2006-1132: PROGRAM ASSESSMENT THE EASY WAY: USING EMBEDDED INDICATORS TO ASSESS PROGRAM OUTCOMES

Fred Meyer, U.S. Military Academy

Lieutenant Colonel Karl F. (Fred) Meyer is an Associate Professor and Civil Engineering Structures Group Director in the Department of Civil and Mechanical Engineering at the United States Military Academy (USMA), West Point, NY. He is a registered Professional Engineer in Virginia. LTC Meyer received a B.S. degree from USMA in 1984, and M.S. and Ph.D. degrees in Civil Engineering from the Georgia Institute of Technology in 1993 and 2002, respectively.

Allen Estes, U.S. Military Academy

Colonel Allen C. Estes is a Professor and Civil Engineering Program Director at the United States Military Academy (USMA), West Point, NY. He is a registered Professional Engineer in Virginia. COL Estes received a B.S. degree from USMA in 1978, M.S. degrees in Structural Engineering and in Construction Management from Stanford University in 1987 and a Ph.D. degree in Civil Engineering from the University of Colorado at Boulder in 1997.

Ronald Welch, U.S. Military Academy

Colonel Ronald W. Welch is an Associate Professor and Acting Deputy Head of the Department of Civil and Mechanical Engineering at the United States Military Academy (USMA), West Point, NY. He is a registered Professional Engineer in Virginia. COL Welch received a B.S. degree from USMA in 1982, and M.S. and Ph.D. degrees in Civil Engineering from the University of Illinois in 1991 and 1999, respectively.

David Winget, United States Military Academy

Major David G. Winget is an Assistant Professor in the Department of Civil and Mechanical Engineering at the United States Military Academy. He is a registered Professional Engineer in Texas and Missouri. Major Winget received a B.S. degree from the United States Military Academy in 1994 and an M.S. degree in Civil Engineering from University of Texas at Austin in 2003.

Program Assessment the Easy Way: Using Embedded Indicators to Assess Program Outcomes

I. Introduction

The culminating design experience for civil engineering majors at the United States Military Academy (USMA) is CE492, Design of Structural Systems. CE492 serves as a "capstone" experience or one in which students are faced with a multi-disciplinary design project incorporating facets from all previous civil engineering courses. Previous capstone experiences have required students to design structures planned for construction or currently under construction at the Academy, thus providing an opportunity for site visitations and active participation with key players in the project development process. Since CE492 provides a multi-disciplinary experience, it also provides an ideal opportunity for the application of embedded assessment indicators.

The purpose of this paper is to describe the use of an embedded assessment technique which has been used successfully for two semesters in CE450, Infrastructure Development and Construction Management, to assess accomplishment of the Academy's Engineering and Technology Goal[1]. By merging the student evaluation and assessment processes in CE492[2], instructor workload was reduced, student evaluation was tied more closely to the relevant academic program and the ASCE Body of Knowledge (BOK) outcomes, and a systematic method was created for identifying shortcomings and areas of excellence in the program.

II. The Civil Engineering Program

The USMA Civil Engineering Program outcomes shown in Table 1 are configured to meet the requirements of ABET 3a-k and specify what civil engineering majors should be able to accomplish at the time of graduation from the USMA. With the evolution of the BOK and the promise of implementation in the near future, the CE Program Outcomes include the requirement for specialization in an area of civil engineering (14), project management, construction and asset management (15), business and public policy and administration (16), and leadership (17), the requirements extending beyond previous ABET 3a-k requirements. The program is assessed by measuring the extent to which graduates can accomplish the 17 CE program outcomes.

Table 1 - The USMA CE Program Outcomes

1.	Graduates can apply the engineering thought process to design civil engineering components and systems.
2.	Graduates demonstrate creativity, in the context of engineering problem-solving.
3.	Graduates are proficient in the structural, environmental (to be construction management as class of 2007 enters senior year), hydrology & hydraulic design, and geotechnical discipline areas of civil engineering.
4.	Graduates are proficient in mathematics, calculus-based physics, and general chemistry.
5.	Graduates can design and conduct experiments, and analyze and interpret data.
6.	Graduates can function effectively on multidisciplinary teams.
7.	Graduates demonstrate an appreciation of the roles and responsibilities of civil engineers and the issues they face in professional practice.
8.	Graduates can use modern engineering tools to solve problems.
9.	Graduates can write effectively.
10.	Graduates can speak effectively.
11.	Graduates demonstrate knowledge of contemporary issues.
12.	Graduates have the broad education necessary to understand the impact of engineering solutions in a global and societal context.
13.	Graduates are prepared for and motivated to pursue continued intellectual and professional growth—as Army officers and engineers.
14.	Graduates can apply knowledge in a specialized area related to civil engineering.
15.	Graduates can explain the elements of project management, construction, and asset management.
16.	Graduates can explain business and public policy and administration fundamentals.
17.	Graduates can explain the role of the leader and leadership principles and attitudes.

