AC 2008-1598: TC2K AND CLASSROOM ASSESSMENT: THE CASE FOR COMPREHENSIVE COURSE ASSESSMENT IN SUSTAINING CONTINUOUS PROGRAM IMPROVEMENT

David Cottrell, University of North Carolina at Charlotte

DR. DAVID S. COTTRELL is an Assistant Professor in the Department of Engineering Technology, University of North Carolina at Charlotte. He graduated from the United States Military Academy in 1978 and retired in 2000 after more than 22 years of service with the US Army Corps of Engineers. Studies at Texas A&M University resulted in an 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, engineering economy, and construction planning, scheduling, estimating, and management.

TC2K and Classroom Assessment: The Case for Comprehensive Course Assessment in Sustaining Continuous Program Improvement

This paper describes practical techniques currently employed to effectively sustain and enhance the ABET accreditation criteria for engineering technology (TC2K) within the University of North Carolina at Charlotte. However, the paper also documents the systematic implementation of course level assessment strategies that cross-reference program outcomes to course learning outcomes in the curriculum. Although program assessment is the accreditation mandate and therefore an appropriate, necessary part of current academia, this paper examines the vital role of comprehensive course assessment to ensuring true continuous improvement. As a practical demonstration, this paper examines a course in construction cost estimating, primarily for junior students pursuing a Construction Management or Civil Engineering Technology Degree. Course content is conventional with the study of direct and indirect costs associated with the numerous technical trades involved with commercial and heavy construction. The paper details the development of course learning outcomes that directly support published program outcomes but that are wholly consistent with the nature and expectations of the course. This paper presents an in-depth look at assessment techniques and procedures that:

- Generate objective assessment data that accomplished the following:
    - Quantification of the level of individual student mastery of specific learning objectives during the course;
    - Creation of an immediate opportunity to respond to the students with identified deficiencies;
    - Initiation of additional instruction as required and revalidation of improved skills;
- Provide tactical feedback to course instructors to afford immediate course correction during the semester to correct, enhance, or improve future blocks of instruction;
- Document strategic information used for program level assessment, evaluation, and process improvement initiative development.

Success in this effort is based primarily on a well developed set of course learning outcomes that contain precisely defined, measurable, objective criteria for assessment. 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 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 outcomes that were linked to a variety of assessment methods including graded exercises and exams. Final course assessments were performed through both objective and subjective means with final exam problems providing final objective assessments on critical learning objectives and student questionnaires yielding the medium for student self-assessment. Nevertheless, as a necessary precursor to understanding course assessment, the paper first provides an overview of the current fully implemented and functioning program level assessment methodology.

Background: Understanding the Current Program Assessment Protocols

The Department of Engineering Technology at the University of North Carolina at Charlotte has developed a comprehensive program leading to an academic environment of continuous improvement consistent with the ABET Technology Criteria 2000 (TC2K).[1] Experts have long debated the pros and cons of assessment at the course level versus program level and the potential for linking student achievement directly to program outcomes[2,3,4,5,6] This Department's systemic approach to assessment links program outcome assessment to specific student level performance on a variety of targeted events such as homework, presentations, exams, etc. Faculty provide the foundational student performance assessment data by participating in the Individual Course Assessment Process (ICAP).[7] This process reviews performance criteria in selected courses in light of their mapped support to specific program outcomes employing multiple techniques and methods often in numerous courses to "triangulate" performance. Although ICAP has proven to be highly successful in supporting program assessment and evaluation, it does not support comprehensive course assessment.

The linchpin of success of any program-level continuous improvement is the development of both objectives and outcomes that adequately capture educational intent. The Civil Engineering Technology (CIET) Program Outcomes reflect the strategy of continuous improvement prevalent in the Department of Engineering Technology. The Program Outcomes have evolved over the years, but have remained the bridge between the Program Educational Objectives shown in Table 1 and the "a-k" requirements of

Table 1: Civil Engineering Technology Program Educational Objectives

1. Applying general and discipline specific concepts and methodologies to identify, analyze, and solve technical problems.
2. Articulating technical material in a professional manner to potentially diverse audiences and in a variety of circumstances.
3. Contributing within team environments, demonstrating ethical, respectful, and professional behavior in all associations.
4. Recognizing and appreciating the environmental, societal and fiscal impact of the technical professions in a local, national and global context.
5. Demonstrating an individual desire and commitment to pursue continuous self-improvement and lifelong learning.

