How to Kill Two Birds with One Stone – Assigning Grades and Assessing Program Goals at the Same Time

LTC Karl F. Meyer, Capt Matthew Morris, COL Allen C. Estes,
and COL Stephen J. Ressler
United States Military Academy

Introduction

The culminating design experience for students enrolled in CE450, Infrastructure Development and Construction Management at the United States Military Academy requires the development of a comprehensive base camp design. The objective of a base camp is to provide the minimum essential facilities necessary for deployed units to become ready for mission operations. That means providing billeting, water, electrical power, waste disposal, munitions storage, organizational shops, roads, and so on. The process involves the translation of concepts and requirements into an actual plan with specific facility, utility, and labor force requirements. A good base camp design plan minimizes the construction necessary by making the maximum use of existing facilities and utilities.

The purpose of this paper is to describe an embedded assessment technique used in CE450 during the fall semester of Academic Year 2004-2005. CE450 serves as the final and culminating course in the civil engineering three-course sequence taken by students who are not majoring in engineering. It is one of seven different three-course sequences, which constitute a portion of the Academy's core curriculum, and in which assessment of the Academy's Engineering and Technology Goal is accomplished[1]. By merging the student evaluation and assessment processes, instructor workload was reduced, student evaluation was tied more closely to the relevant institutional academic program goal, and a systematic method was created for identifying shortcomings and areas of excellence in the program.

The Engineering and Technology Goal

The Engineering and Technology Goal, one of ten institutional academic program goals that all students are expected to achieve, reads as follows: "Graduates apply mathematics, science, technology, and the engineering design process to devise technological problem solutions that are effective and adaptable." The goal is assessed by measuring the extent to which graduates can accomplish the following 12 indicators:

(1) In an environment of uncertainty and change, identify needs that can be fulfilled via engineered solutions.
(2) Define a complex problem, accounting for its technological, political, social, and economic dimensions.
(3) Determine what information is required to solve a problem; acquire that information from appropriate sources; and, when available information is imperfect or incomplete, formulate reasonable assumptions that facilitate the problem solution.

(4) Apply the engineering design process and use appropriate technology to develop problem solutions that are both *effective* and *adaptable*.
(5) Demonstrate creativity in the formulation of alternative solutions.
(6) Apply mathematics, basic science, and engineering science to model and analyze a physical system or process.
(7) Work effectively on a team to solve a problem.
(8) Plan the implementation of an engineered solution.
(9) Communicate an engineered solution to both technical and non-technical audiences.
(10) Assess the effectiveness of an engineered solution.
(11) Demonstrate basic-level technical proficiency in an engineering discipline that is relevant to the needs of the Army.
(12) In response to a technological problem, learn new concepts in engineering and learn about new technologies on their own.

The Assessment Tool

One of the objectives of this assessment tool 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[2]. In order to both evaluate student performance on the course engineering design project (EDP) and simultaneously assess Engineering and Technology Goal 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 directly mapped each requirement of the (EDP) (e.g., base camp layout, road design, schedule) to one or more of the 12 assessment indicators. This mapping included weighting factors that accounted for the extent to which a given indicator represented the various requirements of the EDP. For example, a score of 5 was attributed to the relationship between design requirement 2b (Design and Layout using GeoBEST) and indicator 3 (Determine information). This maximum weight shows there is a high correlation between success on this EDP task and attainment of the relevant indicator.

Completion of the assessment was a three-step process. First, the instructor determined the number of points assigned to each requirement of the design project. Second, and most subjective, the instructor examined each EDP requirement through a lens of the 12 indicators and determined to what extent the requirement contributed to the attainment of each indicator. In many cases, the requirement did not correlate to an indicator, 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 indicator was assessed using a scale of one to five, where one indicated a very weak correlation and five indicated a strong correlation. A thorough understanding of both the EDP and the 12 indicators was required on the part of the instructor to accomplish this step. The instructor accomplished 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. More detail on internal calculations within the spreadsheet will be discussed later in the paper.