III. The Assessment Tool

One of the objectives in creating the assessment tool discussed in this section was to save time by reducing the amount of redundant work required of instructors. In too many cases, faculty will assess courses and programs by creating a special survey or external tool to gather data that can be quantified and analyzed. An embedded assessment is more efficient because it relies on data that already exists within the academic program[3]. In order to both evaluate student performance in CE492 on the course engineering design problem (EDP) and simultaneously assess CE program and BOK outcome accomplishment, grading was performed through the use of a computer spreadsheet into which a standardized cut sheet was incorporated. The spreadsheet shown in Figure 1 provides details from the final EDP submission; several other submissions existed in the overall EDP, but only the final submission is included for this explanation. The figure shows how the majority of activities in the EDP (e.g., executive summary, grading, drainage and utility plan, etc.) mapped directly to one or more of the 17 CE program outcomes. This mapping included weighting factors that accounted for the extent to which a given program outcome represented the various requirements of the EDP. For example, a score of 5 was attributed to the relationship between "Gravity System Analysis and Design Calculations" and Outcome 1 (Apply the engineering thought process). This maximum weight shows there is a high correlation between success on this EDP task and attainment of the relevant program outcome.

Completion of the assessment was a three-step process. First, the instructor determined the number of points assigned to each requirement of the EDP. Second, and clearly the most subjective, the instructor and other senior faculty members examined each EDP requirement through a lens of the 17 program outcomes and determined to what extent the requirement contributed to the attainment of each outcome. In many cases, the requirement did not correlate to an outcome, in which case no assessment was possible. In the remaining cases where a correlation existed, the instructor had to decide the degree to which the outcome was assessed using a scale of one to five, where one indicated a very weak correlation and five indicated a strong correlation. A rating of zero (shown as a blank cell) indicated no correlation existed. A thorough understanding of both the EDP and the 17 program outcomes was required on the part of the instructor to accomplish this step. The instructor completed steps one and two only once, since they applied to all EDPs graded. The third step was to grade the design projects using the established cut scale. The assessment results were calculated automatically by the spreadsheet alleviating the need to again review student work purely for assessment purposes. More detail on internal calculations within the spreadsheet will be discussed later in the paper.

Correlation of CE492 Capstone Design Project Grade Sheet with CE Program Outcomes

