AC 2007-1372: USING STUDENT PERFORMANCE AND FACULTY EXPERIENCE TO ASSESS A MECHANICAL ENGINEERING PROGRAM

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Using Student Performance and Faculty Experience to Assess a Mechanical Engineering Program

Abstract

Assessing the level at which a Mechanical Engineering program achieves its stated outcomes is essential, not only to a successful ABET evaluation but also to the continued improvement and effectiveness of the program. While survey data is valuable, it should only be one component of a broader assessment plan. The Mechanical Engineering (ME) program at the United States Military Academy (USMA) has employed a method to feed graded event averages and standard deviations from student assignments, examinations, and projects into a multi-level assessment tool that provides a valuable measure of how well the students are achieving the program outcomes.

In the fall of 2005, the need arose to objectively evaluate how well the students in a design course were achieving USMA's Engineering and Technology outcomes. The author developed a method to identify the graded events that supported each of the course's objectives, determine how well they supported those objectives, and then link objective achievement to the USMA level outcomes through a subjective pair-wise comparison of the course objectives. Positive feedback from faculty in the ME program led to expansion of this process to capture the student performance data and faculty input from all ME program courses and feed this into a program level assessment. The resulting evaluation combines the strengths of objective evaluation (based on graded events) and subjective evaluation (based on faculty experience).

This paper describes the motivation for developing the assessment tool, the components of the assessment tool, how each component is integrated to provide an assessment of course objectives, and how these assessments combine to produce an evaluation of program outcomes. Examples of course and program assessment results are presented. Finally, the paper describes how the results of this assessment instrument have been used to modify course objectives and improve course content within the ME program. This tool has been extremely effective and is now a key component of the USMA ME program assessment.

Introduction

According to ABET, Inc., all accredited engineering programs must establish outcomes that will lead to the attainment of the program's objectives. There must be a documented assessment process in place "that demonstrates that these program outcomes are being measured and indicates the degree to which the outcomes are achieved."[1] This paper describes a process that is currently in use at USMA to incorporate student performance indicators into the assessment of course objectives and program outcomes.

Mechanical Engineering Program Outcomes

In accordance with ABET, Inc. guidance, the ME program leadership began by defining the outcomes (those things that our students should know and be able to do by graduation) for our program that would support our program objectives. We then performed an analysis to ensure that the program outcomes adequately addressed the sub-components of ABET, Inc. Criterion 3. Table 1 lists the nine outcomes and the supported ABET, Inc. criterion used for the assessment and improvement of the USMA ME program.

Table 1. ME Program Outcomes and Supported ABET, Inc. Criterion

Mechanical Engineering Program Outcome	Supported ABET Criterion/Outcomes
An ability to identify and formulate engineering problems and apply their knowledge of mathematics, science, and engineering along with creativity skills to solve those problems in mechanical engineering and Army contexts.	Criterion 3 Outcomes (a) and (e)
A familiarity with statistics and linear algebra, a knowledge of chemistry and depth in calculus-based physics, and an ability to apply advance mathematics through multivariate calculus and differential equations to solve mechanical engineering problems.	Criterion 8
An ability to function professionally and with ethical responsibility as an individual and on multidisciplinary teams.	Criterion 3 Outcomes (d) and (f)
An ability to design and realize thermal and mechanical systems, components, or processes to meet the needs of the mechanical engineering discipline, the Army, or the nation.	Criterion 3 Outcome (c), Criterion 8
An ability to design and conduct experiments, as well as to analyze and interpret data to support the mechanical engineering design or problem solving process.	Criterion 3 Outcome (b)
An ability to communicate effectively with clear, critical thinking skills required of a junior Army officer and within the context of solving mechanical engineering problems.	Criterion 3 Outcome (g)
A knowledge of contemporary issues and an understanding of the impact of engineering solutions on the Army, the nation, and in global contexts.	Criterion 3 Outcomes (h) and (j)
An ability to continuously improve and engage in life-long learning to adapt to a technologically advancing Army.	Criterion 3 Outcome (i)
An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	Criterion 3 Outcome (k)

Assessment Components

For a number of years, the faculty had used a variety of instruments to assess the ME program. These are graphically depicted in figure 1 and include the typical list: results from the Fundamentals of Engineering examination, capstone design sponsor surveys, advisory board feedback, faculty surveys, and end-of-course student surveys. The senior faculty realized that the assessment process relied too heavily on survey data. An objective assessment of the students' performance and how that supported the overall program outcomes was lacking. That input is represented by the bottom oval in figure 1. The challenge was developing a method to capture and quantify student performance and incorporate it into the program assessment model.

