Evaluation and Outcomes Assessment During the Semester:
Putting Course Learning Objectives to Work

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I. Introduction

In recent years, much has been written about the requirement to perform outcomes and objective assessments to evaluate the strengths of ABET accredited programs in all engineering disciplines including engineering management. In particular, the criteria for accrediting engineering technology programs stipulates that programs must demonstrate that graduates have a commitment to quality, timeliness, and continuous improvement (Technology Accreditation Commission, page 33). At the program level or at the individual student level, a commitment to continuous educational process improvement characterized by routine, outcomes assessment has evolved to become one of the key elements of success for engineering and engineering technology programs alike. This article examines the application of the principal of outcomes assessment during a course dealing with topics very typical of engineering and construction management related curricula – construction planning, budgeting, and scheduling. Just as program and graduate assessments rely on well defined outcomes, goals, and objectives, this article presents a program of student assessments and performance oriented teaching based on clear, published course learning objectives. These internal course assessments effectively ascertained the level of student learning and provided an array of interactive teaching techniques that created opportunities to correct diagnosed student deficiencies in learning that served to rapidly realign the student back within course expectations.

This paper initially discusses the methodology employed to quantify the level of individual student mastery of specific learning objectives during the course, to initiate additional instruction as required, and to revalidate improved skills. A set of well developed learning objectives is paramount to the success of this program and is presented here as an example of engineering management related learning objectives 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 an effective vehicle for evaluating student skills. The paper presents specific examples of learning objectives that were linked to graded exercises and exams. Final course assessments were performed through both
objective and subjective means with Final Exam problems aligned with critical learning objectives and with end-of-semester questionnaires yielding student self-assessment.

II. Course Description and Learning Objectives

The course in this paper is CET 452, a course in construction planning and scheduling. The course is primarily for senior students in the Construction Engineering Technology Program at Pennsylvania State University at Harrisburg. The 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 1, the academic hierarchy provides the framework for developing course organization and subsequent learning objectives. Over-arching program objectives 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

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provide copies of course learning objectives and corresponding exam questions and solutions to interested educators upon request.

III. Performance Oriented Methodology for Interim Outcomes Assessments

The methodology embodies a cyclic, iterative approach designed to foster continuous improvement in both professor and student performance. This technique analyzes course learning objectives and plans specific actions to narrow the gap between academic and scholarly expectations and the measured student performance. As shown in Figure 2, the teaching cycle has four sequential phases built on deliberate planning, dynamic classroom instruction, formal student assessments, and in-process reviews 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).”

Generally recognized as the initial phase in the sequence, planning the course educational template includes development of relevant, specific learning objectives commensurate with the expected, acceptable level of academic skills for that particular area of instruction. Specifically, the second block in this planning and scheduling

![Figure 2. Methodology for Planning and Executing Performance Based Education](image)

<table>
<thead>
<tr>
<th>Table 1. Block #2 Learning Objectives</th>
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<tbody>
<tr>
<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>
</tr>
<tr>
<td>b. (Float) Compute free and total float for each activity.</td>
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<tr>
<td>c. (Path) Identify the critical path through a network.</td>
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<tr>
<td>d. (Prob) Using probabilistic techniques, assess the variable nature of a network critical path.</td>
</tr>
<tr>
<td>2. (Curves) Develop cumulative cost curves and interpret performance parameters.</td>
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The course covered the learning objectives noted in Table 1 shown here. (Note: for future “shorthand” reference in figures, one-word synonyms for each objective were developed as shown.)

The next step in the process concerns executing dynamic instruction and rests primarily on faculty performance. Quality teaching stems from two key dimensions: educational process development based on clearly defined learning objectives and instructional delivery coupled with student rapport. Success in delivery relies on personal subject matter expertise, classroom organization, and dynamic, enthusiastic presentations that engage and excite the student to learn. Outside the classroom activities such as graded home study problems effectively reinforce student achievement of the learning objectives.

Formal assessments of student learning at the conclusion of the block of instruction provide a medium for faculty feedback on the effectiveness of the block of instruction in terms of the expected student outcomes – the learning objectives. 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 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 in the cognitive domain (Wankat, pages 49-50). Bloom divided the domain into the six major sequential levels show 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.

Table 2. Grid for Test Preparation Arraying Bloom’s Taxonomy Against the Exam Questions for Each of the Learning Objectives.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Bloom’s Taxonomy</th>
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<tbody>
<tr>
<td></td>
<td>Knowledge</td>
</tr>
<tr>
<td>1.a. Pass</td>
<td>x</td>
</tr>
<tr>
<td>1.b. Float</td>
<td>x</td>
</tr>
<tr>
<td>1.c. Path</td>
<td></td>
</tr>
<tr>
<td>1.d. Prob</td>
<td>x</td>
</tr>
<tr>
<td>2. Curves</td>
<td></td>
</tr>
</tbody>
</table>
Written examinations provide objective information relating to both individual and collective student performance as well as possible comparative statistics for faculty effectiveness. Figure 3 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 considered 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 4 illustrates one comparative technique for outcome assessment of the student’s mastery of objective #1b by

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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 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.

IV. Conclusion

The performance oriented teaching described above has been used successfully employed in CET 452, “Planning and Scheduling,” a course that represents a typical example of a topical area similar in content to many course found in engineering management 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.

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 learning objectives, ensuring continuous process improvement, and attaining expected 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:


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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 basic tenets of construction engineering management – planning, organizing, staffing, directing, and controlling.