Integrating TC2K from the Macro to the Micro: Program Assessment Inside and Outside of the Classroom

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Introduction

This paper addresses specific, deliberate actions taken by the School of Science, Engineering, and Technology to establish and sustain a comprehensive program of assessment and evaluation consistent with an academic environment of continuous improvement that demonstrates compliance with the technology Criteria 2000 (TC2K). The plan’s primary objective and ultimate end-state was to affect a transition to a student-focused academic environment of excellence. This strategy encompassed a variety of initiatives considered essential for establishing an academic infrastructure for continuous improvement envisioned by the TC2K. This paper describes practical techniques currently employed to effectively integrate the new ABET accreditation criteria into the Structural Design and Construction Engineering Technology Program with the School of Science, Engineering, and Technology at Penn State University at Harrisburg. The paper will report and assess the relative effectiveness of the Continuous Improvement Methodology with specific references to a variety of techniques, practices, and policies taken to develop and implement a program based on continuous process improvements with defined program goals, objectives, and outcomes.

There have been many papers published in the last few years on the topic of assessment as it relates to TC2K. Experts have long debated the pros and cons of assessment at the course level versus program level assessment and the potential for linking student achievement directly to program outcomes. This paper proposes a systemic approach to assessment that links program outcome assessment to course assessment. Specifically, this paper discusses the utility of graded student work linked to course learning objectives as viable unbiased objective input for course and program assessment. Course assessment can be based not just on traditional student surveys but also on the deliberate quantification of the level of individual student mastery of specific learning objectives during a course, the initiation of additional instruction as required, and the revalidation of improved skills – a methodology designed to collectively provide input to program level assessment as well as promote continuous improvement of student performance during the conduct of the course. Success in this effort is based primarily on a well-developed set of course learning objectives that contain precisely defined, measurable, objective criteria for assessment that can be further linked to Program
Figure 1. The SDCET Program Continuous Improvement Methodology

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Objectives. In a course that builds cumulatively on previous material covered in the classroom, student performance on a particular block of instruction often indicates the student’s degree of preparation for the next block of instruction; consequently, poor performance may warrant additional exposure to the material. Assessments data from examinations during the course at the conclusion of each block of instruction provided the primary vehicle for evaluating student skills. The paper presents some specific examples of objectives that were linked to a variety of assessment methods including graded exercises and exams. Final course assessments were performed with final exam problems providing final objective assessments on critical learning objectives and student questionnaires yielding the medium for student self-assessment.

**Perpetuating Program Improvement: The Methodology**

Figure 1 provides a visual representation of the comprehensive continuous improvement methodology employed to make continuous improvement a reality within the SDCET program. The methodology envisions a number of annual events that include not only course assessment but also exit interviews with graduating seniors, input from institutional agencies and hierarchies, and collective assessment and review by the program faculty. The course continuous improvement cycle includes assessment, evaluation, and planning process improvements which feed directly back into the next

<table>
<thead>
<tr>
<th>SDCET PROGRAM OUTCOME #1</th>
<th>3.5</th>
<th>3.75</th>
<th>4.0</th>
<th>4.25</th>
<th>4.5</th>
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<tr>
<td><strong>OUTCOME</strong></td>
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<td><strong>ASSESSMENT VALUE</strong></td>
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<tr>
<td>CET 201, “Plane Surveying”</td>
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<td>CET 431, “Structural Design – Steel”</td>
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<td>CET 432, “Structural Design – Reinforced Concrete”</td>
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<td>CET 452, “Planning and Scheduling”</td>
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<td>CET 458, “Senior Project”</td>
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Figure 2. Alignment and Assessment of a Specific Program Outcome with Those Courses with Supportive Learning Objectives
The respective scores reflect input from both students and professors using a variety of assessment techniques including the “inside the classroom” approach addressed later in this paper.

Figure 3: A Collective Examination All Program Outcomes Based on Junior Courses, Senior Courses, and Overall Assessment
Planning for course assessment commences prior to the semester with a formal review and comparison of Program Objectives and Outcomes to specific course learning goals and objectives. Beginning with current program assessment data using visual tools and arrays such as that depicted in Figure 3, staff and faculty develop a clear snapshot of the condition of the program in terms of the level of mastery of program outcomes as a function of contributory courses. Figure 3 indicates a current assessment of the collective program outcomes based on course assessment for junior courses, senior courses, and overall for all courses. It is critical to note each course does not contribute to all of the program outcomes, but rather only those supported directly by specific course learning objectives. Another assessment matrix similar to Figure 2 is developed that indicates which of the course learning objectives specifically aligns with each respective program outcome.