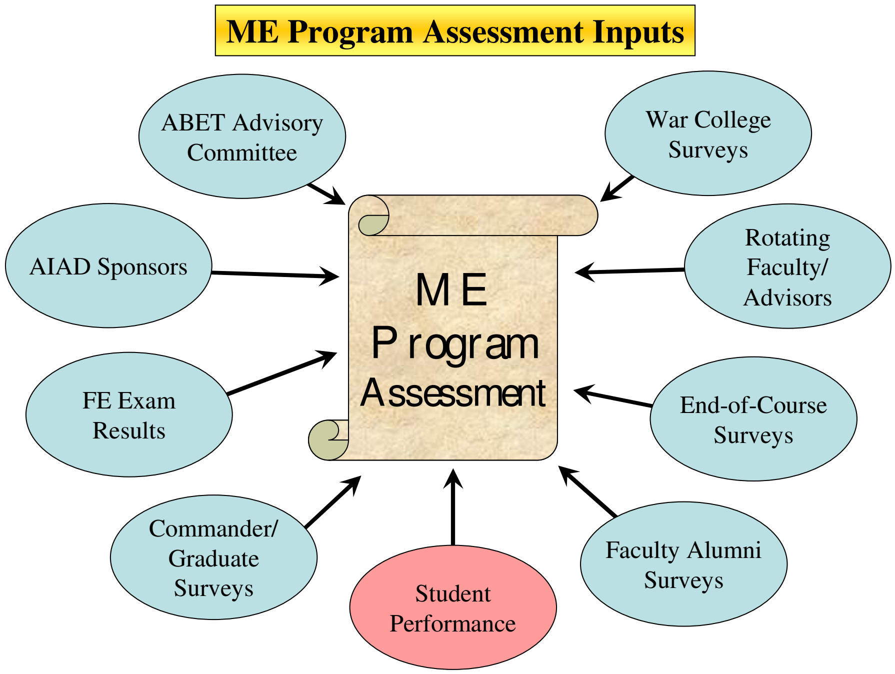

Figure 1. USMA ME Program Assessment Inputs

Assessment Methodology

A need arose in the fall of 2005 to objectively evaluate how well the students in a design course were achieving USMA's Engineering and Technology outcomes. The author developed a method to use graded events from the course in order to evaluate student achievement of the course specific objectives. These objectives were then evaluated to determine how well they supported the achievement of the Engineering and Technology outcomes. Positive feedback from faculty in the ME program led to the modification and expansion of this process to capture the student performance data and faculty input from all ME program courses and feed this into a program level assessment.

The methodology employed to incorporate student performance in the program assessment occurs in two steps. First, student performance in the form of graded events (or embedded indicators) is combined with a subjective faculty rating to produce an assessment of each objective in a course. Second, the faculty member in charge of each course determines which course objectives most strongly support each of the program outcomes. She also subjectively evaluates how strongly the course objective supports the outcome. This experienced evaluation is combined with the results from the embedded indicators to produce a rating of how well the students in a particular course are achieving the ME program outcomes. Figure 2 provides a flow chart depiction of the assessment methodology. The resulting evaluation combines the strengths of objective graded evaluation and subjective faculty assessment.

