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A Metric for Assessment of ABET Student Outcome ”b” – Experimental Design and Analyzing the Results

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A METRIC FOR ASSESSMENT OF ABET ACCREDITATION STUDENT OUTCOME "b" – EXPERIMENTAL DESIGN AND ANALYZING THE RESULTS

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Introduction

The Accreditation Board for Engineering and Technology, Inc. (ABET) requires evaluation of student outcomes (SOs) 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 student outcomes. The Department of Civil and Environmental Engineering at South Dakota State University (SDSU) chose to use student 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, and 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, the one dimensional consolidation test. The rubric consisted of several indicators in each of the categories: below expectations, meets expectations, and exceeds expectations, with a desired average metric threshold score of 2.0 or greater. The rubric was applied to the entire class for the selected laboratory exercise during the years of 2007, 2009, and 2011 through 2014. 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 student outcomes (SOs) 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 (PEOs) during the start of their careers. SOs are measured and assessed routinely through national, university, department, and curriculum level assessment processes. The SOs themselves are evaluated and updated periodically to maintain their ties to both the department's mission and PEOs. The assessment and evaluation process for the student outcomes follows a continuous improvement process. The first step is to establish student outcomes that are tied directly to the program educational objectives. The student outcomes were adopted from the ABET Engineering Criteria 2000. The SOs 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 student 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 student outcomes. In general terms, the following outlines the Student Outcome Assessment Process (SDSU, 2009):

1. A metric or metrics will be established for a SO.
2. A threshold value will be established for each metric by faculty and the advisory board.
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 discussed 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 Rubric

The CEE departmental faculty have established evaluation metrics for the assessment of the achievement of the outcomes for each of the eleven SOs. These metrics include a multitude of survey results, laboratory and course 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 SO "b", 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 assessment 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.

There are numerous articles on methods for rubric development and validation within the context of program assessment. Moskal and Leydens (2000) discuss the validity and reliability in developing rubrics. Lane (1993) discusses aligning instruction, learning, and assessment in a methodical manner and how to define and measure competence in programs. Gardiner et al (2009) discuss rubrics within the framework of program assessment and accreditation. Although focused towards design, Moazzen et al (2013) provides a literature review of engineering assessment tools, of which rubrics are included.

At the time of developing the rubric, the literature was sparse on assessing SO "b" 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 SOs. The Engineering Education Assessment Methodologies and Curricula Innovation Website (2007) also discussed some strategies for SO assessment, but in a broad, general sense. McCreanor (2001) discussed assessing POs from an Industrial, Electrical, and Biomedical Engineering perspective. Winncy et al (2005) discussed meeting SO "b" from a Mechanical and Aeronautical Engineering perspective. Review of the literature revealed the following common features of rubrics: each focused on a stated objective (evaluating a minimum performance level), each used a range of evaluative scores to rate performance, and each contained a list of specific performance indicators arranged in levels that characterized the degree to which a standard had been met.

Many engineering programs also publish their evaluation rubrics for SO "b" (formerly called Program Outcomes by ABET) on their program websites. Although these are not vetted in the literature, they provided a useful basis for developing the rubric discussed in this paper. Although dated (downloaded in 2006), the following program websites were gleaned for rubrics in developing the SO "b" rubric at SDSU:

- Auburn University, Department of Chemical Engineering,
- University of Alabama at Birmingham, School of Engineering,
- University of Delaware Dept. of Civil and Environmental Engineering, and
- Michigan State University, Department of Chemical Engineering and Material Science.

Information obtained in the literature and program websites was coupled with the CEE department's needs relative to the continuous improvement model established for ABET accreditation to produce an evaluation rubric. Table 1 presents the various scoring areas of the rubric.

Experiment Design

The author believes that conducting experiments and analyzing and interpreting the data is well within the capabilities of an undergraduate student. However, it is a challenge for students to design experiments with objectives to produce a specific result. Designing experiments was therefore a key consideration in developing the metric to measure SO “b”. The CEE program at SDSU choose a laboratory experiment that allowed the students the opportunity to choose elements of experimental design in satisfying the SO.

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.

The elements of experimental design included in the laboratory exercise consisted of choosing:

- A testing method that is stress or strain controlled. The student must choose one over the other.
- Analog or digital devices for deformation measurement. Both methods require design in how deformation will be measured and incorporated into the experiment.
- When to apply to next load increment. A primary premise in the test is that the soil reaches equilibrium prior to applying the next load. The students are presented with two methods for determining the time when equilibrium is reached and must decide which to use. The students are also encouraged to devise alternative methods than those presented.
- A method to manage the measurement of time. Without the aid of test automation, managing the measurement of time becomes important in the test. The students are required to devise a method by which they can do this.
- Methods to appropriately represent the data as they perform the experiment. This experiment is an excellent opportunity for the students to design plotting methods during the experiment. Given that methods to determine soil equilibrium are graphical based, the students must devise a plotting scheme for the data as they collect test data. This involves choosing appropriate axis ranges and scale.
- A load schedule by which they will apply the various loads to the soil specimen. The results of the test are usually plotted as a function of log-stress to obtain a linear relation. The students must use testing design to determine the starting and final value of stress.

