Outcomes Assessment Inside the Classroom: Performance Oriented Teaching

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Abstract

This paper presents a methodology employed in an introductory mechanics of materials course to quantify individual student mastery of learning objectives, to initiate additional instruction as required, and to revalidate improved skills. This paper examines the first of four major blocks of instruction in an introductory mechanics of materials course as a vehicle to demonstrate the tenets of performance oriented education.

Introduction

In recent years, much has been written about the requirement to perform outcomes assessments to evaluate the strengths of an ABET accredited program. This article examines the application of the principal of outcomes assessment during a course to ascertain the level of student learning in terms of course learning objectives. Further, it describes the use of interactive teaching techniques that create deliberate opportunities to correct diagnosed deficiencies in learning and 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. Success in this effort is based primarily on a well developed set of 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 the primary vehicle for evaluating student skills. The paper presents some specific examples of objectives that were linked to graded exercises and exams. Final course assessments were performed through both objective and subjective means with Term End Exam problems providing final objective assessments on critical learning objectives and student questionnaires yielding the medium for student self-assessment.

Course Description and Learning Objectives

The course in this paper is an introductory mechanics of materials course offered by the Department of Civil and Mechanical Engineering at the United States Military Academy. All students majoring in civil and mechanical engineering take the course, EM364A Mechanics of Materials, generally during the Fall semester of their junior year. The course content is conventional, with coverage of internal forces, stress, strain, and deformations for various types of loading—axial, flexural, torsion, shear, and internal pressure. For each of these topics, the calculation of stresses and deformations is taught within the context of their application to the analysis and design of actual structural components and systems. 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.

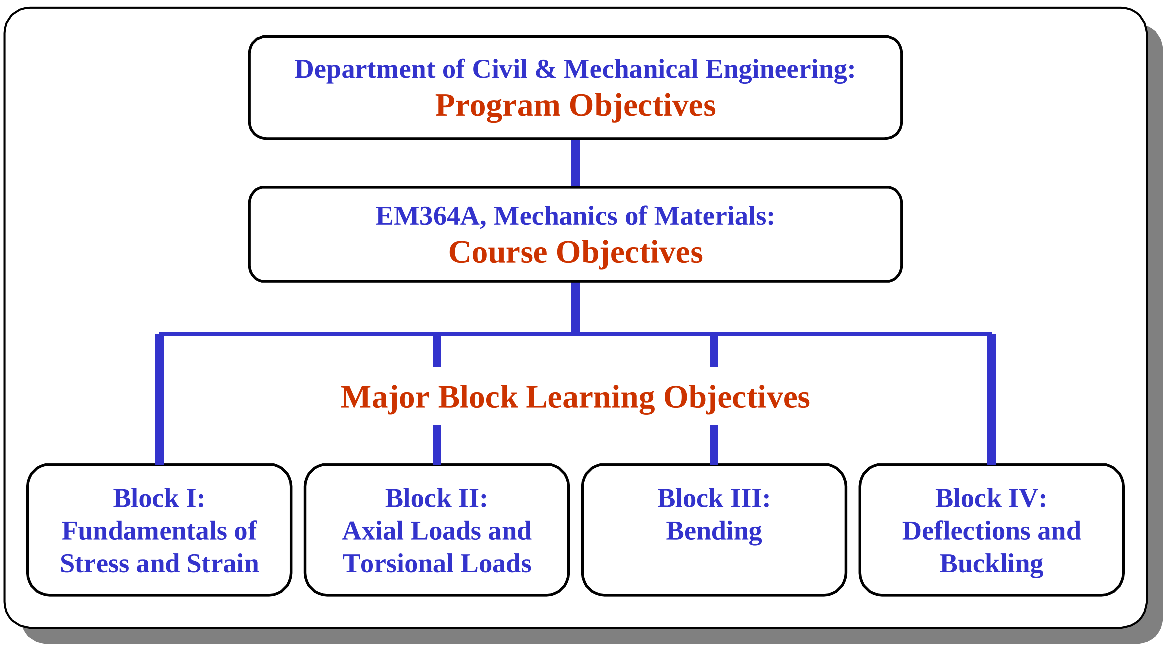

Figure 1. EM364A Mechanics of Materials Infrastructure and Educational Objectives

As shown in Figure 1, the academic hierarchy provides the framework for developing course organization and subsequent learning objectives. Over-aching civil engineering program objectives (Appendix 1) establish an effective backdrop for course objectives (Appendix 2) tailored to the specifics of mechanics of materials. More detailed learning objectives are further developed commensurate with each of the four major blocks of instruction – fundamentals of stress and strain, axial and torsion loads, bending, and deflections and buckling.