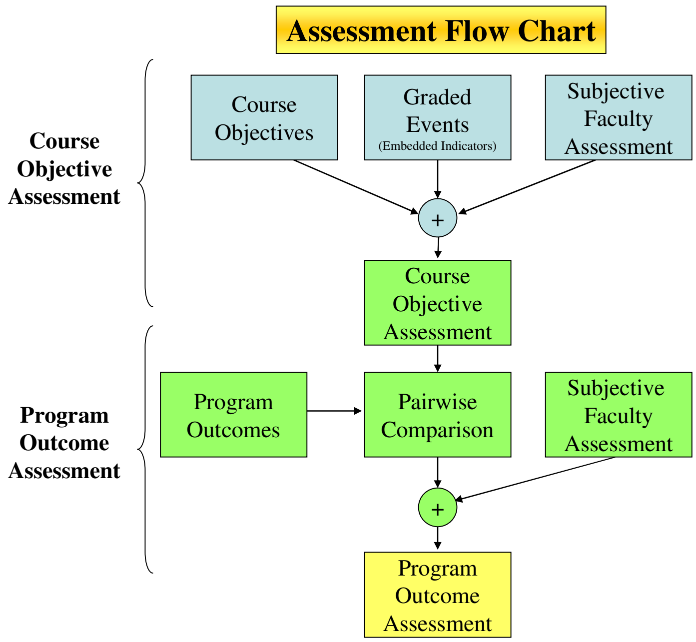

Figure 2. ME Program Assessment Flow Chart

Each objective in each program course is evaluated by using embedded indicators which consist of selected graded events that are contained within the course. Ideally, these indicators are selected prior to the start of the semester. These indicators are entered into a MS Excel spreadsheet, a portion of which is shown in figure 3. The graded events used to assess every course objective in the course are entered in the green shaded blocks under the 'Embedded Indicators' heading along with a description of that indicator if desired, the average grade (in points) earned for that indicator, the standard deviation of the individual grades, and the maximum number of points possible for that graded event. That information is automatically entered beneath each of the courses objectives (two are fully depicted in the figure). The instructor then edits the course objective embedded indicators by deleting the information in the cells for indicators that do not support the assessment of that course objective. For the course depicted in figure three, the first objective uses all of the embedded indicators that are designated for the course. Objective two uses eight of the embedded indicators to assess the student achievement of that objective. The data for each of the embedded indicators is available from the institution's central grades processing program. Once all data is entered into the spreadsheet, it automatically computes the average and standard deviation for each course objective's embedded indicators.

The instructor makes a subjective evaluation of how well the set of embedded indicators assesses student achievement of the course objective. This is accomplished using the Likert scale depicted in table 2 to 'rate' the statement, "The embedded course indicators are a strong measure of student achievement of this course objective." The subjective rating for the first course objective in figure 3 is highlighted by a red oval. This subjective evaluation is multiplied by the embedded indicator percentage to yield an instructor assessment for that course objective. This assessment is routinely used at the end of the semester in the course evaluation where it is compared to student survey evaluations of the same objective. It should be noted that it is entirely possible for the instructor to select and evaluate the embedded indicators prior to the start of a semester, thereby further removing bias from the evaluation.

ME312 COURSE OBJECTIVES ASSESSME

Embedded Indicators					1. Build upon the foundation received in Thermal-Fluids I, integrating the classical subjects of Thermodynamics and Fluid Mechanics.				2. Analyze the performance of internal combustion engines and associated automotive system components.				3. Analyze th propu
Indicator	**Description**	**Avg Pts Earned**	**Stnd Dev %**	**Pts Possible**	**Pts Earned**	**Stnd Dev %**	**Stnd Dev Pts**	**Pts Possible**	**Pts Earned**	**Stnd Dev %**	**Stnd Dev Pts**	**Pts Possible**	**Pts Earned**
Writ		85.85	12.05%	100	85.85	12.05%	12.05	100	85.85	12.05%	12.05	100	
Auto Briefs		47.45	4.56%	50	47.45	4.56%	2.28	50	47.45	4.56%	2.28	50	
Exergy Design		84.80	14.08%	100	84.80	12.05%	12.05	100	84.80	12.05%	12.05	100	
CFR Lab		45.40	9.63%	50	45.40	9.63%	4.82	50	45.40	9.63%	4.82	50	
WPR 1		173.26	13.02%	200	173.26	13.02%	26.04	200	173.26	13.02%	26.04	200	
GT Lab		83.33	13.74%	100	83.33	13.74%	13.74	100					83.33
WPR 2		185.77	10.51%	200	185.77	10.51%	21.02	200					185.77
Powerplant Design		67.43	17.19%	100	67.43	17.19%	17.19	100					
Wind Tunnel Lab		87.92	13.94%	100	87.92	13.94%	13.94	100					87.92
DOE		77.55	8.20%	85	77.55	8.20%	6.97	85					77.55
WPR 3		175.55	20.11%	200	175.55	20.11%	40.22	200					175.55
TEE (Combustion)		44.60	7.60%	50	44.60	7.60%	3.80	50	44.60	7.60%	3.80	50	
TEE (Otto)		62.50	2.80%	65	62.50	2.80%	1.82	65	62.50	2.80%	1.82	65	
TEE (Exergy)		41.80	19.10%	55	41.80	19.10%	10.51	55	41.80	19.10%	10.51	55	
TEE (Modeling)		31.30	9.14%	35	31.30	9.14%	3.20	35					31.30
TEE (Turbojet)		39.20	22.11%	55	39.20	22.11%	12.16	55					39.20
TEE (Comp Flow)		40.95	20.10%	50	40.95	20.10%	10.05	50					40.95
TEE (Lift/Drag)		38.80	21.88%	40	38.80	21.88%	8.75	40					38.80
Totals					1413.46		220.60	1635	585.66		73.36	670	760.37
Assessment					**86.5%**				**87.4%**				
Stnd Dev					**13.5%**				**10.9%**				
Max Level of Support					**5.00**				**5.00**				
Objective Rating					**4.32**				**4.37**				

