Creating a Shared Learning Environment for Engineering and Engineering Technology Students in Strength of Materials

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Abstract: While Engineering (EN) and Engineering Technology (ET) programs are usually quite separate, there are certain curricular areas that both programs share. Strength of Materials is a good example. However, while this is a foundational course for most EN students, usually taken during the sophomore year, many ET students take the course toward the end of their degree programs in the junior, and sometimes even in the senior year. Consequently the learning objectives in Strength of Materials might reasonably be expected to vary between EN and ET programs. When these programs are combined within a single institution, ET students are often expected to take a Strength of Materials course geared for EN students, regardless of their own distinct educational needs. In those cases where ET students are given a course offering separate from EN students, the burden on available learning resources can sometimes lead to a diminished quality of instruction.

The Personalized System of Instruction (PSI) which allows students to progress at their own pace, can also be used to combine EN and ET students in the same classroom, with the same instructor and the same text book, yet with distinct learning objectives tailored to satisfy the needs of their individual programs. The author has taught Strength of Materials to classes designed exclusively for EN students, exclusively for ET students, and designed for a mix of EN and ET students. This past year he has developed and implemented Strength of Materials PSI courses for both EN and ET students based on separate agendas of learning objectives, and is now in a position to combine both courses in the same classroom.

Introduction

My third teaching assignment as a graduate student was a course in Strength of Materials, which was a core requirement for all EAC-ABET Engineering (EN) programs within the College of Engineering and Technology at a western university. It was also a core requirement for our ACCE accredited Construction Management (CM) program, which was otherwise more closely aligned with the College's Engineering Technology (ET) majors. While Strength of Materials was not a prerequisite for any further classes in Chemical (ChE) or Electrical Engineering (EE), it was prerequisite for many core classes in both Mechanical (ME) and Civil Engineering (CE). It was also the prerequisite for two classes required of CM students: Soil Mechanics, and Structural Analysis, which they were required to take with CE students. It was a generally held belief that taking these mathematically rigorous courses with EN students would give CM students excellent preparation for working with Engineers (with typical chauvinism, there wasn't much talk of engineers gaining from exposure to CM students). However, there seemed to be a growing undercurrent of thought that CM students might possibly be better served by separate courses.

This first Strength of Materials teaching assignment had a fairly even mix of students from all five majors. While learning readiness varied among all majors, the CM students generally held their own. As a group they received one of the five A letter grades given (in a class of 35), and none of them received a failing mark. In addition I had a sense that having taken the Strength of Materials class with EN students, CM students would have an easier time in their subsequent CE courses (some CM students chose to take engineering mechanics at a neighboring community college). Although I recognized that CM students (as well as ChE and EE students) might be best served by separate agendas of learning objectives, I did not see any way to accomplish this. Consequently the mismatch of learning objectives for CM students, which certainly wasn't any worse than for ChE or EE students, seemed tolerable.

My next opportunity to teach Strength of Materials came with my first full-time teaching job at a TAC-ABET accredited School of Engineering Technology. While the course was technically transferable to EAC-ABET programs within the state, all of the students were either CM, Mechanical Engineering Technology (MET), Electrical Engineering Technology (EET) or Manufacturing Engineering Technology (MNET) majors. For the CM students, Strength of Materials was a prerequisite for courses in Structural Design, and Soils and Foundations. It was also a prerequisite for additional courses in MET, but was a terminal class for EET and MNET students. While some students did well, learning readiness varied greatly and the thought occurred to me again that there was an unavoidable mismatch of learning objectives for some of the majors.

I next taught Strength of Materials two years later at Boise State University (where I am currently employed) to a group of CM students. This institution had just separated EN and CM students into their own engineering mechanics classes. Having spent the previous two years teaching in a CM program, I was fairly well attuned to their needs and so developed a more finely tailored set of learning objectives. I also kept the same text that was being used to teach the Strength of Materials class to EN students, and reused this text with a revised set of learning objectives the following semester in a Strength of Materials class for EN students.

Because we are a new College of Engineering at Boise State (CM, CE and ME, which require Strength of Materials and EE, which does not), our class sizes are small. Having separate EN and CM courses teaching basically the same thing seems like an expensive luxury. The problem is that combining the two classes with traditional teaching methods would require a compromise in the learning objectives of one or both courses. A possible solution would be to use personalized instruction, have the students work together in the same classroom, but have them work on learning objectives tailored to the needs of their individual programs. Such a situation might even allow for enhanced learning, due to the development of self-directedness. In addition, by taking advantage of the natural diversity of students within the classroom, the context of learning might be broadened for everyone.