	Design Requirements:	Possible Points	Points Earned	Earned %	Civil Engineering Program Outcomes, Correlation with Requirements: 5 (High) - 1 (Low)																
					O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	O13	O14	O15	O16	O17
100% Design	Admin Requirements	20	20	100%																	
	Title Sheet	3	3	100%																	
	Executive Summary	5	5	100%									3								
	Drawing List	3	3	100%																	
	Notes Page	20	20	100%						1											
	Project Scope	2	2	100%																	
	Facts and Assumptions	2	2	100%																	
	Needs Analysis	2	2	100%																	
	General Approach or Methodology	6	6	100%						2	1		2				1				
	Discussion and Results	6	6	100%						3	1		2				2				
	Existing Site Plan	5	5	100%																	
	Site Use Plan	5	5	100%																	
	Site Prep and Demo Plan	5	5	100%																	
	Grading, Drainage, and Utilities Plan	10	10	100%	1	1	1			1								1	1		
	Exterior Architectural Elevations	5	5	100%		2															
	Architectural Roof Plan	5	5	100%																	
	Architectural Floor Plans	7	7	100%																	
	Life Safety Floor Plans	5	5	100%																	
	Roof Framing Plan	10	10	100%			1														
	Floor Framing Plans	30	30	100%			1														
	Truss Elevations	5	5	100%			1														
	Column Schedule	8	8	100%			1														
	LLRS Frame Elevations	15	15	100%			1														
	Typical Details	20	20	100%			1														
	Rock Excavation Plan & Sects	5	5	100%																	
	Foundation Plan	10	10	100%			2														
	Foundation Schedules, Sections, & Details	20	20	100%			2														
	Arch. Floor Plan and Access/Egress Calcs	5	5	100%	1																
	Load Analysis	5	5	100%																	
	Gravity System Analysis and Design Calculations	70	70	100%	5		4	2			1	3						5			
	Lateral System Analysis and Design Calcs	70	70	100%	5		4	2			1	4						5			
	Soil and Foundation Plan Calculations	40	40	100%	1		4	2			1	2						5			
	Drainage Plan Calculations	30	30	100%	1		4	2			1	2						5			
	Environmental Considerations	5	5	100%			1														
	Staircase Layout	5	5	100%																	
	Cost Estimates	15	15	100%						1	1							1	3	1	
	Construction Schedule	5	5	100%															5	1	
	10% Design Cut Sheet	2	2	100%																	
	35% Design Cut Sheet	2	2	100%																	
	65% IPR Cut Sheet	2	2	100%																	
	Documentation	5	5	100%																	
	100% Design Total	**500**	**500**	**100%**																	
	Total EDP	**1500**	**1500**	**100%**																	

Sum of Correlations Required for Acceptable Correlation: 25	Assessment of Standard																
Sum of Correlation Points	82	35	84	27	10	64	46	40	45	15	15	17	63	78	48	21	13
Sum of Squares of Correlation Points	278	97	228	53	14	146	68	74	121	59	39	47	125	256	130	49	39
Measure of Correlation (>1.0 is Acceptable)	11.1	3.9	9.1	2.1	0.6	5.8	2.7	3.0	4.8	2.4	1.6	1.9	5.0	10.2	5.2	2.0	1.6
Assessment Criteria	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	O13	O14	O15	O16	O17

Figure 1 – Data Entry Page of Assessment Tool for CE Program Outcome Assessment

IIIa. Details of the Assessment Tool

The following definitions provide an explanation of the assessment tool seen in Figure 1.

- Design Requirements provide the specific requirements of the EDP. In the example shown, only the requirements for the final design project submission (100%) are shown. Each submission was allocated a specific number of points.
- Possible Points is the number of points assigned to a specific requirement. The instructor apportions the total points for each major requirement into the sub-requirements.
- Points Earned lists the number of points earned by the design team on each requirement.
- Earned % is determined by dividing the Earned Points by the Possible Points and multiplying by 100.
- Correlation with Requirements is a subjective judgment made by the instructor on how well each design requirement contributed to the accomplishment of the 17 program outcomes. A high number (5) means the requirement provides a meaningful assessment of the outcome. A low number (1) means the requirement provides a poor assessment of the outcome. A blank cell means the requirement does not assess the outcome.
- Sum of Correlations Required for Acceptable Correlation is another subjective judgment made by the instructor. If the sum of correlations for a particular outcome totals greater than the specified value (25 in this case), assessment of the outcome is judged to be reliable. The basis of using the number 25 is that it corresponds to the square of five. If one design requirement provides the highest possible degree of assessment (five) for a given outcome, the assessment is considered reliable. In practice, however, a value of 25 could be also be achieved by summing the squares of values less than five.
- Sum of Correlation Points was the sum of Correlation with Requirements values. Since only the final design project submission is shown, the Sum of Correlation Points values may not reflect the sum of the shown Correlation with Requirements values squared.
- Measure of Correlation was determined by dividing the Sum of Squares of Correlation Points value by the Sum of Correlations Required for Acceptable Correlation value. A value greater than one meant the result was a reliable assessment of the particular CE Program Outcome. A value less than one meant the result was perhaps not a reliable assessment of the outcome.

The following definitions apply to Figure 2 which provides a compilation of grade and outcome assessment results for CE492 during the spring semester of Academic Year 2004-2005[4].

- Assessment of each outcome was determined by summing the Correlation with Requirements values multiplied by the Earned % and dividing the result by the Sum of Correlation Points. The assessment values shown are based on the scale in Table 2.

Table 2 – Scale Used for Assessment Values.