Figure 3. ME Course Objectives Assessment Tool

Table 2. Likert Scale

Rating	Associated Meaning
1	Strongly Disagree
2	Disagree
3	Neither Agree nor Disagree
4	Agree
5	Strongly Agree

Once completed, the embedded indicator data is then used to assess the ME program outcomes. This is achieved through the use of an engineering design tool known as the pair-wise comparison. The pair-wise comparison depicted in figure 4 is used to determine which course objective most strongly contributes to the assessment of a particular program outcome. Each course objective is compared to all of the others. For instance, if course objective A more strongly supports the assessment of ME program outcome #1 than does course objective B, course objective A receives a score of one and course objective B receives a score of zero. If the instructor can not determine which course objective is a stronger indicator, a score of 0.5 is assigned to each. Once the comparisons are completed, the scores are totaled. In the example in figure 4, the third course objective has a total score of three and is most suitable for assessing program outcome #1. With this information in hand, the instructor must once again use his experience and the Likert scale to rate the statement: “Student achievement of this course objective is a strong measure of student achievement of this program outcome.” This rating is highlighted by the red oval in figure 4.

This pair-wise comparison is performed for each of the nine outcomes in the ME program. Again, it is significant that this comparison may be performed before this semester begins and before any embedded indicator data has been taken. This also removes some potential for bias from the instructor's assessment of how well this course supports the program outcomes.

OUTCOME #1. An ability to identify and formulate engineering problems and apply their knowledge of mathematics, science, and engineering along with creativity skills to solve those problems in mechanical engineering and Army contexts.

	1. To describe mathematically and understand physically the three-dimensional kinetics of particles using Newton's laws of motion and energy methods.	2. To describe mathematically and understand physically the three-dimensional kinetics of systems of particles using Newton's laws of motion.	3. To describe mathematically and understand physically the three-dimensional kinetics of rigid bodies using Newton's laws of motion.	4. To describe mathematically and understand physically the one-dimensional kinetics of vibrating mass-spring-damper systems.	Sum	Relative Weight	Scaled Weights
1. To describe mathematically and understand physically the three-dimensional kinetics of particles using Newton's laws of motion and energy methods.	X	0	0	0.5	0.5	0.0833	0.83
2. To describe mathematically and understand physically the three-dimensional kinetics of systems of particles using Newton's laws of motion.	1	X	0	0.5	1.5	0.25	2.50
3. To describe mathematically and understand physically the three-dimensional kinetics of rigid bodies using Newton's laws of motion.	1	1	X	1	3	0.5	5.00
4. To describe mathematically and understand physically the one-dimensional kinetics of vibrating mass-spring-damper systems.	0.5	0.5	0	X	1	0.1667	1.67
					6		

On a Scale of 1 - 5, how well does the highest rated course objective support the given ME Program Outcome	5.0