Personalized System of Instruction (PSI)

I had taught five other Engineering classes as a graduate student, besides Strength of Materials and had become concerned about students moving through the required material at an awkward pace (either too fast to truly master the material, or too slow to maintain momentum on a continuous learning curve). Upon exposure to some of the concepts of Mastery Learning (ML), at about the time that I was finishing my dissertation, I began to consider the application of ML to the engineering mechanics sequence. By the fall of 1995, I was ready to offer my first ML course in Engineering Statics.

During this first semester of personalized instruction, I maintained individual consultation hours outside of the classroom, while attempting to teach inside the classroom with the usual lecture methods. The mastery criteria, however, required student pacing and within two or three weeks my students as a group were distributed over several different learning objectives. My first attempt at a remedy was to divide the class into groups, based on the module or learning objective that they were trying to master. In class I would lecture to a specific group while those not intentionally engaged in the lecture were asked to work independently at their desks, and wait for me to deliver a component of lecture to them.

In retrospect, it's hard for me to imagine a less effective process, except possibly lecturing to everyone regardless of whether or not they were ready to assimilate the material. By the second semester, however, I had figured this out and abandoned all hope of using lectures for significant learning transfer. As an alternative I moved the class into a studio format, which was more consistent with the Personalized System of Instruction (PSI), made better use of class time for everyone, and was more conducive of collaborative learning. By witnessing individual consultation in the classroom, as well as in the office, my students began (spontaneously) consulting with each other. The text remained the source of content, but I (as the instructor) was no longer the sole source of clarification.

I have used PSI in at least one class (Statics, Strength of Materials or Structural Analysis) each semester since the fall of 1995, and have refined methods and materials to the point where they have become fairly constant. The ability to group students together who are working on distinct yet related learning objectives (like EN and ET students in Strength of Materials) offers unique opportunities for cooperative learning. The studio format itself encourages collaboration, and the depth of learning is enhanced by the diversity of background within the "studio." By combining EN and ET students in the same course, but with tailored learning objectives, a diverse, apprentice-like environment is created where students learn from the master (the professor), peers (students working on the same learning objective) and advanced peers (who have already mastered the learning objective in question). In addition advanced peers (and the master) broaden the context of their own mastered learning by explaining content and listening to the perceptions of less advanced peers--helping them, also, to achieve mastery.

Because of the diversity of background and learning style, and because of collaborative learning between these students of differing background, the experiential base associated with the subject is broadened. Individual students "construct" their own meaning from the material of study and broaden the context of their own learning by observing the related meanings constructed by others within the classroom. With learning objectives individualized for different programs, there is no compromise required to bring the different programs together. With the studio format, diversity in the classroom becomes an asset rather than a liability. Because of the mastery criteria and the nature of personalized instruction, there is no sense of competition for grades, either within or between the individual majors. What's more, the demand on faculty resources, to produce duplicate course offerings for different programs is eliminated and faculty time is freed to concentrate on enhancing the quality of the learning experience.

Learning Objectives Required of Both CM and EN Students

One of the benefits of PSI, in terms of the quality of instruction, is that it requires a significant commitment to the organization of course content. Since PSI requires the testing of each learning objective, meaningful behavioral objectives need to be formalized (an important instructional step, which is far too often ignored). While these behavioral learning objectives are sometimes shared with the students, helping them to appreciate the relevance of pending evaluations, their key benefit is in giving the instructor a very specific idea of what the students will be expected to do (and therefore what specific content should be emphasized). While there can be aids in writing learning objectives for courses (including the development of college-wide committees) ultimately the responsibility for the learning objectives falls on the instructor. Learning objectives might reasonably be expected to vary from instructor to instructor for the same course, and many of us view this as an issue of academic freedom. However, most of us would also develop different learning objectives for the same course if we were tailoring the course toward different majors. In the paragraphs that follow, I will describe the learning objectives that are used in the Strength of Materials courses that I teach independently to both EN and CM students. These are not presented as absolutes, but just one teacher's opinion.

