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Demonstrating Student Outcomes: Evidence by Sampling

Introduction

Criterion 4 of the ABET Criteria For Accrediting Engineering Programs states, "The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which both the program educational objectives and the student outcomes are being attained." [1] A key aspect of this criterion is that the program must provide evidence demonstrating that the student outcomes (formerly known as program outcomes) have been achieved. ABET will accept many things as evidence, including both direct and indirect measures. As a mechanical engineering evaluator, the author has noted that some programs collect an enormous amount of evidence, to the level that there are concerns about the sustainability of the assessment process. This is especially worrisome at research universities where the reward structure provides little, if any, recognition for these types of efforts. The author's own program uses a sampling approach for outcome evidence, which significantly reduces the burden on the faculty.

Since the establishment of the assessment based ABET criteria, several papers have addressed the issue of Student (previously Program) Outcome Assessment and evaluation. Younis [2] proposed the use of student forums, cooperative education, and the fundamentals of engineering (FE) exam. Gassert and Milkowski [3] have suggested using student work form a program's design program to assess program outcomes. Danielson and Rogers [4] use a very extensive collection of student work (several items) for all of their required courses. Gurocak et al. [5] developed 38 performance criteria for the 11 program outcomes. A spreadsheet was distributed to the faculty for recording of the performance criteria. This paper focuses on this sampling approach and shares what the program has learned in employing such an approach. The paper continues with a brief description on ABET definitions and criteria associated with student outcomes. The outcome assessment process for the mechanical engineering program at Michigan State University is then presented. Next, the evaluation process of the assessment data is provided. The paper concludes with some observations about the process.

Background on Student Outcomes

The Engineering Accreditation Commission of ABET defines student outcomes as:

> Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program. [1]

As delineated in Criterion 3, ABET specifies that a program's student outcomes must include the classical a-k [1], but allows a program to include additional student outcomes that may be appropriate for the program. Criterion 4 requires that the program assesses and evaluates the attainment of the student outcomes.

Assessment of Student Outcomes

The Student Outcomes for the Michigan State University BSME program are shown in Figure 1. To properly assess these outcomes, it is imperative that they be mapped into the program's curriculum. This map is shown in Fig. 2. The level of emphasis indicated on this map was determined the faculty responsible for the course.

Figure 1 Mechanical Engineering Program Student Outcomes

The mechanical engineering program at Michigan State University strives for its graduates to acquire the abilities and attributes listed below by integrating the knowledge and skills acquired in a diverse set of courses, through the culture of the program, and the attitude of the program faculty.

a. Apply the knowledge of basic mathematics, science, and engineering
b. Design and conduct experiments, as well as analyze and interpret data
c. 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
d. Function on multidisciplinary teams
e. Identify, formulate, and solve engineering problems
f. Understand professional and ethical responsibility
g. Communicate effectively
h. Understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. Recognition of the need for, and an ability to engage in life-long learning
j. Knowledge of contemporary issues
k. Use of techniques, skills, and modern engineering tools necessary for engineering practice
l. Application of advanced mathematics
m. Design, build, and test in mechanical systems area
n. Design, build, and test in thermal/fluids area
o. Undertake and manage a major design experience

Figure 2 Relationship of Require ME Courses to Program Outcomes

3 = Strong Emphasis, 2 = Some Emphasis, **1** = Little or No Emphasis

Program Outcome	ME201 Thermodynamics	ME 222 Deformable Solids	ME 280 Computer Graphics	ME 332 Fluid Mechanics	ME 361 Dynamics	ME 371 Mechanical Design I	ME 391 Engineering Analysis	ME 410 Heat Transfer	ME 412 Heat Transfer Lab	ME 451 Control Systems	ME 461 Mechanical Vibrations	ME 471 Mechanical Design II	ME 481 Mechanical Engineering Design Projects	Total
a	3	3	2	3	3	3	3	3	3	3	3	3	3	38
b	1	3	1	3	1	1	1	1	3	3	3	2	2	25
c	2	1	2	1	2	3	1	2	3	2	1	3	3	26
d	2	1	2	3	1	3	1	1	3	2	2	3	3	27
e	3	3	1	2	2	3	1	3	2	2	2	3	3	30
f	2	1	2	1	1	2	1	1	1	1	1	2	3	19
g	1	2	2	3	1	2	1	1	3	3	3	2	3	27
h	2	1	1	1	1	2	1	1	1	1	1	1	2	16
i	1	1	1	1	1	2	1	1	2	1	1	1	3	17
j	2	1	2	1	1	2	1	2	1	1	1	1	2	18
k	2	2	3	2	2	2	2	2	3	2	3	3	3	31
l	1	1	1	3	1	1	3	2	2	2	3	1	1	22
m	1	1	1	1	1	3	1	1	1	1	1	3	2	18
n	1	1	1	1	1	1	1	1	3	1	1	1	2	16
o	1	1	1	1	1	2	1	1	2	1	1	2	3	18