Figure 4. ME Program Course Objective to Program Outcome Mapping

Figure 5 depicts the spreadsheet that is used to capture the rollup of the embedded indicators used in the course objectives analysis and is used to assign an assessment value to each of the program outcomes. The 'Weights' are read from each of the course objective pair-wise comparisons (red oval in figure 4) and are multiplied by the embedded indicator percentage rating (from the 'Assessment' row in figure 3 and carried forward into the 'Mean' entry in figure 5) for the course objective to provide a numerical assessment ('Score') for how well that course objective assesses the program outcome in question. For any given in the program outcome a final assessment is assigned by selecting the maximum assessment value and its associated standard deviation from the scores of each course objective. These are carried to the 'Assessment' column for each program outcome.

ME Program Outcomes	Assessment	Standard Deviation	Subjective Rating	1. Objective 1				
				Weight	Mean	Std Dev	Score	Score SD
1. An ability to identify and formulate engineering problems and apply their knowledge of mathematics, science, and engineering along with creativity skills to solve those problems in mechanical engineering and Army contexts.	4.53	0.43	5.00	5.00	90.7%	8.5%	4.53	0.4267
2. A familiarity with statistics and linear algebra, a knowledge of chemistry and depth in calculus-based physics, and an ability to apply advance mathematics through multivariate calculus and differential equations to solve mechanical engineering problems.	4.53	0.43	5.00	0.00	90.7%	8.5%	0.00	0
3. An ability to function professionally								

Figure 5. ME Program Outcome Rating Tool

Figure 6 is a visual representation of the assessments of all nine program outcomes by a particular course. The evaluation is entered as a Likert rating with an error bar representing the standard deviation of the rating. The green shaded area indicates a strong assessment of the outcome. The red area represents a weak assessment.

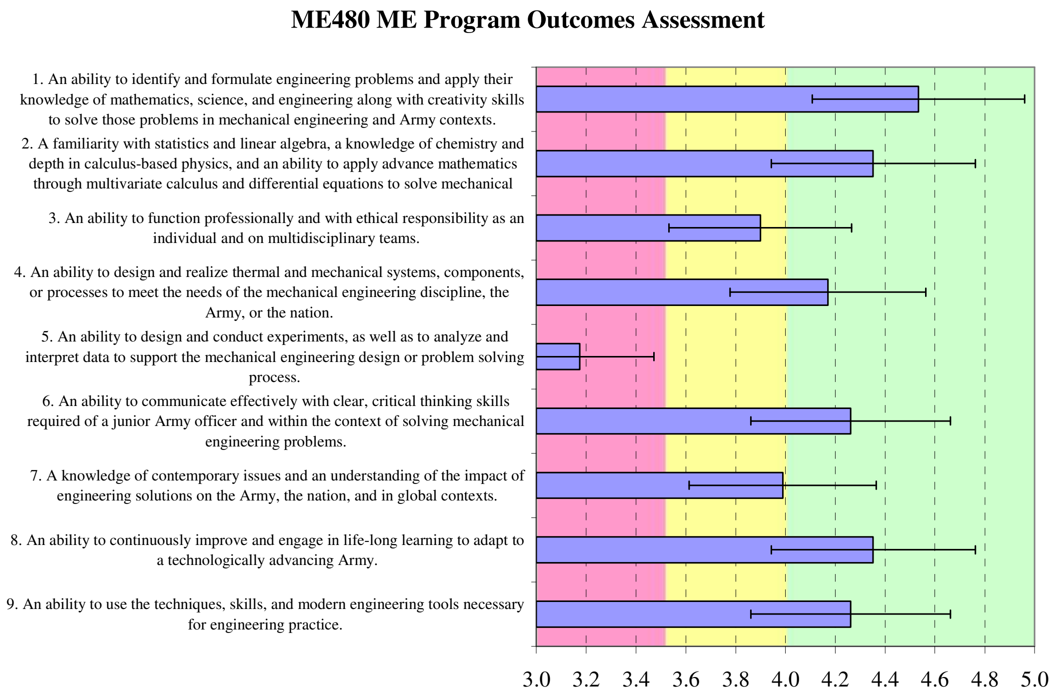

Figure 6. Course Specific Achievement of ME Program Outcomes

The results from each course are combined into a chart which compares the course assessments of each program outcome. An example of the assessment of outcome #1 is shown in figure 7. The maroon bar indicates the subjective rating of that course's objective used to assess the outcome.

