AC 2008-778: DIRECT MEASURES FOR COURSE OUTCOMES ASSESSMENT FOR ABET ACCREDITATION

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Direct Measures for Course Outcomes Assessment for ABET Accreditation

Abstract - Direct measures provide for the direct examination or observation of student knowledge or skills against measurable learning outcomes. ABET has been putting increasing emphasis on direct measures for a program to demonstrate its achievement of program outcomes and educational objectives. In this paper, an approach for assessment of course outcomes using direct measures is presented. The knowledge and skills described by the course outcomes are mapped to specific problems on homework and exams. Throughout the semester the instructor keeps track of the performance of each student on each course outcome. At the end of the semester students receive letter grades as usual. But in addition each student receives a "score" on the scale of 1-to-5 for every course outcome indicating how well he/she achieved each outcome. The data (scores) coming from each course are used at the program level to assess the program outcomes. The paper provides an example and concludes with recommendations for other institutions that may choose to adapt a similar approach.

I.   Introduction

ABET Criterion 3 for accrediting engineering programs requires each program to have program outcomes. Furthermore, it requires that "*… these program outcomes are being measured and [assessment process] indicates the degree to which the outcomes are achieved*"[1]. Assessment methods are classified into direct and indirect methods. Direct methods can be used to assess knowledge or skills attained by students through direct examination or observation of student performance in meeting a specific outcome. Although the ABET criteria do not specify any assessment methods, using direct measures provides stronger evidence of student learning attributed to the program effectiveness[2]. Typical direct measure opportunities include end-of-course assessment, targeted assignments, capstone experience, capstone examination and portfolios[3-9].

The mechanical engineering program at Washington State University Vancouver has implemented an ABET assessment system where course outcomes are tied to program outcomes through a set of program-level performance criteria. Performance criteria (PC) are measurable attributes identifying the performance required to meet an outcome and are confirmable through evidence. A mapping of these PCs to each course defines the course outcomes. In each course faculty measure how well each course outcome was met using scores on the scale of 1-to-5 (highest). At the end of each semester these scores are processed by the curriculum committee to evaluate achievement of the program outcomes. In the following section, a direct measurement approach for course outcomes is explained.

II.   Direct measures for course outcomes

As stated earlier, direct measures provide for the direct examination or observation of student knowledge or skills against measurable learning outcomes. The approach explained in this

section is used to measure how well each student does in achieving each course outcome. In this approach, the instructor keeps track of the performance of each student on every course outcome throughout the semester. At the end of the semester students receive letter grades as usual. But in addition, each student receives a "score" on the scale of 1-to-5 (highest) for every course outcome indicating how well he/she achieved each outcome.

In this paper a senior level automation course (Mech 467) is used as an example. The course outcomes are given in Table 1.

Table 1. Mech 467 "Automation" course outcomes.

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, simulate system response.
K-4. Use MATLAB software for analysis.

A-2, A-7, B-4, etc. indicate links back to the program-level performance criteria.

The course outcomes are measured by assigning problems targeting these skills on homework and exams. For example, to measure A-2, two questions on homework 1, and one question on exam 1 were asked. Exam 1 also contained two questions targeting A-7 and a question for B-4.

At a first glance this seems to be an increased load. However, it is not very different than what a faculty typically does to teach a course. There are three basic requirements to implement this approach: (1) At the beginning of the semester make a course plan including assessment, (2) Break down grading along course outcomes on the assignments/exams using a grade box, and (3) Enter scores into grade spreadsheet for each course outcome.

II.1. Course plan

Faculty need to plan which assignments/questions will be used to assess each course outcome throughout the semester. For that reason, at the beginning of the semester a course plan similar to the one shown in Table 2 is developed. The plan shows topics to be covered, when assignments would be given and which outcomes would be measured.

Table 2. Course plan (first 5 weeks shown).

Week	Topic	Assignment	Target Outcomes
1	*Dynamic Response* Controller Design, Math models; Transfer functions		

2	*Dynamic Response (cont'd)*
	    Poles and zeros; First order system response, Second order
	    system response
		HW #1	A-2

3	*System-type; Stability* System-type and steady-state accuracy	HW #2 Lab #1	A-7 B-4, G-1

4	*System-type (cont'd)*
	    System-type table and steady state accuracy; Stability; exam
	    review
		HW #3	A-7, E-3, K-4

5	***EXAM 1***		A-2, B-4, A-7

II.2. Breaking down grading

When assignments and exams are graded, we track how many points each student earns towards each targeted outcome. This is done by adding a "grade box" on each assignment (Figure 1).

Question	Course outcome	Grade
1a, b	A-2	/ 30
2a, b, c, d	B-4	/ 30
3a, b	A-7	/ 40
TOTAL:		/ 100

Figure 1. Sample grade box on exam 1.

Each assignment has a similar box showing the mapping between questions, course outcomes and score earned by the student towards each outcome. As the faculty or the teaching assistant grades an assignment, he grades each question as usual but tallies up the grades in this box. For example, in exam 1 questions "1a" and "b" were worth 30 points total. The student may earn 21 points. Then, the faculty writes 21 in the grade box (21 / 30). The box enables a break down of the exam grade along the targeted course outcomes. It also gives the student feedback in how well he is doing in each course outcome.