During this deliberate process, professors develop course assessment plans identifying techniques to assess each learning objective that influences associated program outcomes. Course instructors are responsible for implementing and tracking specific process improvement initiatives. Nevertheless, it an effort to standardize at least the format for data collection efforts to ensure compatibility for integrating input from various courses, SDCET developed survey templates for collecting both professor and student perceptions of student mastery of course learning objectives. Implementation was affected via Penn State's Course Management System. Appropriately entitled "A New Global Environment for Learning" or "ANGEL," this software enables faculty, instructors, and teaching assistants to use the Web to enhance their courses without any knowledge of HTML. ANGEL is designed to be used in any academic discipline without imposing a particular teaching methodology on instructors and students. The anonymous data provided by ANGEL assesses student perception of their mastery of course learning objectives and subsequently program outcomes. This summary data alone, of course, fails to substantiate evaluative conclusions and must be augmented by other assessment techniques. Professors individually develop and implement additional assessment practices as appropriate which may include objective data collected from student performance on examinations administered during the course (a technique specifically addressed later in this paper) or any of the following recognized techniques:

- Oral Exams
- Individual or group exercises, home work, or projects
- Performance Appraisals
- Simulations
- Exit surveys and interviews
- Focus Group discussions
- External Examination by another member of the staff and faculty
- Behavioral observations

At the program level, the program chairman in consultation with the staff and faculty completes a comprehensive program level assessment based on course assessments and a variety of other measures appropriate for gathering information germane to the
effectiveness of the Program in achieving its objectives and outcomes. Other sources of information include routine surveys and consultations, focus groups, and interviews with constituencies from outside the college such as alumni, employers, and industry representatives to solicit input concerning the development and appropriateness of program objectives and outcomes and the relative quality of graduates from the program. Input from constituents allows consideration of the relevancy of the program, the caliber of its graduates, and supports the review of the program outcomes and objectives themselves to ensure that they collectively respond to the needs of the industry. Program evaluation follows and prompts the development of strategies to implement and track specific process improvement initiatives to respond to assessed strengths and areas of improvement. A written report currently scheduled to be published every three years defines the state of the program and maps a strategic plan for fostering continuous improvement in the educational process.

Assessment inside the Classroom: Tightening the Loop

This paper presents an in-depth look at a technique employed to generate objective assessment data and perhaps more importantly, an immediate opportunity to respond to identified deficiencies. This paper examines CET 452, a course in construction planning and scheduling, primarily for senior students pursuing the Construction Option within the SDCET Program. Course content is conventional, with coverage of basic project management fundamentals in planning, organizing, staffing, directing, and controlling constructive endeavors. Not necessarily a unique learning paradigm, the course builds on knowledge gained in previous courses as well as previous blocks of instruction within the same course.

As shown in Figure 4, the academic hierarchy provides the framework for developing course organization and subsequent learning objectives. Over-arching program outcomes
establish an effective backdrop for course objectives (Appendix A) which are tailored to the specifics of planning and scheduling. More detailed learning objectives are further developed commensurate with each of the three major blocks of instruction. This paper examines Block #2 learning objectives and diagnostics to demonstrate the utility of performance oriented education and outcome assessments. Due to space limitations, examples of exam problems designed to assess specific learning objectives are not included; however, the author will provide copies of course learning objectives and corresponding exam questions and solutions to interested educators upon request. In any case, the examination is not standard but rather varies from semester to semester depending on the course director’s creativity in developing test questions and problematic applications that address the corresponding learning objectives. The common denomination among the exams, however, is that they are deliberately developed in light of course learning objectives and subsequently the associated program outcomes as well.

The key to executing dynamic and effective courses is included within the methodology previously discussed (Figure 1) and embodies a cyclic, iterative approach designed to foster continuous improvement in both professor and student performance. This technique analyzes course objectives and plans specific actions to narrow the gap between academic expectations and the measured student performance. The teaching cycle has four sequential phases built on deliberate process improvement planning, quality classroom instruction, course (student) assessments, and evaluation to adjust and respond to defined needs. Equally applicable for individual lessons, for blocks of instruction, or for an over-arching total course assessment, repetitive application of the cycle sequentially plans improvements, implements innovative initiatives, verifies results, and takes affirmative action to standardize gains and provide timely feedback for planning new improvements. To demonstrate this methodology, this paper examines its application to the second block of instruction, “Network Analysis Systems (CPM, PERT, and Precedence).”