A Strength of Materials course exclusively for CM students (EN 306) was first offered at Boise State University in the fall of 1996. The course was not a prerequisite for any further CM offerings, although some of the topics developed (particularly Axial Stress, Mohr's Circle and Stress Transformations) would be used in a subsequent (or simultaneously undertaken) required class in soil mechanics (which I also teach). Behavioral learning objectives were identified in seven broad areas (modules): Axial Stress, Axial Strain, Torsional Stress, Beam Stress, Stress Transformation, Beam Design and Column Design.

In these seven modules, twenty-four learning objectives were identified as a core requirement, for which mastery would have to be demonstrated to receive a passing (C) letter grade. Twelve additional learning objectives were identified as being of significant benefit to CM students, but of lessor importance. If mastery was demonstrated for six of these (in addition to the core of twenty-four) learning objectives, then the student would receive a B letter grade. If mastery was demonstrated in all thirty-six identified learning objectives, then the student would receive an A letter grade. Students were allowed to take mastery exams on individual learning objectives only after orally reviewing the assigned homework problems (4 to 8 problems per learning objective) with the instructor or with designated class members (advanced peers). In keeping with PSI methods, students were allowed to retake a different version of failed mastery exams (there were a total of five mastery exams per learning objective) after completing and orally reviewing additional homework problems. However, because of the extent of feedback on the orally reviewed problem assignments, failure on the learning objective exams was rare.

All of these thirty-six learning objectives were incorporated into the Strength of Materials course for EN students (EN 350) offered the following semester (two EN 306 learning objectives were combined). Several additional behavioral learning objectives were identified and added to those used the previous semester. In addition, several introductory topics were identified as important qualitative objectives for EN students, but were not written as behavioral learning objectives. These were instituted as expressive learning objectives and dealt with in the reading assignments and in mini-lectures and demonstrations, but were not tested at the individual learning objective level. To accommodate these additional learning objectives (the second course had fifty in all), the seventh module (Design of Columns) became an optional, extra credit module. Table I outlines the differences in the learning objectives developed for mastery in the two courses. The letter R designates required learning objectives. Optional learning objectives are indicated with the letter O, and the letter E marks expressive learning objectives. The language of these topic headings, while not formal behavioral objectives, is meant to convey the flavor of the objectives. The actual objectives were used for purposes of instructional organization, and only these heading were distributed to the students.

Issues in the Depth of Learning

In addition to differing sets of learning objectives, there are also differences between the needs of CM and EN Strength of Materials students in terms of depth of learning. This is not really an issue of degree of mastery or near-mastery, which although occasionally addressed in the literature is more relevant to ML than PSI methods. Rather, what is meant here is the depth of context and the extent of integration within the sets of learning objectives (the constructivist paradigm). While the demonstration of mastery on individual learning objectives seemed adequate for the CM students, I felt that EN students (because of the extent to which the content forms a core for their future academic work) needed additional integration of learning objectives. As a consequence I incorporated module exams for each of the seven modules (required and optional) and concluded the course with a comprehensive final. The combined score on all of these integrating exams was then used to determine the student's final grade.

In general, student performance on the module exams and the final was extremely good (perfect exams were frequent and the few errors that occurred were usually very minor). These exam scores, typically 20% higher than scores on similar tests in more traditional Strength of Material courses, may derive from the large amount of time devoted to testing, which did a lot to reduce test anxiety and familiarize the student with successful cognitive strategies. Alternately, the immediate nature of feedback on homework and learning objective exams may have provided enhanced reinforcement, or may simply have convinced students that they were not going to be able to slide through on the grading curve (the mastery criteria precludes reliance on "partial credit"). Perhaps the collaborative learning with peers may have provided a superior experiential context, or perhaps the high exam scores show that the integrating exams are just doing their job.

Conclusions

This past fall semester (1997) I used a similar PSI format, with integrating module exams and a final, in a Structural Analysis course. I have now been able to follow many of the EN students from the spring Strength of Materials course through the fall Structural Analysis class (one CM student from the previous fall CM Strengths course also enrolled in the class, as a technical elective), and have seen a remarkable development in confidence and problem solving ability. Also, over the period of two semesters, I've seen these students grow in their willingness to engage in collaborative learning. In my first "traditional" Strength of Materials course, the great diversity in the classroom was wasted, because the students were required to work independently. Having used collaborative learning for a year, these Structural Analysis students have now become committed to the process. Having seen the benefit of collaborative learning, I too am committed to the process and require evidence of consultation (a learning log submitted at the end of the semester) between PSI students.