II.3. Grade spreadsheet

Since the goal is to track how well each student does in every course outcome, the grade spreadsheet needs to be able to accommodate scores coming from the grade boxes on the assignments. There are various ways to design such a grade spreadsheet. Figure 2 shows a segment of the spreadsheet used in the Automation course.

	A-2			A-7					B-4					
Student ID	Hw1(1,2)	Exm1(Q1a,Q1b)	Score	Hw2(1,2,3)	Exm1(Q3a,Q3b)	Hw3(1)	Final (3)	Score	Lab1/2	Lab3/4	Exm1(Q2a,b,c,d)	Lab 5	Exm2(3)	Score
6617	100	21	5	99	10	20	18	4	26	24	10	22	10	4
7814	95	25	5	72	25	20	20	4	24	27	20	30	0	4
7825	100	30	5	91	20	20	20	4	28	30	25	27	10	5
5267	87	25	4	0	13	20	20	3	0	30	9	30	10	4
4450	100	26	5	95	35	20	18	5	18	30	18	27	10	4
3515	0	14	2	40	22	20	16	3	11	30	13	30	10	4
2906	20	18	2	47	33	0	20	3	17	18	17	0	10	3
1006	90	21	4	73	10	4	17	3	11	30	10	29	0	3
3460	100	30	5	100	40	20	16	5	24	30	10	27	10	4
4427	100	27	5	74	40	10	16	4	30	30	12	0	10	4
3244	100	26	5	0	25	20	20	4	0	30	18	30	10	4
5314	85	4	3	93	7	20	20	4	11	27	12	30	10	3
2337	100	25	5	0	10	20	19	3	12	30	5	30	10	3
4696	100	24	5	70	34	20	18	4	22	29	23	27	10	4
3024	100	30	5	91	40	20	20	5	27	30	23	27	10	5
5667	100	30	5	0	32	20	20	5	24	29	15	25	10	4
9584	100	30	5	95	40	20	18	5	21	30	25	29	10	4
4404	100	30	5	100	28	20	17	5	17	30	15	30	0	4
Maximum Points	100	30	5.0	100	40	20	20	5.0	30	30	30	30	10	5.0
Class Average	87.61	24.22		63.33	25.78	17.44	18.50		17.94	28.56	15.56	25	8.33	
Outcome Average			4.4					4.0						3.9

Figure 2. Grade spreadsheet.

Each course outcome shows the assignments and questions for assessment. Looking at the column labeled "Exm1" under each outcome, it can be seen that the grade box on the exam (Figure 1) has been mapped to the spreadsheet (Figure 2). At the bottom of each column total possible points for a particular set of questions/assignment is shown. For example, in exam 1 questions "1a" and "1b" were worth a total of 30 points. In this exam, the first student earned 21 points out of 30. The last student earned 30 out of 30.

In assigning an outcome score (1-to-5 scale) to a student, the following formula is used as a starting point:

$$SCORE = \frac{\sum \text{all points earned by the student in outcome "X"}}{\sum \text{all possible points in outcome "X"}} \times 5$$

The scores are rounded up. This provides only a starting point. The instructor then carefully reviews these scores and can make adjustments depending on the observations of the performance of a particular student throughout the semester. For example, sometimes a good student is unable to submit homework due to a reason beyond his/her control. Just using the formula above can significantly reduce his/her performance score. In other cases, a student may receive good grades on a homework but simply due to help received from others. In this case his score may be reduced by the instructor. Small class sizes (15-30 students) in our program enables faculty to get to know each student quite well.

The achievement of the outcomes at the course level can be assessed by taking an average of all student scores in each outcome (highlighted yellow in Figure 2). For example, overall achievement of the course outcome A-2 was 4.4 / 5.0. The grade spreadsheet also creates a table summarizing the course outcomes and a distribution (frequency) of each score (Table 2). This table is sent to the departmental curriculum committee. The committee processes similar data coming from each course to assess the achievement of the outcomes at the program level (ABET Criterion 3a through k).

Table 2. Course outcomes assessment data.

Course Outcome	Average (Ave.)	Distribution (%)				
		5	4	3	2	1
A-2	4.4	72%	11%	6%	6%	6%
A-7	4.0	33%	39%	28%	0%	0%
B-4	3.9	11%	67%	22%	0%	0%
E-3	4.1	33%	50%	11%	6%	0%
G-1	4.5	67%	28%	0%	0%	6%
K-3	4.4	56%	39%	0%	6%	0%
K-4	4.6	67%	22%	11%	0%	0%

III.   Closing the loop

At the end of the semester, each instructor prepares a brief course assessment report. In this report there is a standard form called "action form". Based on the results in Table 2, if a course outcome scores less than or equal to 3.0, the instructor indicates that outcome on the form and suggests either minor or major changes (actions) to be taken by the program. The major changes are things that would result in modifications of the master syllabus of the course such as adding, rewording or deleting a course outcome, or changes in the list of topics covered. Minor changes are things that can be implemented next time when the course is offered without altering its master syllabus. These could include additional lecture to be spent to cover a particular topic, a change in software, use of supplemental textbooks, etc.