	CE450 Base Camp Planning and Design Project Grade Sheet and E & T Goal Assessment Sheet															
	Design Requirements:	Possible Points	Earned Points	Earned %	Degree of Assess (DOA)- 5 (High) - 1 (Low)											
					1	2	3	4	5	6	7	8	9	10	11	12
35 % Design Submission	**1. Presentation**	70	**68**	97%	0	0	0	0	0	0	5	0	5	0	0	0
	2. Layout Base Camp	20	**19**	95%												
	a Requirements	10	**10**	100%	5	0	5	0	3	0	0	0	0	0	0	0
	b Sketch	10	**9**	90%	4	0	3	0	5	0	0	0	0	0	0	0
	3. GeoBEST Layout	40	**37**	93%												
	a Design & Layout	30	**30**	100%	5	0	3	5	5	0	0	4	0	0	0	2
	b Rationale	10	**7**	70%	0	2	4	4	5	3	0	4	0	2	0	0
	4. Earthmoving	60	**54**	89%												
	a Centerline Profile	5	**5**	100%	0	0	0	2	0	0	0	0	0	0	2	0
	b Earthmoving Data Spreadsheet	30	**26**	87%	0	0	0	2	0	0	0	0	0	0	3	0
	c Mass Diagram	5	**5**	90%	0	0	0	2	0	0	0	0	0	0	4	0
	d Analyze Mass Diagram	20	**18**	90%	0	0	0	2	0	0	0	2	0	0	5	0
	5. Machine Power	60	**58**	97%												
	a Usable Power	20	**19**	95%	0	0	2	0	0	0	0	0	0	0	2	0
	b Cycle Times	20	**20**	100%	0	0	0	0	0	0	0	0	0	0	3	0
	c Total Project Duration	20	**19**	95%	0	0	0	0	0	0	0	0	0	0	4	0
	35% Submission Possible Points	250	**236**	94%												
IPR	**In-Progress Review**	100	**86**	86%	0	0	0	0	0	0	5	0	5	0	0	0
	IPR Possible Points	100	**86**	86%												
Final Design Submission	**1-4. Redo Old Attachment**	50	**46**	92%												
	a Attachments 1 & 2	25	**21**	84%	5	2	4	5	4	3	0	4	0	2	0	2
	b Attachments 3 & 4	25	**25**	100%	0	0	0	2	0	0	0	2	0	0	4	0
	5. Pavement Evaluation	20	**18**	90%												
	a All questions answered	10	**9**	90%	0	0	4	0	4	0	0	0	0	0	0	0
	b Show work on attached charts	10	**9**	90%	0	0	2	0	0	0	0	0	0	0	0	0
	6. Road Design	30	**26**	87%												
	a Draw and label road design	20	**16**	80%	0	0	4	0	0	0	0	0	0	0	0	0
	b Highlight charts	10	**10**	100%	0	0	2	0	0	0	0	0	0	0	0	0
	7. Formwork	40	**37**	93%												
	a Formwork Design	20	**19**	95%	0	0	4	0	3	0	0	0	0	0	4	0
	b Labeled Sketch	10	**9**	90%	0	0	3	0	0	0	0	0	0	0	0	0
	c Bill of Materials	10	**9**	90%	0	0	0	0	0	0	0	2	0	0	0	0
	8. Cost Estimate	60	**48**	80%	0	0	5	3	0	0	0	0	0	0	0	0
	9. Schedule	90	**53**	59%												
	a Schedule (network, task rpt, gantt)	30	**23**	77%	0	0	4	5	0	0	0	0	0	0	0	0
	b Number of people to hire	10	**10**	100%	0	0	3	0	0	0	0	0	0	0	0	0
	c How to crash project?	10	**0**	0%	0	0	0	0	3	0	0	0	0	0	0	0
	d Safety Plan	20	**20**	100%	0	0	0	0	0	0	0	3	0	0	0	0
	e Quality Control Plan	20	**0**	0%	0	0	0	0	0	0	0	3	0	0	0	0
	10. Wrap Up	60	**54**	90%												
	a Priority List	20	**18**	90%	0	0	0	0	0	0	0	4	0	0	0	0
	b Hardening Plan	20	**18**	90%	0	0	0	0	0	0	0	4	0	0	0	0
	c Social, Political, Economic Impact	20	**18**	90%	0	5	0	0	0	0	0	0	0	5	0	0
	Final Submission Possible Points	350	**282**	81%												
Total EDP Points Possible =======>		**700**	**604**	**86%**												

Sum of DOAs for Compliance ====>	10	**Assessment of Standard**

Indicator Number ===================>	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Sum of DOAs ======================>	19	9	52	32	32	6	10	32	10	9	31	4
Assessment of Indicator ==============>	94%	84%	88%	86%	81%	77%	92%	81%	92%	84%	94%	92%
Compliance w/Indicator (>1.0 is Reliable) =>	1.9	0.9	5.2	3.2	3.2	0.6	1.0	3.2	1.0	0.9	3.1	0.4

Figure 1 – Data Entry Page of Assessment Tool

Before deciding on the above assessment tool, another format involving a reverse process was considered. Since the initial objective was to assess achievement of the Engineering and Technology Goal, it was thought that a design project could be evaluated indirectly and a grade assigned based on how well the project satisfied the 12 indicators. Implementation of such a procedure was tried and found to be too cumbersome. Instructors found themselves trying to "adjust" indicator assessment values to achieve specific project grades they felt the students deserved. This format was discarded and the previously described format was adopted.