TC2K ABET TAC Criteria 2. The Program Outcomes describe the knowledge and skills of graduates with a Bachelor of Science in Engineering Technology (BSET) at the time of their graduation from the program. As shown in Table 2, each Program Outcome includes a number of sub-outcomes that elaborate, clarify, and support implementation, assessment, and evaluation of the continuous improvement processes.

Table 2: Civil Engineering Technology Program Outcomes and Sub-Outcomes

1. Use appropriate tools to acquire data and analyze problems in civil and construction technology.
    i. Demonstrate the proper use of appropriate software to solve technical problems.
    ii. Use proper resources to obtain necessary information.
    iii. Operate discipline specific lab equipment.
2. Demonstrate effective skills in the development and presentation of team projects.
    i. Exhibit effective team skills.
    ii. Present oral reports.
    iii. Produce a written report.
    iv. Complete assigned tasks in a timely manner.
3. Exhibit knowledge and skills consistent with the expectations of a practicing civil engineering technologist.
    i. Take part in continued education and/or training.
    ii. Participate in appropriate activities or organizations, or obtain employment in a relevant position.
    iii. Perform tasks in a professional manner.
4. Generate creative and realistic solutions to defined problems and projects in civil and construction technology.
    i. Solve structured technical problems.
    ii. Solve technical problems to satisfy a given set of specifications.
    iii. Develop alternate strategies to solve open-ended problems.
5. Recognize the value of diversity, and identify ethical and societal issues in business and technical tasks.
    i. Participate in a diverse group.
    ii. Discuss ethical and societal issues related to technology.
6. Solve problems and design components, systems or processes appropriate to the discipline of civil engineering technology.
    i. Utilize graphic techniques to produce engineering documents.
    ii. Conduct standardized field and laboratory testing on civil engineering materials
    iii. Utilize modern surveying methods for land measurement and/or construction layout.
    iv. Determine forces and stresses in elementary structural systems.
    v. Estimate material quantities for technical projects.
    vi. Employ productivity software to solve technical problems.
    vii. Plan and prepare design and construction documents such as specifications, contracts, change orders, engineering drawings, and construction schedules.
    viii. Perform economic analysis and cost estimates related to design, construction, operations, and maintenance of systems in the civil specialties.
    ix. Select appropriate engineering materials and practices.
    x. Apply basic technical concepts to the solution of civil problems involving. 1) hydraulics, 2) hydrology, 3) geotechnics, 4) structures, 5) materials behavior, 6) transportation systems, and 7) water & wastewater systems.
    xi. Perform standard analysis and design in structures, geotechnical, transportation, construction or water resources/environmental engineering