The departmental curriculum assessment committee receives tabular data as shown in Table 2 from each course along with the action forms. Furthermore, other data coming from exit surveys, focus groups, student course surveys are incorporated into the analysis. The data are assembled through a complex process to create scores and distributions for each of the program outcomes "A" through "K". The results are summarized as "track record" charts as shown in Figure 3.
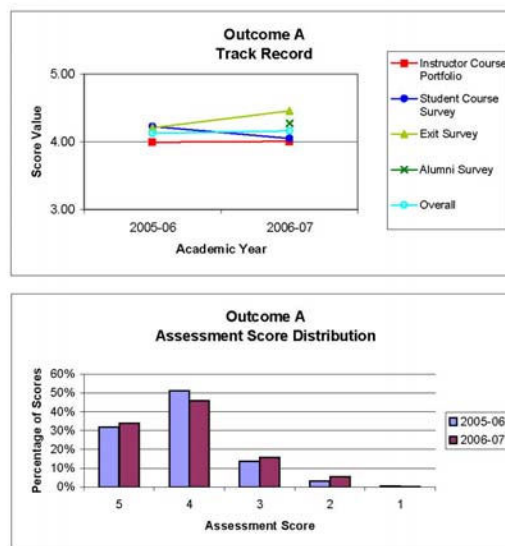

Figure 3. Track record for program outcome A.

The top chart in Figure 3 is an average score on the scale of 1 to 5 indicating how well the program achieves the program outcome. On this chart we plot assessment results coming from each tool, such as exit survey, course portfolio, etc. The bottom chart in Figure 3 is a distribution of scores on the scale of 1 to 5.

The committee also assembles all suggestions coming back from the instructors on the action forms. The program faculty hold an annual "closing the loop" meeting where the track record charts are examined and the suggestions are discussed. The major change suggestions are implemented the following year, if they receive approval from the program faculty. The master syllabi affected by the approved changes are modified and the instructors are notified of the changes to be implemented in the following year. These meetings are well-documented as part of the evidence of continuous improvement for future ABET visits.

IV. Conclusions

In this paper an assessment approach has been presented for direct measurement of how well students achieve course outcomes. Throughout the semester, assignments are graded and students receive their letter grades at the end of the semester as usual. But in addition, the approach leads to an assessment "score" for each student on the scale of 1-to-5. These scores can also be used to compute assessment scores for the course for each outcome. The scores are direct measures of the student performance in a particular outcome whereas the final letter grade given to a student is an indication of his cumulative achievement which is computed using some sort of a weighted average (30% HW grade, 20% exam grade, 10% project grade, etc.).

There are three basic requirements to implement this approach: (1) At the beginning of the semester make a course plan including assessment, (2) Break down grading along course outcomes on the assignments/exams using a grade box, and (3) Enter scores into grade spreadsheet for each course outcome.

For faculty who have teaching assistant support, most likely items 2 and 3 would be done by their assistant. The most critical thing is to have a good course plan at the beginning to implement this approach successfully. In our program class sizes are about 15-30 students thus making it easier to implement the described assessment approach. In larger classes, this approach may need to be further simplified. For example, instead of using all assignments and exams, a representative subset can be used.

This approach has been used by all faculty in our program in all courses for the past three years. We recently had a successful ABET accreditation visit of our program.

References

1. ABET Criteria for Accrediting Engineering Programs, http://www.abet.org/forms.shtml .
2. Rogers, G. "Assessment 101: Direct or Indirect Measures? Are we asking the right question?", *CommunityMatters* , Nov. 2007, http://www.abet.org/newsletter.shtml .
3. Shaeiwitz, J. and Briedis, D., "Direct Assessment Measures", *Proceedings, 2007 ASEE Annual Conference and Exposition*, June 2007, Honolulu, Hawaii.

4. Shaeiwitz, J. A., "Mining Capstone Engineering Experiences for Program Assessment Results," International Journal of Engineering Education, 18 (2), 193-198 (2002).
5. Lingard, R. "A Process For The Direct Assessment Of Program Learning Outcomes Based On The Principles And Practices Of Software Engineering", *Proceedings, 2007 ASEE Annual Conference and Exposition*, June 2007, Honolulu, Hawaii.
6. Gassert, D., Milkowski, L., "Using Rubrics to Evaluate Engineering Design and to Assess Program Outcomes", *Proceedings, 2005 ASEE Annual Conference and Exposition*, June 2005, Portland, OR.
7. Dettman, M., "Effective, Efficient, Direct Assessment of Programmatic Outcomes", *Proceedings, 2005 ASEE Annual Conference and Exposition*, June 2005, Portland, OR.
8. Lin, P., Broberg H., "Capstone Courses and Program Outcomes - TC2K Assessment", *Proceedings, 2004 ASEE Annual Conference and Exposition*, June 2004, Salt lake City, UT.
9. Pape, D., "Linking Student Achievement to Program Outcomes Assessment", *Proceedings, 2004 ASEE Annual Conference and Exposition*, June 2004, Salt lake City, UT.