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, the EDP report consisted of 10 attachments highlighted in bold in Figure 1. Each requirement was allocated a certain 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.
- Earned Points 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.
- Degree of Assessment is a subjective judgment made by the instructor on how well each design requirement contributed to the accomplishment of the 12 indicators. A high number (5) means that the requirement provides a very meaningful assessment of the indicator. A low number (1) means that the requirement provides a poor assessment of the indicator. A blank cell means the requirement does not assess the indicator.
- Sum of Degrees Of Assessment (DOA) for Compliance is another subjective judgment made by the instructor. If the sum of Degree of Assessment values for a particular indicator totals greater than the specified value (10 in this case), assessment of the indicator is judged to be reliable. The basis of using the number 10 is that it corresponds to two separate design requirements providing the highest possible degree of assessment for a given indicator. In practice, however, a value of 10 could be made up of two values of five, five values of two, or any other combination totaling 10.
- Sum of Degrees of Assessment was the sum of Degree of Assessment Values.
- Assessment of Standard was determined by summing the Degree of Assessment values multiplied by the Earned % and dividing the result by the Sum of Degrees of Assessment. A value of 100% indicated the best possible assessment of an indicator and is comparable to a student grade of 100% or a maximum score.
- Compliance with Indicator was determined by dividing the Sum of Degrees of Assessment value by the Sum of Degrees of Assessment for Compliance value. A value greater than one meant the result was a reliable assessment of the particular indicator. A value less than one meant the result was perhaps not a reliable assessment of the indicator.

Figure 2 provides a compilation of grade and indicator assessment results for all 24 EDP teams in CE450 during the fall semester of Academic Year 2004-2005. The following definitions provide an explanation of values listed at the base of the figure.

- Average lists the average of the assessments for each design group for each indicator.
- Compliance is the same value as Compliance with Indicator from Figure 1.
- Assessment Average is the overall assessment average for all indicators.
- EDP Average Grade lists the average grade across the course for all requirements in the EDP.

Team #	EDP Grade	Indicator Assessment											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	**78.2%**	64%	80%	78%	72%	70%	80%	80%	80%	80%	80%	81%	57%
2	**69.7%**	79%	65%	75%	62%	80%	64%	85%	65%	85%	65%	60%	71%
3	**72.8%**	56%	60%	72%	63%	59%	34%	85%	52%	85%	60%	79%	32%
4	**62.6%**	42%	53%	68%	57%	55%	50%	71%	61%	71%	53%	61%	8%
5	**90.6%**	85%	83%	89%	85%	77%	75%	88%	86%	88%	83%	94%	75%
6	**86.2%**	94%	84%	88%	86%	81%	77%	92%	81%	92%	84%	94%	92%
7	**79.4%**	83%	79%	80%	82%	83%	83%	90%	76%	90%	79%	78%	80%
8	**87.4%**	88%	84%	87%	83%	90%	89%	93%	89%	93%	84%	84%	86%
9	**84.2%**	89%	71%	83%	85%	85%	67%	89%	73%	89%	71%	90%	89%
10	**89.6%**	74%	87%	88%	83%	83%	84%	92%	83%	92%	87%	96%	59%
11	**78.4%**	82%	79%	84%	80%	86%	90%	85%	70%	85%	79%	85%	65%
12	**69.0%**	44%	64%	69%	65%	53%	50%	69%	55%	69%	64%	77%	30%
13	**84.3%**	94%	92%	88%	87%	85%	89%	91%	80%	91%	92%	85%	92%
14	**78.5%**	91%	85%	84%	84%	89%	92%	81%	78%	81%	85%	67%	92%
15	**90.3%**	92%	94%	89%	84%	90%	93%	93%	91%	93%	94%	86%	90%
16	**93.0%**	95%	89%	93%	98%	95%	100%	95%	94%	95%	89%	95%	100%
17	**90.4%**	97%	92%	92%	97%	92%	95%	94%	84%	94%	92%	94%	100%
18	**78.0%**	80%	82%	84%	80%	83%	84%	89%	77%	89%	82%	60%	92%
19	**88.4%**	89%	85%	89%	87%	92%	92%	93%	88%	93%	85%	88%	89%
20	**90.1%**	99%	94%	91%	90%	94%	100%	97%	90%	97%	94%	90%	98%
21	**88.6%**	81%	85%	89%	82%	80%	73%	76%	83%	76%	85%	96%	68%
22	**72.0%**	88%	77%	74%	79%	83%	86%	78%	72%	78%	77%	71%	91%
23	**90.4%**	84%	76%	85%	82%	80%	65%	97%	80%	97%	76%	94%	82%
24	**87.6%**	91%	91%	85%	88%	93%	98%	95%	90%	95%	91%	83%	91%
Average		**81.7%**	**80.5%**	**83.4%**	**80.8%**	**81.5%**	**79.6%**	**87.4%**	**78.2%**	**87.4%**	**80.5%**	**82.8%**	**76.2%**
Compliance		**1.9**	**0.9**	**5.2**	**3.2**	**3.2**	**0.6**	**1.0**	**3.2**	**1.0**	**0.9**	**3.1**	**0.4**
Indicator		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**