Table 3: Mapping the Curriculum to the Program Outcomes

Semester	Course Number	Course Title	Program Outcomes*					
			1	2	3	4	5	6
1st Semeter (16 hours)	ENGL 1101	English Composition	x	x				
	ETCE 1121	Construction Methods	x					
	ETGR 1100	ET Computer Appklications	x					
	ETGR 1103	Technical Drawing I	x					
	ETGR 1201	Intro to ET Practices & Principles	x	x	x	x	x	
	MATH 1100	College Algebra and Probability	x					
2nd Semeter (15 hours)	ENGL 1102	Writing in the Academic Community	x	x				
	ETCE 1211	Surveying I	x					
	ETCE 1222	Construction Materials	x	x				
	ETGR 1104	Technical Drawing II	x					
	MATH 1103	Pre-Calculus Mathematics	x			x		
3rd Semeter (17 hours)	ETCE 2112	Surveying II	x		x			
	ETGR 2101	Applied Mechanics I	x					
	MATH 1121	Calculus (ET)	x			x		
	PHYS 1101	Introductory Physics I	x					
	PHYS 1101L	Introductory Physics I Lab	x					
		Science Elective	x					
4th Semeter (16 hours)	ETCE 2410	Intoduction to Environmental Technology	x			x		
	ETGR 2102	Applied Mechnics II	x					
	PHYS 1102	Introductory Physics II	x					
	PHYS 1102 L	Introductory Physics II Lab	x					
	STAT 1220	Elements of Statistics	x					
		Social Science Elective					x	
5th Semeter (14 hours)	ETCE 3111	Structural Analysis I	x					x
	ETCE 3121	Foundations and Earthwork	x		x	x		x
	ETCE 3151	Soil Testing Laboratory	x	x				x
	ETGR 3222	Engineering Economics	x			x		x
	ETGR 3071	ET Professional Seminar		x	x		x	
	LBST 110x	Arts and Society					x	
6th Semeter (16 hours)	ETCE 3112	Structural Analysis II	x					x
	ETCE 3132	Hydraulics	x		x	x		x
	ETCE 3150	Hydraulics and Materials Lab	x	x				x
	ETGR 3171	Engineering Analysis I	x			x		
	LBST 2101	Western Culture and History					x	
	LBST 2102	Global Connections					x	
7th Semeter (17 hours)	ETCE 3212	Structural Steel Design	x		x	x		x
	ETCE 3243	Project Management Technology	x		x		x	x
	ETCE 3252	Intro to Environmental Engineering or	x		x	x		x
	ETCE 3281	Cost Estimating	x		x			x
		Science Elective	x					
		Science Elective Laboratory	x					
		Major Elective	x		x	x		x
		Major Elective Laboratory	x	x				
8th Semeter (17 hours)	ETCE 3211	Reinforced Concrete Design	x		x	x		x
	ETCE 3241	Highway Design and Construction	x	x	x	x		x
	ETCE 3293	Building Sustems or	x		x	x		x
		Major Elective						
	ETCE 3642	Senior Design Project	x	x	x	x	x	x
		Major Elective	x		x	x		x
	LBST 221x	Ethical and Cultural Critique					x	

*Defined Program Outcomes: See Table 2

Table 4: Assessment Tools for Program Outcomes (PO) and Program Educational Objectives (PEO) Employed by the Engineering Technology Department and the College of Engineering (COE)

Assessment Tool	Item(s) Assessed or Input Sources	Frequency
Student Survey	PO, Perceptions of COE, Program, Facilities, & Support	Every Spring
End of Semester Course Evaluation	PO, Perceptions of Instructors & Programs	Every Semester
Alumni Survey	PO, PEO, Perceptions of COE & Program	Every Three Years (Beginning 2000)
Employer Survey	PO, PEO, Perceptions of COE & Program	Every Three Years (Beginning 2000)
Faculty Survey	PO, PEO, Perceptions of COE & Program	Every Spring
Senior Exit Surveys	PO, PEO, Perceptions of UNC Charlotte, COE & Program, Faculty, Facilities, & Support	Every Semester
Change of Major Survey	Perceptions of Overall Department and COE	Every Time a Student Leaves the Department
Individual Course Assessment Process (ICAP)	PO	Each Semester, Each Course Taught
Focus Area Improvement Teams (FAIT)	PO, PEO	Every Semester
Program Educational Objectives (PROBE)	PEO	Annually
Faculty Meetings	PO, PEO	Regular Basis; Usually Monthly
Industrial Advisory Committee Meeting	PO, PEO, Perceptions of Department, Programs, & Facilities	Once Every Semester
Community College Articulation Conference	PO, PEO, Perceptions of Department & Programs	Every Two Years (Beginning 2002)
FE Exam	Fundamentals of Engineering	Fall and Spring Semesters

*Note: ET Students were eligible for the Fundamentals of Engineering (FE) Exam in North Carolina for the first time at the end of the Spring semester, 2004.