The program uses a sampling approach to assess and evaluate its Student Outcomes. Using the Course/Outcome Map of Fig. 2, courses with a major emphasis on a specific student outcome have been identified as an appropriate source of evidence for the outcome. The teaching staff then identifies a specific assignment on the course as the evidentiary item for the outcome. For

example, ME 481 Mechanical Engineering Design Projects has been identified as having a major emphasis for outcome g (Communicate effectively). The instructional staff for ME 481 identified the English grading of the final project report (carried our by the program's director of communication) and the faculty grading of the final presentation (carried out by the design team's faculty advisor) as two items of evidence for the achievement of outcome g. For each Program Outcome, 1-3 items of evidence have been identified. This evidence is collected one semester each academic year. The instructor of the course is asked to provide a copy of the assignment and the following information for the assignment:

Minimum Competency Level
Total number of students
Number of students above the minimum competency level
Copy of the assignment

The minimum competency level (a numerical score) is set by the course instructor. The program defines minimum competency as performance that does not show mastery, but such that the instructor would feel comfortable with the student practicing the topic as an engineer. For most faculty members this will correspond to a 2.0 or 2.5 on the MSU grading system.

Not all of the evidence is tied to course assignments. For example, in some cases results of the FE exam are used or graduating senior focus group input. The graduating senior focus group is conducted in the spring semester of each year. Twelve students are invited to lunch. Three students are selected from each quartile of the descending grade point average list. There is also an attempt to have diversity with respect to gender and ethnicity. At this lunch the students are asked to complete a background survey. The discussion questions for the focus group are prepared before hand and are consistent from year to year. Detailed notes are taken of the discussion and these provide the needed evidence.

For each outcome evidence a metric goal has been set. The evidence and metric goal are summarized in Tables 1 and 2. The outcome assessment data is processed by the Associate Chair for the Undergraduate Program.

Evaluation Process

On a 2-3 year cycle the assessment data is evaluated by both the program's curriculum committee and industrial advisory board. In evaluating the evidence for each outcome, these committees are asked to use the MSU grading system to assign a grade to each outcome. These grades are recorded in the table shown as Table 3. These committees also provide qualitative comments. Based on these grades and comments each committee reports out to the faculty with recommendations for changes. These may be changes in the program to address strengthening the achievement of the outcomes or changes in the assessment process. The faculty approves (or not) these changes and implementation is carried out by the Associate Chair for the Undergraduate Program.

Final Thoughts

Though not as thorough as more exhaustive outcome review, a sampling approach does allow for the identification of program improvements similar to those from a more exhaustive review.

More importantly, it requires considerably less faculty time and effort and, hence, it much more sustainable.

References

1. ABET. ***Criteria for Accrediting Engineering Programs, 2012 – 2013***, http://www.abet.org/engineering-criteria-2012-2013/, visited January 11. 2012.
2. Younis, Nashwan, "Supplementary Assessment Tools for the Enhancement of the Program Assessment Plan", Proceedings of the 2005 ASEE Annual Conference, June 2005.
3. Gassert, John D. and Milkowski, Lisa, "Using Rubrics to Evaluate Engineering Design and to Assess Program Outcomes", Proceedings of the 2009 ASEE Annual Conference, June 2005.
4. Danielson, Scott and Rogers, Bradley, "A Methodology for Direct Assessment of Student Attainment of Program Outcomes", Proceedings of the 2007 ASEE Annual Conference, June 2007.
5. Gurocak, Hakan, Chen, Linda, Kim, Dave, and Jokar, Amir , "Assessment of Program Outcomes for ABET Accreditation", Proceedings of the 2009 ASEE Annual Conference, June 2009.