The second block in this planning and scheduling course covered the learning objectives noted in Table 1. (Note: For future “shorthand” reference in figures, one-word synonyms for each objective were developed as shown.) Formal assessments of student learning at the conclusion of the block of instruction provided a medium for faculty feedback on the effectiveness of

<table>
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<tr>
<th>Table 1. Block #2 Learning Objectives</th>
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<td>1. Understand the basic tenants of network analysis systems including CPM, PERT, and Precedence.</td>
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<tr>
<td>a. (Pass) Perform a forward and backward pass procedure on a network for computing early and late start/finish times for all activities.</td>
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<tr>
<td>b. (Float) Compute free and total float for each activity.</td>
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<td>c. (Path) Identify the critical path through a network.</td>
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<td>d. (Prob) Using probabilistic techniques, assess the variable nature of a network critical path.</td>
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<td>2. (Curves) Develop cumulative cost curves and interpret performance parameters.</td>
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Effective assessments are a direct result of deliberate planning. To initially ensure that the test questions adequately cover the objectives appropriately and provide some valid assessment data, a grid similar to the one shown in Table 2 is developed that essentially correlates the test questions for each objective with a relevant level of the taxonomy in the cognitive domain. In this instance, the grid relied on the widely accepted efforts of an educational committee lead by B. S. Bloom that examined knowledge, intellectual abilities, and intellectual skills. Bloom divided the domain into the six major sequential levels shown in the grid, progressing from knowledge of facts and definitions to higher levels of analysis, synthesis, and evaluation. The strategy for the exam presented here recognized that covering all levels of the taxonomy for each question was not practical; nevertheless, the exam ultimately was deemed an appropriate compromise and a fair representation of the coverage of the material during lectures and homework.

Written examinations provide objective information relating to both individual and collective student performance as well as possible comparative statistics for faculty effectiveness. Figure 5 presents results for the exam covering Block #2, “Network Analysis Systems.” Split among two sections, enrollment at the time of the exam was greater than 30. The scores of 79 % and better were benchmarked a
“success story” for these respective learning objectives. However, the unexpected achievement of a 64th percentile for the second objective for computing and analyzing free/total float warranted an investigation and some degree of response. Initial assessment efforts examined a number of issues other than student related factors. These after-exam reviews are vital to document not only positive trends that need to be continued but also any systemic educational barriers that might have been overlooked as well as the initiation of any subsequent corrective actions as appropriate – immediately if possible or as a follow-up for future semesters. A number of factors may contribute to exam results including a relative increase in difficulty of this particular objective as well as perhaps simply a lack of adequate time allotted on the exam for the more complex problems associated with this objective. Pertaining to this particular result on objective 1b, quantifying whether this was a teaching issue, simply a poor test question, or some other factor was difficult but not impossible. The test question was reviewed and in comparison was determined to be similar to problems already completed on both classroom worksheets and homework. Further, other professors from outside the course were consulted as to the relevancy of not only the learning objective but the exam question as well. Their assessment supported the validity of the course objective and the applicability of the exam question and concluded the exam results were probably not a result of some systemic problem but rather reflected an apparent lack of student mastery of the objective. Subsequently, a formal review of individual test results ensued which allowed the routine identification of students that struggled with the objective and that perhaps required assistance to achieve the expected level of mastery. These students were counseled and encouraged to participate in a voluntary program of additional, and often, individual instruction.

To ultimately evaluate the effectiveness of this performance oriented teaching methodology, both quantitative and subjective final assessments were completed at the end of the semester. The comprehensive Final Examination provided some additional objective measures for assessment of student mastery of the course learning objectives. Figure 6 illustrates one comparative technique for outcome assessment of the student’s mastery of objective #1b by aligning results from the Block #2 exam with the performance on the Final Examination. Analysis indicates a marked increase in student proficiency exceeding the 78th percentile. Although some isolated student scores were below acceptable levels, the overall results testify to a success for the students in mastering this learning objective. Students are also required to complete individual questionnaires to subjectively report their own perception of mastery for individual course objectives. Student subjective feedback reinforced this positive

![Figure 6. Comparative Results for Block #2 Learning Objective #1b, "Computing Free and Total Float."]
assessment on Learning Objective #1b by indicating that they possessed overall a very high confidence in their understanding and ability to apply the principles stated by the learning objective.