Assessment Average	**81.7%**
Compliance Average	**2.1**
EDP Average Grade	**82.5%**

Figure 2 – Compilation of Assessment Results

Implementation of the Assessment Tool

Three distinct requirements comprised the EDP in CE450--a 35% submittal, a formal in-progress review (IPR), and a 100% final submittal, as shown in Figure 1. The cadets accomplished the EDP in teams of two or three 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 three submissions and an assessment of the cadets' work based on the 12 indicators. Another worksheet as shown in Figure 2 compiled the results from the 24 design groups to provide an evaluation of overall design project performance and an assessment of the 12 indicators for the course.

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 relevant institutional academic program goal, and create a more systematic method for assessing the program goal. After creating the assessment tool and implementing it, our initial impressions are that these objectives have been met. 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 indicators is clear from the results.

The results showed that, on average, the indicators were assessed at about 81.7 percent. Two indicators, numbers 7 (Work on team) and 9 (Communicate), were both assessed above average at 87.4 percent, meaning better assessment on average than the other indicators. Indicator 12 (Learn new concepts) was assessed below average at 76.2 percent, meaning a somewhat lower assessment on average. Based on these results only, the instructor would conclude that, at a minimum, requirements related to indicator 12 might require increased emphasis in order to better satisfy the Engineering and Technology Goal.

The assessment average was not the complete story, however. In examining the compliance values, indicators 2 (Define problem), 6 (Apply math and science), 10 (Assess effectiveness), and 12 (Learn new concepts) had values less than one, meaning there was inadequate coverage of the indicators by the requirements of the design project. Since these four indicators had low compliance values, the instructors could not make reliable conclusions about the corresponding assessments. Recalling that indicator 12 had a low assessment average as well caused instructors to more closely examine and possibly adjust requirements contributing to that indicator. As an alternative, the instructors might consider documenting some other area of the course where that indicator receives better coverage. In cases where compliance 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 81.7 percent with the average EDP grade of 82.5 percent, one could not help but think there was a direct correlation between student grades and assessment of program indicators. On the surface it might seem possible 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 slightly 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 goal. As Figure 1 shows, several indicators had either low assessment averages or low compliance values or, in the case of indicator 12, 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 12 indicators was necessary to identify shortcomings in accomplishment of the overall program goal.

The assessment also showed areas where perhaps too much emphasis was given. In the case of indicator 3 (Determine information) specifically, the assessment was above average and the compliance was 5.2. Such a result might cause instructors 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 goal indicators, there might be reason to consider deleting this requirement from the EDP or, conversely, to examining the definition of the indicator.

As this was the first use of this assessment technique, there was no historical data against which to compare. Comparison to future applications of this technique that reflect modifications to CE450 to address noted shortcomings will be useful in further validating its usefulness.

Conclusions

The embedded assessment technique proposed herein proved to be far superior to surveys and other non-embedded assessment tools. Linking goal 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 goal, 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 goal assessment with little additional effort and can be easily tailored for use in other courses or program goal 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[3]. Further use in CE450 will establish historical data that will assist in identifying the effectiveness of changes to address program shortcomings. This technique has huge potential for linking specific course requirements to program outcomes in support of the assessment process that is part of ABET program accreditation. Embedded assessments reduce the need for creating external and specialized data collection tools.

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Author Biographies

KARL F. MEYER
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) at 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.

MATTHEW R. MORRIS
Captain Matthew Morris is an Instructor in the Department of Civil and Mechanical Engineering at the United States Military Academy. Captain Morris received a B.S. degree from the University of Colorado at Boulder in 1999 and an M.S. degree in Civil Engineering from University of Colorado at Boulder in 2001.

ALLEN C. ESTES
Colonel Allen C. Estes is an Associate Professor and Civil Engineering Program Director at the United States Military Academy (USMA). 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.

STEPHEN J. RESSLER
Colonel Stephen J. Ressler is Deputy Head of the Department of Civil and Mechanical Engineering at the U.S. Military Academy at West Point, NY. He earned a B.S. degree from USMA in 1979 and M.S. and Ph.D. degrees in Civil Engineering from Lehigh University in 1989 and 1991. He is a registered Professional Engineer in Virginia. He serves as a member of the ASCE Educational Activities Committee and ASCE Committee on Curricula and Accreditation. He is a former Chairman of the ASEE CE Division.