These outcomes are well publicized within the Engineering Technology Department and College of Engineering documents, newsletters, and the University website and undergraduate catalog. They embrace all eleven of the “a-k” outcomes established in the TC2K ABET TAC Criteria 2 standards as well as the Civil Engineering Technology program requirements. Effectively closing the program assessment loop, each course in the curriculum has been linked directly to one or more of the Program Outcomes (Table 3) as well as the eleven “a-k” outcomes. Further, the Program Outcomes include relevant performance criteria that were crafted to ensure that each outcome requirement of Criteria 2 was represented at least once as a primary map. The performance criteria or measures selected as benchmarks for assessing the program’s progress in achieving the outcomes have been directly mapped to the six Program Outcomes in addition to identifying opportunities, tool(s), reporting mechanisms, and archival requirements. As seen in Table 4, the assessment process employs a wide range of tools and survey instruments that vary from annually for student and faculty surveys, to a multi-year cycle in the case of alumni and employer surveys. The Individual Course Assessment Process (ICAP) and Focus Area Improvement Team (FAIT) meetings operate each semester as does the end of semester Student Evaluation of Teaching. Collectively, this infrastructure testifies to a functioning process that directly links program assessment activities to Program Outcomes that is, in turn, linked directly to the TAC of ABET Criterion 2 outcomes and the program criterion specified in TC2K criteria (lead society, ASCE).

Individual assessment linked to Program Outcomes is achieved and documented primarily through the Individual Course Assessment Process or ICAP. This process provides the foundation for reviewing and improving course content, ensuring continuity, promoting course enhancements, and identifying areas of deficiency that need improvement in order to support the program-level continuous improvement imperative. ICAP provides a framework for sharing this information among faculty that teach the same course(s) either concurrently or in future semesters. ICAP also provides a source of information for content threads in a given area, and therefore, is often used as a catalyst for program improvement. Each semester, instructors of targeted courses receive ICAP forms via email for each defined program measure. They are provided with information as to the previous semester's recommendations for course improvement or enhancement that in turn may be a compilation of several cycles of suggestions. The instructor is then responsible for planning and implementing the course and providing required input to the assessment process. Instructors must indicate current sample size, performance with respect to the defined measure(s), the status of previous recommendations as well as recommendations or observations from the current semester. In this way, a written record of the course history is maintained, learning outcomes are addressed, and a concrete strategy for continuous improvement is in place. All ICAP reports are archived in a database maintained at the departmental level, with college level technical support. The contents of the ICAP may be compiled and provided in terms of program outcome, Criterion 2 outcome, and/or course designation. Faculty meet on a regular basis to solicit input for improvement strategies and/or report their recommended changes. The following process improvement initiatives have been emplaced to ensure that the ICAP process is implemented:

- Key required courses in the curriculum are identified for continuous assessment and improvement. Courses are selected to ensure a comprehensive coverage of Criterion 2 (a-k) outcomes and program outcomes, which contain Criterion 8 (Program Criteria) topics.

- Each semester, ICAP summaries are prepared for the program-level assessment implications with separate reports generated for the Criterion 2 outcomes and Program Outcomes. Summaries are analyzed and, along with recommendations and/or concerns with other courses in the program, a consensus is reached as to the implementation of further enhancements and/or the addressing of any deficiencies.

- Program level discussions and recommendations are formalized and submitted to the Department Chair for information and the departmental staff for archiving. Recommendations are discussed and implemented, as appropriate, during regular faculty meetings. Implementation, modifications, and any further suggestions are recorded in the ICAP database as information to be provided during the next ICAP cycle.

Table 5: ETCE 3281 Course Learning Outcomes

Students completing ETCE 3281, **"Cost Estimating,"** will be able to accomplish the following:
a. Describe the basic project delivery processes in engineering and construction
b. Extract information from standard construction contract and bid documents
c. Compare alternative construction methods and materials
d. Perform material quantity calculations and take-offs
e. Estimate labor and equipment requirements for construction activities
f. Prepare comprehensive construction cost estimates
g. Use spreadsheets and industry software as aids in preparing cost estimates.

Direct Assessment inside the Classroom: Course Learning Outcomes and Subject Areas of Emphasis

The ICAP process was developed specifically to support program assessment, and consequently, it is not a challenge to understand its resulting effectiveness in providing a foundation for continuous program improvement. However, for continuous course improvement, it harbors significant limitations. The ICAP selectively identifies singular events within the courses that provide snapshots of the effectiveness of the educational process to develop student skills and knowledge in terms of the Program Outcomes. It is assumed that as a practical matter, all events within the course simply cannot be recorded and fed into the Program Assessment process. Consequently, a significant amount of data pertaining to planned, assessed/graded events are not formally captured or more importantly, assessed and evaluated. If not fortunate enough to be tied directly to an assessment of a program outcome, course learning objectives are not routinely, systematically reviewed for adequacy and teaching techniques, educational initiatives, and student performance and feedback are not documented for future development. This paper provides an example of a comprehensive course assessment process that not only supports program assessment but also provides a foundation for future development and improvement of the course itself.