Conclusion

TC2K implementation must be an ongoing process to embody continuous improvement. This paper reports the current efforts by the staff and faculty at Pennsylvania State University at Harrisburg to integrate the new ABET accreditation criteria for engineering technology (TC2K) into the Structural Design and Construction Engineering Technology Program within the School of Science, Engineering, and Technology. This multi-year process has involved deliberate planning and execution of a comprehensive plan designed to successfully link established program outcomes, classroom instruction, assessment and evaluation processes, and process improvement initiatives. Building on course assessment as a foundational linchpin, the methodology effectively integrates input from alumni, employers, industry advisory panels, faculty, and students. Iterative techniques incorporate multiple reviews during the education process and subsequently provide timely opportunities for implementing education initiatives and for creating a positive, conducive environment to accommodate continuous improvement.

The performance oriented teaching described above has been successfully employed in CET 452, “Planning and Scheduling,” a course that represents a typical example of a topical area similar in content to many courses found in engineering curricula. This cyclic, interactive approach effectively fostered continuous improvement in both professor and student performance. It deliberately assessed the mastery of course learning objectives and executed planned actions to narrow the gap between expectations and student performance. This instructional technique features four phases encompassing deliberate planning, dynamic classroom instruction, formal student assessments, and in-process reviews to adjust and make corrections as needed. Equally applicable for individual lessons, for blocks of instruction, or for the course in total, repetitive application of the methodology sequentially plans improvements, implements innovative initiatives, verifies results, and takes affirmative action to standardize gains and provide timely feedback for planning new improvements.

The primary objective and ultimate end-state for this plan was to affect a transition to a student-focused academic environment of excellence. As a result of his personal involvement in the actions described in this paper, the author is confident that the Program is making positive, deliberate strides toward full implementation of the tenets of continuous improvement embraced by TC2K.
Bibliography:


DR. DAVID S. COTTRELL is an Assistant Professor in the School of Science and Engineering Technology at Pennsylvania State University at Harrisburg. He graduated from the United States Military Academy in 1978 and retired in 2000 after over 22 years of military service with the US Army Corps of Engineers. Studies at Texas A&M University resulted in a MS Degree in Civil Engineering in 1987 and a PhD in 1995. He is a registered Professional Engineer and has taught courses in statics, dynamics, mechanics of materials, graphic communications, and construction planning, scheduling, estimating and management.
Appendix A

Course Objectives for CET 452, “Planning and Scheduling”

- Explain the relationship between the three principal components of a construction project: Scope, Budget, and Scheduling.
- Explain the phases of a project from the owner’s definition of the need through construction and project close-out.
- Explain the uses and relative level of accuracy associated with project estimates developed by the owner, the designer, and the contractor.
- Apply basic economic concepts pertaining to time value of money including:
  - Single payment compound amount and present worth factors;
  - Uniform Series Compound Amount, sinking funds, capital recovery, and present worth factors;
  - Interest factor relationships with linear interpolation;
  - Computing repayment periods and unknown interest rates;
  - Analysis of interest periods with equivalent, smaller, and larger payment periods;
  - Discrete and continuous payments;
  - Comparing economic alternatives;
  - Computing the attractive rate of return.
- Complete benefit-cost analysis for alternative comparison.
- Compare the four primary contractual methods for compensating for design services – lump sum, salary times a multiplier, cost plus a fixed payment, and percentage of the construction cost.
- Compare two primary contractual methods for compensating for construction services – fixed price (i.e., lump sum or unit price) and cost reimbursable.
- Explain the roles of the project manager and the owner in reviewing the design and developing the work breakdown structure for a construction project.
- Compare the four basic types of organizational structures: product oriented, functional, discipline, and matrix.
- Develop a work breakdown structure for a project.
- Analyze a project through a network analysis system including the Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), or Precedence.
- Develop cumulative cost curves to forecast and monitor performance in terms of budgeted cost of work performed (BCWP) and the actual cost of work performed (ACWP).
- Determine project performance descriptives such as percent complete in terms of earned value.
- Explain the significance of integrated resource management for manpower, materials, machines, money, and time.
- Apply the tenets of management – planning, organizing, staffing, directing, and controlling.