This paper examines Block I learning objectives and diagnostics as a vehicle to demonstrate the tenets of performance oriented education. Due to space limitations, examples of exam problems designed to specifically assess learning objectives are not included; however, the author will provide copies of course learning objectives and corresponding exam questions and solutions to interested mechanics educators upon request.

Performance Oriented Methodology

The methodology embodies a cyclic, iterative approach designed to foster continuous improvement in both professor and student performance. This technique analyzes the course learning objectives and develops planned actions to narrow the gap between expectations and student performance. As shown in Figure 2, the teaching cycle has four 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 the course in total, 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 first block of instruction, "Fundamentals of Stress and Strain."

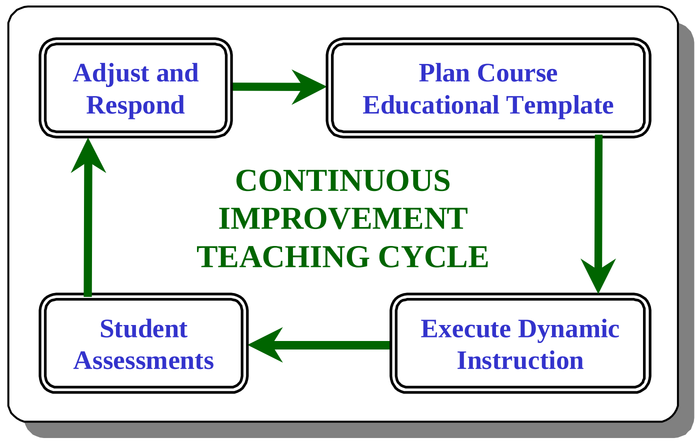

Figure 2. Methodology for Planning and Executing Performance Based Education

Planning naturally focuses initially on the development of relevant, specific learning objectives commensurate with the expected, acceptable level of academic skills for that particular area of instruction. Specifically, for the first block in this Mechanics of Materials course, learning objectives include the following:

1. Calculate internal forces (axial forces, shears, moments, and torque) in a structural member.
2. Analyze/design a centric axially loaded (2 force) member.
3. Plot / interpret normal stress – normal strain (σ vs ε) and shear stress – shear strain (τ vs γ) curves.
4. Given a state of stress at a point, calculate the principle stresses (σ_1 and σ_2) and the maximum in-plane shear stress (τ_{max}), the angle to the principle plane (θ_p) and the state of stress on any plane through the point ($\sigma_{x'}$ and $\tau_{x'y'}$).
5. Given a state of strain at a point, calculate the principle strains (ε_1 and ε_2) and the maximum in-plane shear stress (τ_{max}), the angle to

the principle plane (θ_p) and the state of stress on any plane through the point ($\varepsilon_{x'}$ and $\gamma_{x'y'}$).

Phase II of the methodology rests on the performance of the faculty. Quality teaching stems from two key dimensions: educational process development based on clearly defined learning objectives and instructional delivery. Success in delivery relies on personal subject matter expertise, classroom organization, and dynamic, enthusiastic presentations that engage and excite the student to learn. Graded home study problems completed outside the classroom effectively reinforce student achievement of the learning objectives.