Once the test is complete, the students analyze the data and assemble the results in a report. Given the size of the class and limitation of instructors, there is no in-laboratory assessment relative to the rubric. A cutoff score of 2.0 (Meets Expectations – Table 1) 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, but was changed to every year in 2009.

Table 1. Rubric Scoring Criteria

	Level 1 *Below Expectations*	Level 2 *Meets Expectations*	Level 3 *Exceeds Expectations*
Expectations Characterized By	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 • 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 • 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 • 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

It should be emphasized that the rubric was used to evaluate the department's student outcomes, not the course outcomes in the particular course where the rubric was administered. The scoring/grades that students received on the laboratory assignment were assigned relative to course outcomes. Therefore, when the rubric was applied, the laboratory assignments were graded twice for each evaluation purpose. As such, students were not aware of the assessment relative to the department's SO "b". 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 in multiple laboratory sections. Laboratory sections were taught by the same Teaching Assistant to avoid epistemic variation. The laboratory data was collected the first week by the students and subsequently analyzed in a second week of the laboratory. The students' reports were submitted for grading one week after that. Thirty three laboratory reports were evaluated with a resulting average score of 2.0 and a standard deviation of 0.9. Therefore, the student 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. These included:

- Terminology was updated to the standard of practice and synchronized with the laboratory Teaching Assistant's lecture notes.
- Figures between the course lecture notes and the self-developed laboratory manual were also edited for consistency.
- Photographs as figures were added to the laboratory manual.
- Additional reading materials was placed on the course webpage (as a Desire2Learn page).

The rubric was re-administered in the 2006-2007 and 2008-2009 academic years, and then every academic spring starting in 2011. Table 2 summarizes the results of the rubric effort. As shown in Table 2, the average scores are consistently above the threshold of 2.0. Given the averages increased and the standard deviations decreased compared to the baseline, the implemented improvements (at year one of administering the rubric) 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 student outcome was considered achieved and no changes were made to the lecture materials thereafter.

Table 2. Rubric Results by Year

Semester Administered	Number of Scored Reports	Average	Standard Deviation
Spring 2007	33	2.0	0.9
Spring 2009	48	2.5	0.4
Spring 2011	50	2.2	0.5
Spring 2012	46	2.4	0.6
Spring 2013	45	2.3	0.4
Spring 2014	31	2.1	0.6

Conclusions

A well-established evaluation metric, a rubric in this case, can be used to both evaluate and enhance Student 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 SO “b” allowed for evaluation relative to meeting the desired outcomes, but also allowed to review curriculum in addressing specific areas of concern.
- Stated outcomes are reasonably assessed by rubric scoring.

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Epilog

During the ABET CE program review at SDSU in the fall of 2009, the Program Evaluator (PEV) made complimentary comments regarding the rubric presented in this paper. In fact, the main reason for the change in administering the rubric from biennial to yearly in 2009 was based on discussions with the PEV. It is under the encouragement of that PEV that this paper is being published. The department now has six cycles of continuing data and looks forward to our program review in 2015.

References

Engineering Education Assessment Methodologies and Curricula Innovation Website, "Learning Outcomes/Attributes, ABET b—Designing and conducting experiments, analyzing and interpreting data", University of Pittsburg, accessed January 2007.

Felder, R.M., and Brent, R. (2003). "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria", Journal of Engineering Education, 92:1, 7-25.

Lane, S. (1993). "The Conceptual Framework for the Development of a Mathematics Performance Assessment Instrument", Journal of Educational Measurement: Issues and Practice, Issue 12, pages 16–23.

Gardiner, L. R., Corbett, G., Adams, S. J. (2009). "Program Assessment: Getting to a Practical How-To Model", Journal of Education for Business, Volume 85, Issue. 3, 2009.

McCreanor, P.T. (2001). "Quantitatively Assessing an Outcome on Designing and Conducting Experiments and Analyzing Data for ABET 2000", Proceedings, Frontiers in Education Conference, October 10 – 13, 2001, Las Vegas, Nevada.

Moazzen, I., Hansen, T., Miller, M., Wild, P., Hadwin, A., and Jackson, L. A. (2013). "Literature Review on Engineering Design Assessment Tools", Proceedings of the 2013 Canadian Engineering Education Association (CEEA13) Conference, Montreal, QC, June 17-20, 2013.

Moskal, B. M. and Leydens, J.A. (2000). Scoring rubric development: validity and reliability. Practical Assessment, Research & Evaluation, 7(10).

South Dakota State University, Civil Engineering Program. (2009) "ABET Self-Study Report", Confidential Document.

Winncy Y. Du, Burford J. Furman, Nikos J. Mourtos. (2005). "On the ability to design engineering experiments" 8th UICEE Annual Conference on Engineering Education Kingston, Jamaica, 7-11 February 2005.

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