Table 1 Outcome Evidence

Outcome	Evidence
a. Apply the knowledge of basic mathematics, science, and engineering	a-1. ME 361 Final Exam a-2. ME 332 Final Exam
b. Design and conduct experiments, as well as analyze and interpret data	b-1. ME 332 Lab Final Project b-2. ME 412 Error Experiment b-3. Radiation Experiment
c. 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	c-1. ME 471 Design Project c-2. ME 412 Design Project
d. Function on multidisciplinary teams	d-1. ME 412 Team Building Experiment d-2. ME 412 Design Project Team Participation Evaluation d-3. ME 481 Design Project Team Participation Evaluation
e. Identify, formulate, and solve engineering problems	e-1. ME 410 Convection Exam e-2. ME 451 Final Exam
f. Understand professional and ethical responsibility	f-1. ME 481 Ethics Quiz f-2. FE Ethics Part f-3. Graduating Senior Focus Group
g. Communicate effectively	g-1. ME 412 Thermocouple Memo English Grading g-2. ME 481 Final Report English Grading g-3. ME 481 Final Oral Presentation Grading
h. Understand the impact of engineering solutions in a global, economic, environmental, and societal context	h-1. Graduating Senior Focus Group h-2. ME 481 Economics Quiz h-3. ME 481 Final Report Economics Section
i. Recognition of the need for, and an ability to engage in life-long learning	i-1. ME 481 2nd Report Research Section i-2. Alumni survey lifelong education questions
j. Knowledge of contemporary issues	j-1. Graduating Senior Focus Group j-2. ME 481 Global Warming Quiz
k. Use of techniques, skills, and modern engineering tools necessary for engineering practice	k-1. ME 471 FEA Project k-2. ME 412 Convection Experiment k-3. ME 461 Lab Tests
l. Application of advanced mathematics	l-1. ME 410 Heat Conduction Exam l-2. ME 461 1st Exam l-3. ME 391 Final Exam
m. Design, build, and test in mechanical systems area	m-1. ME 371 Final Design Project m-2. ME 471 Final Design Project
n. Design, build, and test in thermal/fluids area	n-1. ME 412 Design Project
o. Undertake and manage a major design experience	o-1. ME 481 Design Project

Table 2 Metric Goals for Outcome Evidence

Evidence	Metric Goal
a-1. ME 361 Final Exam	80% above minimum competency
a-2. ME 332 Final Exam	80% above minimum competency
b-1. ME 332 Lab Final Project	80% above minimum competency
b-2. ME 412 Error Experiment	90% above minimum competency
b-3. Radiation Experiment	90% above minimum competency
c-1. ME 471 Design Project	90% above minimum competency
c-2. ME 412 Design Project	90% above minimum competency
d-1. ME 412 Team Building Experiment	95% above minimum competency
d-2. ME 412 Design Project Team Participation Evaluation	95% above minimum competency
d-3. ME 481 Design Project Team Participation Evaluation	95% above minimum competency
e-1. ME 410 Convection Exam	80% above minimum competency
e-2. ME 451 Final Exam	85% above minimum competency
f-1. ME 481 Ethics Quiz	90% above minimum competency
f-2. FE Ethics Part	90% exceed national average
f-3. Graduating Senior Focus Group	Less than 25% negative input
g-1. ME 412 Thermocouple Memo English Grading	90% above minimum competency
g-2. ME 481 Final Report English Grading	95% above minimum competency
g-3. ME 481 Final Oral Presentation Grading	95% above minimum competency
h-1. Graduating Senior Focus Group	Less than 25% negative input
h-2. ME 481 Economics Quiz	90% above minimum competency
h-3. ME 481 Final Report Economics Section	90% above minimum competency
i-1. ME 481 2nd Report Research Section	90% above minimum competency
i-2. Alumni survey lifelong education questions	75% positive response
j-1. Graduating Senior Focus Group	Less than 25% negative input
j-2. ME 481 Global Warming Quiz	90% above minimum competency
k-1. ME 471 FEA Project	80% above minimum competency
k-2. ME 412 Convection Experiment	90% above minimum competency
k-3. ME 461 Lab Tests	80% above minimum competency
l-1. ME 410 Heat Conduction Exam	75% above minimum competency
l-2. ME 461 1st Exam	75% above minimum competency
l-3. ME 391 Final Exam	75% above minimum competency
m-1. ME 371 Final Design Project	90% above minimum competency
m-2. ME 471 Final Design Project	90% above minimum competency
n-1. ME 412 Design Project	95% above minimum competency
o-1. ME 481 Design Project	95% above minimum competency

Table 3 Outcome Achievement Grading

Outcome	**Achievement Grading (0.0, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0)**
a. Apply the knowledge of basic mathematics, science, and engineering	
b. Design and conduct experiments, as well as to analyze and interpret data	
c. 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	
d. Function on multidisciplinary teams	
e. Identify, formulate, and solve engineering problems	
f. Understand professional and ethical responsibility	
g. Communicate effectively	
h. Understand the impact of engineering solutions in a global, economic, environmental, and societal context	
i. Recognition of the need for, and an ability to engage in life-long learning	
j. Knowledge of contemporary issues	
k. Use of techniques, skills, and modern engineering tools necessary for engineering practice	
l. Application of advanced mathematics	
m. Design, build, and test in mechanical systems area	
n. Design, build, and test in thermal/fluids area	
o. Undertake and manage a major design experience	