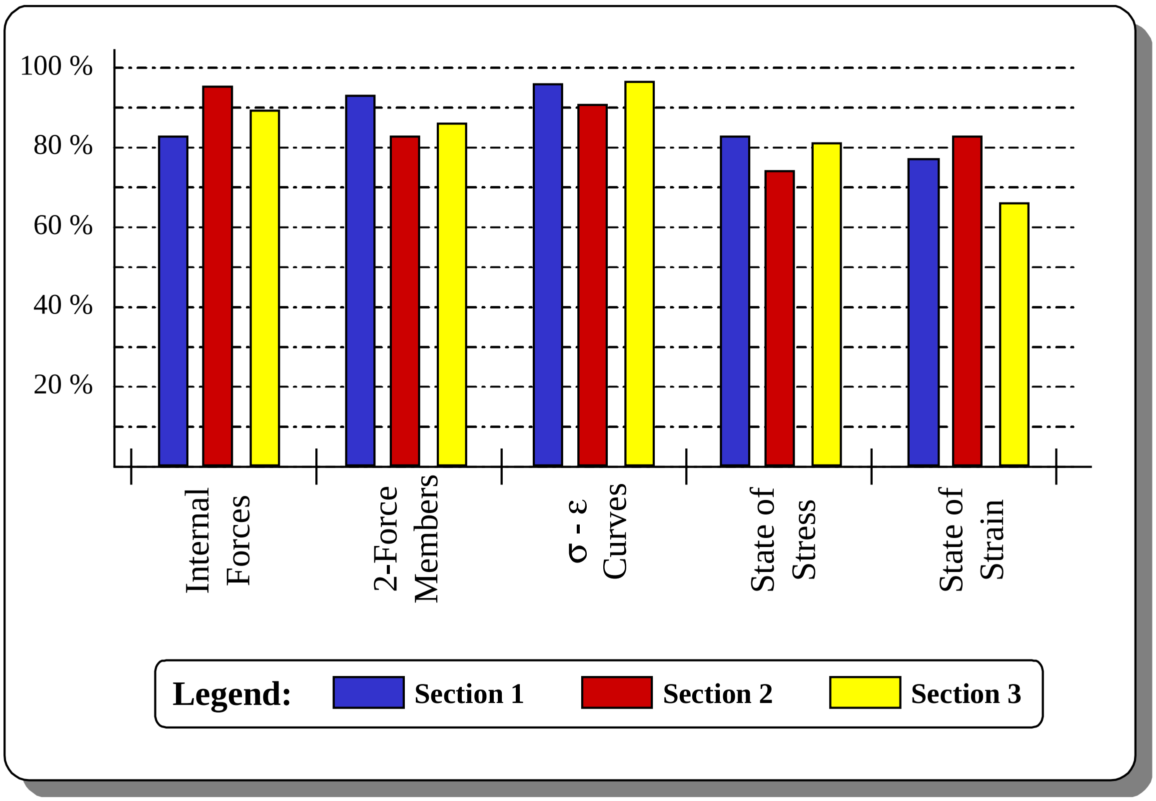

Figure 3. Exam Assessment of Block I Learning Objectives Separated by Section

The next phase encompasses formal assessments of student learning at the conclusion of the block of instruction. 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 collective results for Block I, “Fundamentals of Stress and Strain.” Each of these sections had different professors and approximately the same number of total students (each greater than 30). These particular results indicate a success story for each of the first three learning objectives for all three sections with each exceeding the 80^{th} percentile. The decrease in performance on the last two objectives warranted a review to identify any potential systemic educational barriers that had been overlooked and subsequently the initiation of corrective actions as appropriate – immediately if possible or for follow-on semesters. A number of factors may have contributed to these results including a relative increase in difficulty of the objectives themselves as well as perhaps a lack of adequate time allotted on the exam for the more complex problems associated with these two objectives. Individual results from the exam provided the basis for a review of each student performance. Students exhibiting difficulty with one or more of the learning objectives were counseled and encouraged to participate in the program of additional instruction.

To ultimately evaluate the effectiveness of the performance oriented teaching methodology, both quantitative and subjective final assessments were completed at the end of the semester. Comprehensive in nature, the Term End Final Examination provides objective measures for learning objectives developed for the course. To illustrate this comparative technique for tracking performance, Figure 4 presents the results for Learning Objective #4 from Block I dealing with "State of Stress." Analysis indicates a marked increase in student proficiency exceeding the 90th percentile in each of the three sections. 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 objects. Student subjective feedback reinforced this assessment on Learning Objective #4 by indicating that they possessed a very high confidence in their understanding and ability to apply the principles stated by the learning objective.