As a practical demonstration of a direct, objective course assessment methodology, this paper examines ETCE 3281, a course in construction cost estimating primarily for 3rd year students pursuing a degree in either Construction Management or Civil Engineering Technology. ETCE 3281 provides the student with a working knowledge of the concepts, terminology, and methods associated with estimating the costs of construction activities. Students who successfully complete this course will be able to visualize the construction process for a project, to understand the way work is to be performed and the time required based upon a set of drawings and specifications. The resulting estimate is the basis for the bid that may or may not be good enough to win the job. No two projects are exactly alike, yet the contractor is frequently called upon to set a fixed price for the work to be performed. Therefore, to best prepare the student for this unique area of construction management, the course enables students to accomplish the skills listed in Table 5 above. Consistent with the Outcome-Curriculum mapping in Table 3, each of the Course Learning Outcomes directly support Program Outcomes #1, #3, and #6 for Civil Engineering Technology.

The key to executing dynamic and effective courses embodies a cyclic, iterative approach designed to foster continuous improvement in both professor and student performance above and beyond program assessment. This technique includes analysis of course learning outcomes and planning for specific actions to narrow the gap between academic expectations and 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.

As a pragmatic approach to properly assess the Course Learning Outcomes, the instructor identified specific Subject Areas of Emphasis (SAE) that provided a medium for assessing student performance throughout the course. For instance, one outcome dealt with developing the skills necessary to review a set of plans and determine the precise quantities of materials necessary for a particular salient feature of a proposed facility of structure. However, effective assessment of this outcome must encompass several areas of emphasis spanning at a minimum earthwork, highways, concrete, metals, wood, and masonry. Table 6 (See the Appendix) defines each Area of Emphasis and provides the targeted opportunity and objective measure for each area; Table 7 (See the Appendix) maps the SAE to the Course Learning Outcomes above providing the infrastructure for course assessment and subsequent input for Program Outcome assessment.

Due to space limitations, examples of exam problems designed to assess specific course learning outcomes or Subject Areas of Emphasis 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, examinations are not standard but rather vary from semester to semester depending on the course director's creativity in developing test questions and problematic applications that