90-100%	Excellent	5
80-90%	Good	4
70-80%	Marginally Satisfactory	3
65-70%	Marginally Unsatisfactory	2
0-65%	Unsatisfactory	1

- Group Average is the average of assessment values O1-O17 for each team.
- Outcome Average lists the average assessment for all teams for each program outcome.
- Measure of Correlation is the same value as defined in Figure 1.
- Assessment Average is the overall average of all outcome averages.
- Correlation Average is the overall average of all Measure of Correlation values.
- EDP Average Grade lists the average grade across the course for all requirements of the EDP. This value is not based on the Assessment Average or the Correlation Average.

CE492 Assessment of the CE Division Program Outcomes

Team #	EDP Grade	Assessment : 5 (High) - 1 (Low)																	Group Average
		O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	O13	O14	O15	O16	O17	
1	73.4%	2	3	3	2	4	3	3	1	3	4	4	5	4	2	3	4	4	3.2
2	100.0%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5.0
3	82.1%	3	4	3	4	4	4	4	3	5	5	5	4	4	3	4	4	5	4.0
4	95.2%	5	5	4	4	5	5	5	4	5	5	5	4	5	4	5	5	5	4.7
5	103.6%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5.0
6	77.9%	3	3	4	3	4	3	3	3	3	4	5	5	4	3	4	4	4	3.6
7	80.6%	3	4	3	1	3	4	3	2	4	4	5	5	4	2	4	4	4	3.5
8	71.7%	1	1	1	1	2	2	2	1	2	4	3	3	3	1	3	3	3	2.1
9	78.0%	3	3	3	2	2	3	3	3	4	5	4	4	4	3	4	4	4	3.4
10	99.6%	5	4	4	4	5	5	4	4	5	5	3	4	5	4	5	5	5	4.5

	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	O13	O14	O15	O16	O17
Outcome Average	3.5	3.7	3.5	3.1	3.7	3.9	3.7	3.1	4.1	4.6	4.4	4.4	4.3	3.2	4.2	4.3	4.4
Measure of Correlation (>1.0 is Acceptable)	11.1	3.9	9.1	2.1	0.6	5.8	2.7	3.0	4.8	2.4	1.6	1.9	5.0	10.2	5.2	2.0	1.6

Assessment Average	3.9
Correlation Average	4.3
EDP Average Grade	86%

Figure 2 – Compilation of Assessment Results

IIIb. Implementation of the Assessment Tool

Five distinct chronological requirements comprised the CE492 EDP including a 10% submittal, a 35% submittal, a 35% presentation, a 65% formal in-progress review (IPR), and a 100% final submittal. The students accomplished the EDP in teams of four over the course of the semester. At the end of the semester, the instructor had a completed worksheet, as in Figure 1, for each design team. The individual worksheet listed an overall evaluation of the five submissions and an assessment of the students' work based on the 17 CE program outcomes. Another worksheet as shown in Figure 2 compiled the results from the 10 EDP groups to provide an evaluation of overall design project performance and an assessment of the 17 CE program outcomes.

IV. Results of the Assessment

The original objectives of creating an embedded assessment by merging the student evaluation and assessment processes were to reduce instructor workload, tie student evaluation more closely to the CE program goals, and create a more systematic method for assessment. After applying the assessment tool for the second time, this time on a much more involved CE design project, our impressions are that the value of this assessment tool has been once again validated. Creating the assessment tool requires significant thought and effort. Once created, the only time investment is entering student grades into the spreadsheet. Assessing the degree to which the individual design requirements satisfy specific outcomes is clear from the results.

The results showed that, on average, the outcomes were assessed at about 3.9 out of a possible 5 indicating the EDP teams were achieving the "good" category on average. Outcomes 10 (Speak effectively), 11 (Knowledge of contemporary issues), 12 (Impact of engineering solutions), 13 (Continued intellectual and professional growth), 15 (Elements of project management), 16 (Business and public policy), 17 (Role of the leader) were assessed above average meaning better assessment on average than the other outcomes. Outcomes 4 (Proficiency in mathematics, calculus-based physics, and general chemistry) and 8 (Use modern engineering tools to solve problems) were assessed below average at 3.1, meaning a somewhat lower assessment on average. Based on these results only, the instructor would conclude that, at a minimum, requirements related to outcomes 4 and 8 might require increased emphasis in order to better satisfy the CE program outcomes.

