects vary in scope, these courses potentially support all of the ABET outcomes a through k. In particular, these courses are typically assessed for outcomes a, b, c, d, e, g, i and k. Outcome i, focused on ethical and social responsibilities, is often addressed via the nature of the project itself. Some projects have a clear link to social issues, for instance projects done during 2006 – 2007 and 2005 – 2006 related to bio-fuels and physical rehabilitation devices. Ethical issues related to design (minimizing risk of injury, etc.) are also a part of the course. Assessment of this outcome is done by direct measures (faculty observing student discussion or the project's written materials).

It is important to point out that effective evaluation of program outcomes requires more than one independent means of assessment must be in place, so that potential improvements may be reliably identified through "triangulation." For example, results gathered through surveys of graduates may be compared with those obtained through evaluation of bellwether courses, as described in this paper. The principle of triangulation for the global assessment process is also relevant within the specific assessment of bellwether courses because of the improvements in technical maturity of the students as they move through the curriculum, and because of inevitable variations in the content and delivery of specific courses. For this reason, it is necessary that no individual program outcome be assessed by a single bellwether course. Representative courses should be chosen at a variety of levels throughout the curriculum, and assessments of specific outcomes should be attained from courses covering independent topics. For example, Thermodynamics I and II should not be considered to be independent assessments of the same outcome.

Conclusions

The faculty-driven, direct assessment of student attainment of program outcomes used by the MMET Department at Arizona State University has proven to be a successful methodology. The system provides faculty information about student attainment of program outcomes, thus enabling curriculum improvement. It earned positive comments by an ABET evaluation team. The method does not require sophisticated technology or require students to create and maintain portfolios.

Also, the system directly links examples of student work to program outcomes—a significant advantage as it melds the old and new accreditation requirements regarding student work samples. The method configures the materials used by the faculty each semester for their assessment of outcomes in the same format as viewed by ABET evaluators during a visit. Thus, last minute ABET visit preparation is minimized.

The use of a subset of a courses in an engineering technology curriculum, called bellwether courses, as one of the tools to assess program outcomes has focused and simplified the assessment effort. The process requires course and curriculum outcomes to be mapped to both general program outcomes, the required ABET a-k outcomes, and to specific program outcomes under ABET Criterion 8. The bellwether courses are identified as representative courses in support of these outcomes. At least two bellwether courses are assessed in depth and support of each outcome, providing "triangulation." The results of these assessments can then be used in conjunction with other assessment tools, including indirect data from surveys, to further triangulate student outcome attainment and guide the continuous improvement process for the curriculum.

Bibliography

1. ABET, Inc. (2006). CRITERIA FOR ACCREDITING ENGINEERING TECHNOLOGY PROGRAMS (Effective for Evaluations During the 2007-2008 Accreditation Cycle). Accessed at http://www.abet.org/forms.shtml on January 12, 2007.
2. Rogers, G. (2004). How are we doing? In *Communications Link*, ABET, Inc. Also accessed at http://www.abet.org/Linked%20Documents-UPDATE/Assessment/Assessment%20Tips8.pdf on January 12, 2007.
3. Rogers, G. (2006). Assessment 101: Direct and Indirect Assessment: What are they good for?, *CommunityMatters, ABET, Inc.* Accessed at http://www.abet.org/Linked%20Documents-UPDATE/Newsletters/06-08-CM.pdf on January 12, 2007.
4. Stiggins R.J. (2002). Assessment Crisis: The Absence of Assessment FOR Learning, *Kappan Professional Journal*. Accessed at http://www.pdkintl.org/kappan/k0206sti.htm on February 21, 2007.
5. Sanoff A.P. (2005). Measure for Measure, *ASEE Prism*, Vol. 14, No 5, January, pp. 36-40.
6. Morrell, D., Roberts, C., Grondin, R., Kuo, C.Y., Hinks, R., Henderson, M., Sugar, T., & Danielson, S. (2006). Beyond Measurement: Designing Engineering Outcomes to Foster Student Achievement. In the *2006 Annual Conference Proceedings*, American Society for Engineering Education, June 12-15, Chicago, IL. New York: American Society for Engineering Education.