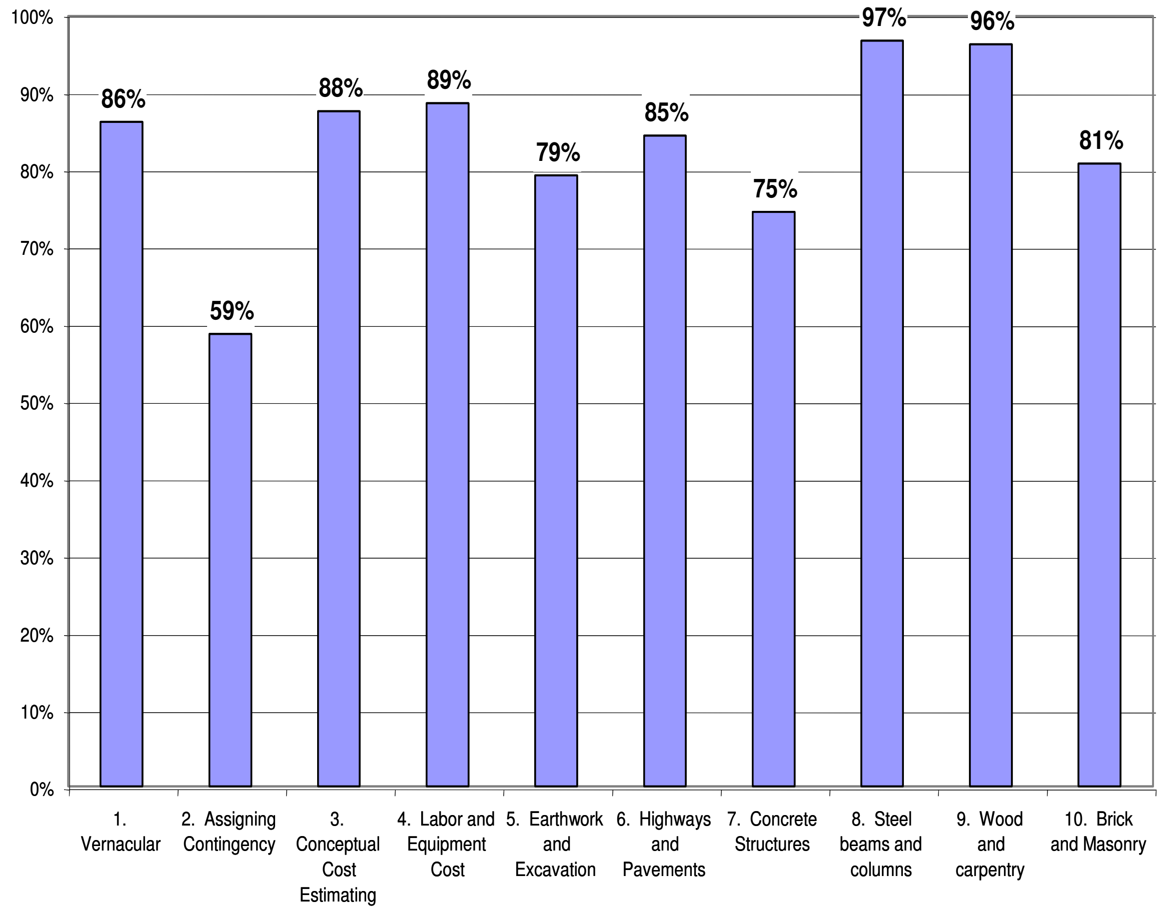

Figure 1: Baseline Assessment of the ETCE 3281 Subject Areas of Emphasis Compared to an Individual Targeted Performance Benchmark of 82.5 Percent. (Fall 06)

address the corresponding learning objectives. Homework remains similar in scope but has different parameters (dimensions, costs, etc) to aid in providing a unique challenge to each student. The common denominator among the exams and the homework, however, is that they are deliberately developed in light of course learning objectives and subsequently the associated program outcomes.

Figure 1 provides the assessment results of the course Subject Areas of Emphasis. The targeted benchmark for each Subject Area of Emphasis was 82.5%, indicated in red hatch-marks in Figure 1. Student performance testifies to a good grasp of the basic fundamentals of cost estimating although there is certainly room for improvement in a number of areas where they failed to meet the targeted benchmark. Assessing risk and assigning a cost contingency are clearly weaknesses that require corrective action. The area dealing with concrete received particular emphasis during the semester and student performance at 75% was significantly less than expected. Areas 5 and 10 are also marginally acceptable at 79% and 81% respectively; these assessed areas must also be examined for opportunities to improve student performance. Naturally, the key to course assessment is arraying the Subject Area of Emphasis to appropriately feed an assessment of the Course Learning Outcomes. Figure 2 indicates the resulting assessment in