The assessment average did not provide the complete story, however. In examining the correlation values, outcome 5 (Design and conduct experiments) had a value less than one, meaning there was inadequate coverage of the outcome by the requirements of the EDP. Since this outcome had a low correlation value, the instructors were not able to make reliable conclusions about the corresponding assessments. Recalling that outcome 5 had a below-average assessment of 3.7 as well caused instructors to more closely examine and possibly adjust requirements contributing to that outcome. As an alternative, the instructors might consider documenting some other area of the course or program where that outcome receives better coverage. In cases where correlation values were in excess of one, the instructors were able to conclude with greater confidence that the assessment values were meaningful.

In comparing the assessment average of 3.9 (out of 5) with the average EDP grade of 86 percent, there was some indication of a correlation between student grades and assessment of program indicators. A value of 3.9 would yield almost a "good" assessment while an average of 86% would fall squarely into the "good" category. At first glance, it might seem plausible to apply the resulting average EDP grade directly as a program assessment. The flaw with this reasoning is as follows. The average EDP grade indicates that, across the course, students are doing above average work on the EDP, which is useful for assigning grades. However, this conclusion is not useful for determining what areas of the course require adjustment to better satisfy the program outcomes. As Figure 2 shows, several outcomes had either low assessment averages or low correlation values or, in the case of outcome 5, both. The instructor would not be able to easily identify such shortcomings based on grades alone. A thorough, systematic assessment of the EDP based on the 17 outcomes was necessary to conclusively identify shortcomings.

The assessment also showed areas where perhaps too much emphasis was given. In the case of outcome 13 (Continued intellectual and professional growth) specifically, the assessment of 4.4 (out of 5) was well above average and the correlation was 5.0. With a result strong in both categories, instructors might have cause to rethink the design of the EDP to shift emphasis from areas meeting the standard and redirecting it to areas needing improvement. Additionally, if specific EDP requirements had little contribution to program outcomes, there might be reason to consider deleting the requirement from the EDP or, conversely, to examining the definition of the outcome.

As this was the first use of this assessment technique in CE492, there was no historical data against which to compare. Comparison to future applications of this technique that reflect modifications to CE492 to address noted shortcomings and to applications in other courses will be effective in further validating its usefulness.

V. Conclusions

The embedded assessment technique proposed herein proved to be far superior to surveys and other non-embedded assessment tools. Linking program outcome assessments to the grading process accomplished three objectives. The technique reduced instructor work load, tied student evaluation more closely to the relevant institutional academic program outcomes, and provided a systematic method for identifying both shortcomings and areas of excellence in a program. Once created, the tool can be used repeatedly for outcome assessment with little additional effort and can be easily tailored for use in other courses or program applications. Since the assessment results are calculated automatically by the spreadsheet, multiple instructors applying the tool to student work produce more consistent assessment results thus avoiding a problematic aspect of assessment that others have noted[5]. Further use in CE492 will establish historical data that will assist in identifying the effectiveness of changes to address program shortcomings.

References

1. Meyer, K., Morris, M., Estes, A., and Ressler, S. "How to Kill Two Birds with One Stone – Assigning Grades and Assessing Program Goals at the Same Time." Proceedings of the 2005 American Society for Engineering Education Annual Conference. American Society for Engineering Education. June 2005. Session 1834.

2. Welch, R., Estes, A., Winget, D., "Assessment of Squishier Outcomes: Open-Ended Problem Solving through Client-Based Projects," Proceedings of the 2005 ABET National Conference. Accreditation Board for Engineering and Technology. November 2005.

3. Farmer, D.W., *Enhancing Student Learning: Emphasizing Essential Competencies in Academic Programs*. King's College Press, Wilkes-Barr, PA, 1988.

4. Winget, David G., CE492 Annual Design Assessment and Course Assessment Documents, Department of Civil and Mechanical Engineering, USMA, 2005.

5. Keith, B., LeBoeuf, J., Meese, M., Malinowski, J., Gallagher, M., Efflandt, S., Hurley, J. and Green, C. "Assessing Students' Understanding of Human Behavior: A Multi-Disciplinary Outcomes-based Approach for the Design and Assessment of an Academic Program Goal." *Teaching Sociology*, Vol. 30, 2002, pp. 430-453.