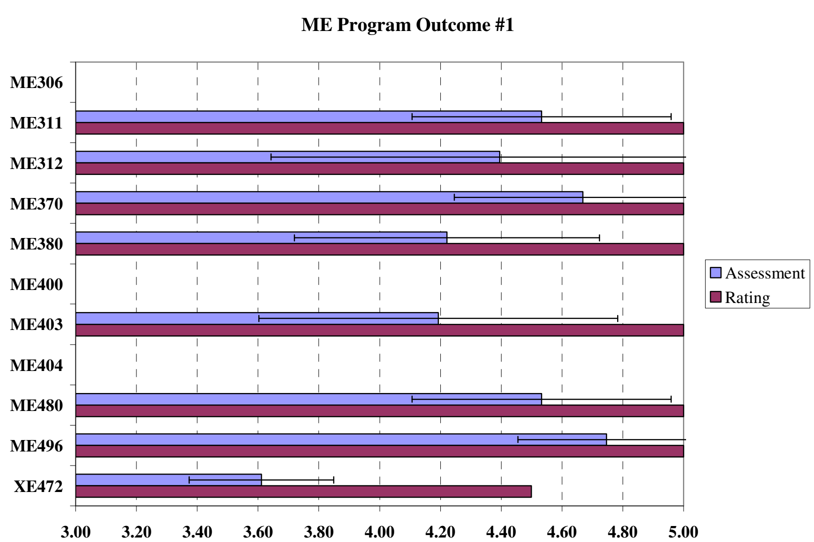

Figure 7. Consolidated Course Assessments of ME Program Outcome #1

The blue bar indicates the assessment of the outcome and includes the standard deviation information. When examining each outcome, the strongest assessment is that in which the red bar is at a five, the blue bar is close to it, and the standard deviation is small.

Results

While no method is completely objective or exact, the assessment method presented in this paper has allowed the mechanical engineering faculty to make several adjustments to the ME program components. Examples of these are shown in the data included in this paper.

First, the course objective assessment depicted in figure 3 indicates that the course objective in the first column is supported by each of the embedded indicators in the course. This indicates an objective that may be overly broad in its scope. Upon further review, the faculty determined that this was the case. This particular course objective was also written in a way that made it difficult to directly measure. In the end, the faculty agreed that this should be considered a goal for the course, but not an objective.

The data presented in figure six indicates that for the course in question (heat transfer), there is not a strong assessment of the fifth program outcome. This, in and of itself, is not a problem as long as there are other courses in the program which support the achievement of this outcome and can be used to assess the level to which our graduates are meeting it. Not every course has to achieve every program outcome.

On the other hand, there was one instance in which the end of course data indicated an outcome assessment that was significantly lower than expected. The instructor had expected a higher assessment. A review of course content by senior faculty members also confirmed that there was ample content in the course to justify a strong assessment of the particular program outcome. What was missing was a specific course objective addressing that area. The content in the course was present and the students were performing the work, but there was no objective to match this content. Discussions with several faculty resulted in the unanimous decision that this should be an objective of the course, and it was subsequently added. This is a shortcoming that most likely would not have been addressed had this assessment tool not been in place.

Conclusion

While there is no assessment 'silver bullet,' the methodology presented in this paper has been continually developed and served the USMA ME program well over the past two years. It has allowed the faculty to easily see connections and relationships in the various levels of assessment that had previously gone unnoticed. An added benefit has been the ability to 'kill three birds with one stone' by using graded course events to assess student performance, assess achievement of objectives at the course level, and add a student performance component to the assessment of the ME program's outcomes. Finally, the ability to complete the subjective portions of the assessment prior to the collection of data has allowed the program to take advantage of the considerable amount of faculty experience in the program while reducing the bias that inevitably comes with self-assessment.

Bibliography

1. "Criteria for Accrediting Engineering Programs", Engineering Accreditation Commission, ABET, Inc., Baltimore, MD, Dec 2005.