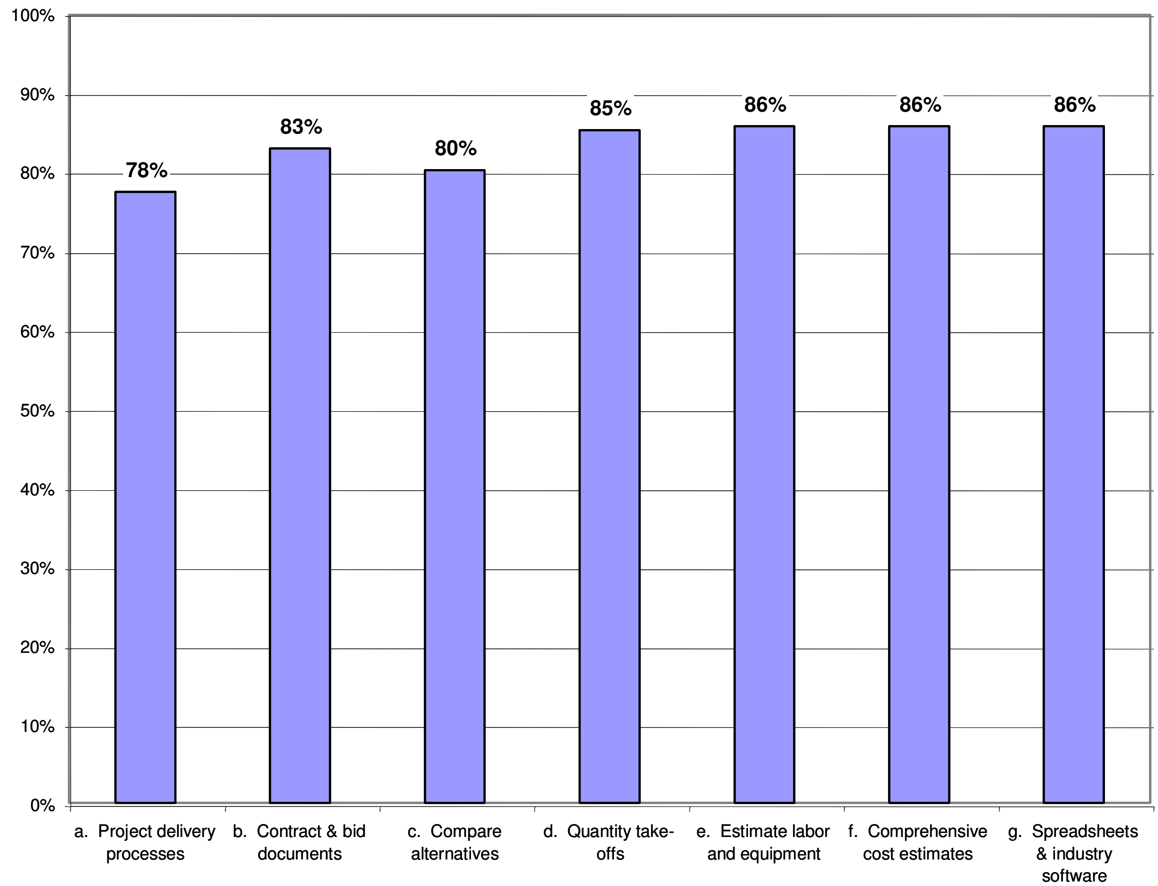

Figure 2: Assessment of the ETCE 3281 Course Learning Outcomes based on Subject Areas of Emphasis Compared to an Individual Targeted Performance Benchmark of 82.5 Percent. (Fall 06)

accordance with the mapping indicated by Table 7. The targeted benchmark was 82.5 percent indicated in red hatch-marks in Figure 2.

Consistent with the previous analysis of the individual Subject Areas of Emphasis, the student performance testifies to a good grasp of the basic fundamentals of cost estimating although there is room for improvement, particularly in the first and third outcomes that fail to achieve the targeted benchmark. Understanding project delivery and analyzing and selecting alternatives are contained in a number of courses in the curriculum, but this course certainly provides a timely opportunity to present this topic in terms of practical consequences regarding the cost of planning and building the project. This comprehensive continuous improvement process will focus on improving future performance in these areas to hone student skills and comprehension. Going beyond the traditional macro-assessment at the program level, it will support real long-term improvement of the individual course. Applied across the curriculum, this assessment is the ideal mate to a firmly imbedded commitment to program continuous improvement.

III. Conclusion

The performance oriented teaching described above has been used successfully in ETCE 3281, "Cost Estimating," a course that represents a typical example of a topical area similar in content to many courses found in engineering and engineering technology curricula. This approach effectively fostered continuous improvement in both professor and student performance by deliberately assessing the mastery of Course Learning Outcomes providing timely feedback. 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.

As a result of this experience, the author concludes that (1) it is indeed possible to integrate an iterative methodology to plan, instruct, assess, and respond to the students needs in achieving Course Learning Outcomes, ensuring continuous process improvement, and supporting attainment of program outcomes and (2) performance oriented teaching provides a viable medium for enhancing student performance by creating deliberate opportunities to correct diagnosed deficiencies in student learning and to rapidly realign student learning back with course expectations.

Bibliography:

1. "Criteria for Accrediting Engineering Technology Programs, Effective for Evaluations During the 2002-2003 Accreditation Cycle." Technology Accreditation Commission, Accreditation Board for Engineering and Technology, Inc., 2000.

