

A METRIC FOR ASSESSMENT OF ABET ACCREDITATION OUTCOME 3B – DESIGNING EXPERIMENTS AND ANALYZING THE RESULTS

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Introduction

The Accreditation Board for Engineering and Technology, Inc. (ABET) requires evaluation of program outcomes (POs) as part of the undergraduate engineering curricula accreditation process. Assessment under this criterion is one or more processes that identify, collect, and prepare data to evaluate the achievement of program outcomes. The Department of Civil and Environmental Engineering at South Dakota State University (SDSU) chose to use program outcomes originally established, known as the “a” through “k” outcomes. Evaluation of outcome “b”, “a graduating student should have an ability to design and conduct experiments, as well as to analyze and interpret data” was accomplished using a well-designed rubric, as is the subject of this paper. The rubric was established and administered in CEE-346L, Geotechnical Engineering Laboratory. The means of assessment was a particular laboratory experiment, One Dimensional Consolidation Test. The rubric consisted of several indicators in each of the categories: “1” – Below Expectation, “2” – Meets Expectation, and “3” – Exceeds Expectations, with a desired metric threshold score of 2 or greater. The rubric was applied to the entire class for the selected laboratory exercise during the years of 2007, 2009, and 2010. The class average was used as assessment relative to the threshold score. Data collected to date indicates the threshold score is being met; however evaluation of the metric has promulgated minor adjustments in selected areas of the curriculum to improve scores. This paper outlines the details of the assessment process, metric results, and changes to the curriculum.

Accreditation Framework

The ABET program outcomes (POs) are statements that describe what students are both expected to know and to apply at the time of graduation. This achievement indicates that the student is equipped to attain the program educational objectives. POs are measured and assessed routinely through national, university, department, and curriculum level assessment processes. The POs themselves are evaluated and updated periodically to maintain their ties to both the department’s mission and program educational objectives (PEOs). The assessment and evaluation process for the program outcomes follows a continuous improvement process. The first step is to establish program outcomes that are tied directly to the program educational objectives. The program outcomes were adopted from the ABET Engineering Criteria 2000. The POs were reviewed by the faculty in the Department of Civil and Environmental Engineering (CEE) at SDSU as well as the department’s advisory board before being adopted by the program. SDSU’s Civil Engineering program outcomes “a” through “k” are adopted from

ABET criterion three. During the Fall semester of 2008, the CEE department faculty established the following formal methodology for reviewing and revising program outcomes. In general terms, the following outlines the Program Outcome Assessment Process (SDSU, 2009):

1. A metric or metrics will be established for a PO.
2. A threshold value will be established for each metric.
3. The value of the metric will be determined for an evaluation cycle and compared to the threshold value. Typically, the value will be determined and evaluated annually based on a 2-year moving average value of the metric.
4. For the first evaluation cycle:
 - a. If the value of the metric exceeds the threshold value, then no action is necessary,
 - b. If the value of the metric is less than the threshold value, then the variance is noted and possible causes for the variance will be discuss and reported by the department faculty, but no additional action is required at this time.
5. For the second evaluation cycle:
 - a. For those metrics that previously exceeded the established threshold from 4a:
 - i. If the value of the metric again exceeds the threshold value, then no action is necessary,
 - ii. If the value of the metric is now less than the established threshold, then same response as 4b above.
 - b. For those metrics that previously were less than the established threshold from 4b:
 - i. If the metric now exceeds the threshold value, then no action is required,
 - ii. If the value of the metric again is less than the established metric value, then the situation is considered to be a concern. The departmental faculty will at this time develop potential corrective action(s) that will be agreed upon by consensus.
6. For subsequent evaluation cycles:
 - a. If the value of the metric exceeds the established threshold value, then no action is necessary,
 - b. If the value of the metric exceeds the threshold value for three consecutive evaluations, the department will consider increasing the threshold value.

Evaluation Metric for ABET Program Outcome 3b

The CEE departmental faculty has established evaluation metrics for the assessment of the achievement of the outcomes for each of the eleven POs. These metrics include survey results, laboratory rubrics, class assignments, interviews, and results from the Fundamentals of Engineering (FE) examination. A critical threshold value for each metric has been established that is realistic and attainable, yet ambitious enough to result in continuous improvement. Evaluation of ABET PO 3b, the subject of this paper, “a graduating student should have an ability to design and conduct experiments, as well as to analyze and interpret data” was accomplished using a well-designed rubric.