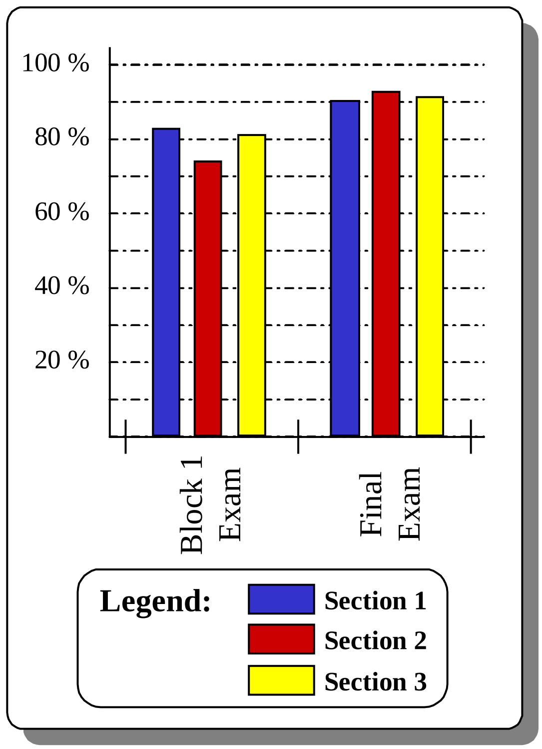

Figure 4. Comparative Results for Block I Learning Objective #4, "State of Stress."

Conclusion

The performance oriented teaching described above has been used successfully employed in EM364A, Mechanics of Materials. This cyclic, interactive approach effectively fostered continuous improvement in both professor and student performance. It deliberately assessed course learning objectives and executed planned actions to narrow the gap between expectations and student performance. This instructional technique features four phases built on 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 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.

LIEUTENANT COLONEL DAVID S. COTTRELL graduated from the US Military Academy in 1978. He has a Masters Degree (1987) and a PhD (1995) from Texas A&M and is a registered Professional Engineer. He has served as an Assistant Professor in the Department of Civil and Mechanical Engineering at USMA (1995-1998). He has taught courses in statics and dynamics, mechanics of materials, and construction engineering.

Appendix 1, Civil Engineering Program Objectives

Department of Civil & Mechanical Engineering:
Program Objectives

Produce Civil Engineering graduates who demonstrate:

- **Creativity**
- **Proficiency in mathematics, calculus-based physics, and general chemistry**
- **The ability to apply the engineering thought process**
- **The ability to design CE components and systems to meet desired needs**
- **Proficiency in structural engineering**
- **Proficiency in environmental engineering**
- **Proficiency in hydrology & hydraulic engineering**
- **Proficiency in geotechnical engineering**
- **The ability to design and conduct experiments in both structural and geotechnical discipline areas**
- **The ability to function on multi-disciplinary teams**
- **An understanding of the roles and responsibilities of civil engineers and the issues associated with professional practice**
- **The ability to use modern engineering tools necessary for engineering practice**
- **The ability to write and speak effectively**
- **Knowledge of contemporary issues**
- **Broad education and understanding of the impact of engineering solutions in a global/societal context**
- **The preparation for and willingness to pursue continued intellectual and professional growth**

Develop and maintain a faculty team that is a model of professional excellence for the students

Appendix 2, EM364A Mechanics of Materials Course Objectives

EM364A, Mechanics of Materials:
Course Objectives

- **Apply the general analysis procedure to analyze stress, strain, and deformation on structural members subjected to axial, torsion, bending, and combined loads.**
- **Apply the design process to designing structural members subjected to axial, torsion, and bending loads.**
- **Perform the simple tension test and pure torsion test on engineering materials in the laboratory and construct the associated stress-strain curves. Conduct a bending test and take field data from strain gages.**
- **Know the definition of stress of state of stress and state of strain at a point on a body.**
- **Use Mohr's Circle to calculate principal stresses and strains, maximum in-plane shear stresses and strains, and the stress and strain on an arbitrary plane.**
- **Evaluate the suitability of a material for the specific purpose based on a stress-strain curve.**
- **Use deformation compatibility to analyze statically indeterminate structures subjected to axial, torsion, or bending loads.**
- **Know the maximum normal stress and shear stress theories of failure and apply Euler's critieria for columns.**
- **Have a working knowledge of the analysis and design of a thin-walled pressure vessels and Euler's columns.**
- **Have a introductory knowledge of fatigue and stress concentrations.**
- **Know the importance of Mechanics of Materials and how it fits into other engineering courses.**