2. Aldridge, M. D. and L. D. Benefield, "A Model Assessment Plan," ASEE Prism, May-June 1998, pp. 22-28.

3. Ressler, S. J. and T. A. Lenox, "Implementing an Integrated System for Program Assessment and Improvement," Proceedings of the ASEE Annual Conference, 1999.

4. Pape, David A., "Linking Student Achievement to Program Outcomes Assessment," Proceedings of the ASEE Annual Conference, 2004.

5. Gibson, Ronald F, Kenneth A. Kline, Jerry Ku, Trilochan Singh, and Chin An Tan, "Achievement of Course Leaning Objectives: An Assessment Tool That Promotes Faculty Involvement," Proceedings of the ASEE Annual Conference, 2003.

6. King, Franklin G. and Shamsuddin Ilias, "Imbedding Assessment and Achievement of Course Learning Objectives with Periodic Reflection," Proceedings of the ASEE Annual Conference, 2003.

7. Cottrell, David S, Bruce Gehrig, and Anthony Brizendine, "TC2K: A Successful Working Model for Continuous Improvement," accepted for publication in the peer-reviewed Proceedings of the 2006 Annual Conference of the American Society for Engineering Education, Chicago, Illinois, June 2006.

Appendix

Table 6: Subject Areas of Emphasis and Assessment Tools

Subject Areas of Emphasis	Assessment Tool
1. Vernacular: Demonstrate a mastery of basic terminology addressing the art and science of cost estimating and the associated processes.	Part A on the Mid-Term and Final Examinations
2. Traditional Methods of Assigning Contingency: Employ standard techniques for predicting uncertainty and adjusting a bid estimate based on calculated risk.	Page #III on Mid-Term Examination
3. Conceptual Cost Estimating: Demonstrate a variety of standard techniques for employing historical cost data for projecting future project construction costs.	Problems 4-2, 4-8, 4-9, & #II on Mid-Term Exam
4. Cost of Construction Labor and Equipment: Calculate costs associated with crews and equipment including ownership and usage costs and indirect labor costs.	Problems 5-2 & 5-2
5. Earthwork and Excavation: Balance production rates and cost of equipment to compare alternatives and determine the expected duration and total direct cost. Analysis will include mass diagrams.	Problems 7-5, 7-8, 7-10, & Page #IV on Mid-Term Exam
6. Highways and Pavements: Estimate the total cost and cost per acre for clearing, grubbing, and otherwise preparing land for subsequent highway development and paving operations.	Problems 8-1, 8-2, & Page #V on Mid-Term Exam
7. Concrete Structures: Estimate the total cost for forming, reinforcing, placing, and curing concrete pads and columns.	Problems 10-1, 10-2, 10-3, 10-4, 10-7, 10-8, & Page #Ia, #Ib, & #Ic on Final Exam
8. Steel beams and columns: Estimate the cost of erecting beams and columns.	Problem 11-1
9. Wood and carpentry: Estimate the cost for wall and roof structures.	Problems 12-3 & 12-4
10. Brick and Masonry: Estimate the total cost for furnishing and placing both bricks and concrete masonry units	Problems 15-1, 15-3, & Page #II on Final Exam

Table 7: Mapping the Subject Areas of Emphasis to the Course Learning Outcomes

Course Learning Outcomes	Subject Areas of Emphasis									
	1. Vernacular	2. Assigning Contingency	3. Conceptual Cost Estimating	4. Labor and Equipment Cost	5. Earthwork and Excavation	6. Highways and Pavements	7. Concrete Structures	8. Steel beams and columns	9. Wood and carpentry	10. Brick and Masonry
a. Describe the basic project delivery processes in engineering and construction	Yes	Yes	Yes							
b. Extract information from standard construction contract and bid documents		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
c. Compare alternative construction methods and materials	Yes	Yes	Yes	Yes						
d. Perform material quantity calculations and take-offs					Yes	Yes	Yes	Yes	Yes	Yes
e. Estimate labor and equipment requirements for construction activities				Yes	Yes	Yes	Yes	Yes	Yes	Yes
f. Prepare comprehensive construction cost estimates				Yes	Yes	Yes	Yes	Yes	Yes	Yes
g. Use spreadsheets and industry software as aids in preparing cost estimates.				Yes	Yes	Yes	Yes	Yes	Yes	Yes