Rubrics are scoring tools that are generally considered subjective assessments. A set of criteria and/or standards are created to assess a student's performance relative to some educational outcome. The unique feature of a rubric is that it allows for standardized evaluation of each student to specified criteria, making grading more transparent and objective. A well-designed rubric allows instructors to assess complex criteria and identify areas of instruction that may require revision to achieve the desired outcome.

The literature is sparse on assessing PO 3b directly in civil engineering; therefore the literature was searched in constructing the rubric from other engineering disciplines. Felder and Brent (2003) discuss instructional techniques in meeting evaluation criteria for the various POs. The Engineering Education Assessment Methodologies and Curricula Innovation Website (2007) also discusses some strategies for PO assessment, but in a broad, general sense. McCreanor (2001) discusses assessing POs from an Industrial, Electrical, and Biomedical Engineering perspective. Winncy et al (2005) discusses meeting PO 3b from a Mechanical and Aeronautical Engineering perspective. Review of the literature revealed the following common features of rubrics: each focus on a stated objective (evaluating a minimum performance level), each use a range of evaluative scores to rate performance, and each contain a list of specific performance indicators arranged in levels that characterize the degree to which a standard has been met.

Information gleaned from the literature was coupled with the CEE department's needs relative to our continuous improvement model established for ABET accreditation to produce an evaluation rubric. Table 1 presents the various scoring areas of the rubric. Note that reporting is not explicitly part of the Criteria 3b, but was included in the rubric none-the-less.

The final important step was to select a laboratory exercise that would allow assessment of the various areas of the rubric. The One Dimensional Consolidation Test laboratory exercise in CEE 346L – Geotechnical Engineering Laboratory was chosen for the rubric. The laboratory exercise was initially evaluated to have the expectation elements outlined in Table 1. The consolidation test is used to evaluate the load deformation properties of fine-grained soils. When an area of soil is loaded vertically the compression of the underlying soil near the center of the loaded area can be assumed to occur in only the vertical direction, that is, one-dimensionally. This one-dimensional nature of soil settlement can be simulated in a laboratory test device called a consolidometer. Using this device, one can obtain a relationship between load and deformation for a soil. Analysis of the results ultimately allows the calculation or estimation of the settlement under induced loads such as a building or other large structure.

A cutoff score of 2 (meets expectations) was established after the rubric was initially developed. The rubric was then applied to the entire class of multiple laboratory sections for the selected laboratory exercise. The class average was used as assessment relative to the cutoff score. The rubric was originally developed to be administered every other academic year. However, during SDSU's on-site evaluation by ABET for reaccreditation in 2009, the ABET program evaluator encouraged the CEE department to administer the rubric yearly.

Table 1. Rubric Scoring Criteria

<u>Level 1 Below Expectations</u>	<u>Level 2 Meets Expectations</u>	<u>Level 3 Exceeds Expectations</u>
Uses unsafe and/or risky procedures	Observes occasional unsafe laboratory procedures	Observes established laboratory safety plan and procedures
Does not develop a systematic plan of data gathering; experimental data collection is disorganized and incomplete	Development of experimental plan does not recognize entire scope of the laboratory exercise, therefore data gathering is overly simplistic (not all parameters affecting the results are	Formulates an experimental plan of data gathering to attain the stated laboratory objectives (develops a plan, tests a model, checks performance of equipment)
Data are poorly documented	Not all data collected is thoroughly documented, units may be missing, or some measurements are not recorded	Carefully documents data collected
Does not follow experimental procedure	Experimental procedures are mostly followed, but occasional oversight leads to loss of experimental efficiency or loss of some data	Develops and implements logical experimental procedures
Cannot select the appropriate equipment and instrumentation	Needs some guidance in selecting appropriate equipment and instrumentation	Independently selects the appropriate equipment and instrumentation to perform the experiment
Does not operate instrumentation and process equipment, does so incorrectly or requires frequent supervision	Needs some guidance in operation of instruments and equipment	Independently operate instruments and equipment to obtain the data
Makes no attempt to relate data to theory	Needs some guidance in applying appropriate theory to data, may occasionally misinterpret physical significance of theory or variable involved and may make errors in conversions	Independently analyzes and interprets data using appropriate theory
Is unaware of measurement error	Is aware of measurement error but does not systematically account for it or does so at a minimal level	Systematically accounts for measurement error and incorporates error into analysis and interpretation
Seeks no additional information for experiments other than what is provided by instructor	Seeks reference material from a few sources - mainly from the textbook or the instructor	Independently seeks additional reference material and properly references sources to substantiate analysis
Reporting <ul style="list-style-type: none"> ● Reporting methods are poorly organized, illogical and incomplete ● Uses unconvincing language ● Devoid of engaging points of view ● Uses inappropriate word choices for the purpose ● Consistently uses inappropriate grammar structure and has frequent misspellings 	Reporting <ul style="list-style-type: none"> ● Reporting methods are mostly organized with areas that are incomplete ● Uses language that mostly supports means and methods ● Occasionally makes engaging points of view ● Mostly uses appropriate word choices for the purpose ● Occasionally uses incorrect grammar structure and/or misspellings 	Reporting <ul style="list-style-type: none"> ● Reporting methods are well organized, logical and complete ● Uses convincing language ● Makes engaging points of view ● Uses appropriate word choices for the purpose ● Consistently uses appropriate grammar structure and is free of misspellings
Evaluative score of 1	Evaluative score of 2	Evaluative score of 3
Expectations Characterized By		

It should be emphasized that the rubric was used to evaluate the department's program outcomes, not the course outcomes in the particular course where the rubric was administered. The scoring/grades that students received were assigned relative to course outcomes. Therefore, when the rubric was applied, the laboratory assignments were graded twice for each evaluation. As such, students were not aware of the assessment relative to the department's program outcome 3b. This was by design so as not to bias student's effort and work for the particular laboratory assignment.

Results

The constructed rubric was initiated in the 2006-2007 academic year. Laboratory data collection by students was performed in the laboratory on March 14 and 15, 2007 (multiple laboratory sections). Laboratory data analysis was subsequently performed by the students in the laboratory March 21 and 22, 2007. The students' reports were submitted for grade one week later. Thirty three laboratory reports were evaluated with a resulting average score of 2.0 and a standard deviation of 0.9. Therefore, the program outcome for 2007 was achieved and a baseline for future evaluation was established. Although the cutoff was met, the class average was exactly at the cutoff score and enhancements were qualitatively deemed advisable to address the level 1 performer. Therefore, selected technical aspects of the lecture materials were enhanced to address areas of the rubric that were scored lower than desired. The technical content of the lecture materials are beyond the scope of this paper.

The rubric was re-administered in the 2008-2009 and 2009-2010 academic years. Laboratory data collection by the students was performed in the laboratory March 24, 25, and 26 in 2009 and March 23, 24, and 25 in 2010 (multiple laboratory sections). Laboratory data analysis was performed by the students the following week and handed in for grade one week later similar to the prior year. Fifty one and 33 laboratory reports were evaluated for the progressive academic years, respectively, resulting in an average score of 2.5 with a standard deviation of 0.4 for the 2008-2009 academic year and an average of 2.3 and a standard deviation of 0.6 for the 2009-2010 academic year. Given the averages increased and the standard deviations decreased over the baseline, the implemented improvements were achieved in evaluated student performance. Most notable was the improvement in the range of student performance; there were fewer students that performed at Level 1. The program outcome was considered achieved and no changes were made to the lecture materials.

Conclusions

A well established evaluation metric, a rubric in this case, can be used to both evaluate and enhance Program Outcomes in an ABET accreditation process. Based on the experience from the process outlined in this paper, the following conclusions are offered:

- Evaluation metrics should be conceived based on the continuous improvement process of: desired outcome → devise metrics → establish threshold and actions → first evaluation cycle and actions, if necessary → subsequent evaluation cycles and actions, if necessary.

- Evaluation metrics can take on many forms, choose the appropriate metric to measure the desired outcome.
- The rubric used to assess ABET criteria 3b allowed for evaluation relative to meeting the desired outcomes, but also allowed to review curriculum in addressing specific areas of concern.
- Stated outcomes are easily assessed by rubric scoring.

References

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