While the time commitment on my part is significant (2 to 3 times that required in a traditional lecture course), the obvious development of my students has been a rewarding compensation. As collaborative learning increases, demand on faculty time for student consultation decreases. Also, the demand on faculty time is decreased by re-using mastery exams and other course materials. However, I find the growth of my students such a rewarding experience that any extra time seems quickly absorbed in other PSI projects (additional course materials and mastery exams, expanding PSI to other course offerings, and writing about my experiences in qualitative papers such as this).

Having developed independent PSI courses in Strength of Materials for both CM and EN students, I am now ready to recombine these students in a single classroom. Since our College of Engineering is applying for initial EAC-ABET accreditation in the fall of 1998, there is a reluctance with some of the other EN departments to have students from the two courses in the same classroom. But I have presented this (and will continue to present it) as a viable option to reduce the number of courses that EN faculty are required to teach. While we are a young College of Engineering, and our course sizes remain small, eventually this option will become attractive to the College administration. In the mean time, I will continue to teach these two Strength of Materials classes (and others) with PSI methods, individually tailored learning objectives and testing criteria, but in *separate* classrooms.

Bibliographic Information

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Biographical Information

DAVID HAWS received undergraduate degrees in English (University of California at Berkeley) and Civil Engineering (University of Utah), and completed master's and doctorate in Civil Engineering at Brigham Young University. He has completed post-doctorate course work in adult education, and instructional and performance technology, and is an Assistant Professor of Civil Engineering at Boise State University

	EN 306	EN 350
AXIAL STRESS		
Calculate Axial Stress	R	R
Calculate Bearing Stress	R	R
Calculate Direct Shear	R	R
Solve Simple Axial Structures	R	R
Calculate Factor of Safety	R	R
Calculate Stress on Oblique Planes		R
AXIAL STRAIN		
Calculate Axial Strain	R	R
Analyze Stress-Strain Plots	R	R
Calculate Axial Deflection	R	R
Calculate Stress Concentrations	R	R
Solve Statically Indeterminate Axial Structures	O	R
Solve Temperature Change Problems	O	R
Solve Axial Structures with Poisson’s Ratio	O	R
Calculate Shear Strain	O	R
Appreciate Superposition		E
Appreciate Residual Stress		E
Appreciate Saint Venant’s Principle		E
Appreciate Elastic/Plastic Behavior		E
TORSIONAL STRESSES		
Calculate Torsional Stress	R	R
Calculate Angle of Twist	R	R
Solve Statically Indeterminate Shafts	O	R
Calculate Power Transmission	O	R
Calculate Stress Concentrations	O	R
Solve Thin-walled Shafts	O	R
Appreciate Non-Circular Torsion		E
BEAM STRESSES		
Plot Shear and Moment Diagrams	R	R
Calculate Bending Stresses	R	R
Solve for Eccentric Axial Loads	R	R
Calculate Shear Stresses	R	R
Calculate Stresses for Combined Load	R	R
Solve Composite Beams	O	R
Resolve Unsymmetric Bending		R
Analyze Shear Flow and Shear Center		R
Appreciate Beam Curvature		E
Appreciate Plastic Deformation in Beams		E
STRESS TRANSFORMATION		
Find Stress on a Plane	R	R
Solve for Principal Stresses	R	R
Transform Stress with Mohr’s Circle	R	R
Solve Pressure Vessels	O	R
Appreciate 3 Dimensional Stress		E
Appreciate Failure Criteria		E
BEAM DESIGN		
Select Beam Parameters	R	R
Calculate Deflection by Moment Area	R	R
Calculate Deflection by Integration	O	R
Solve Statically Indeterminate Beams	O	R
Appreciate Load/Shear/Mom. Relations		E
Appreciate Principal Stresses on Beams		E
Appreciate Method of Superposition		E
COLUMN DESIGN		
Calculate Euler Buckling Load	R	O
Design for Concentric Load	R	O
Design for Eccentric Loads	R	O

TABLE I: SHARED LEARNING OBJECTIVES IN EN AND CM STRENGTH OF MATERIALS

1. Engineering materials and their properties 1.1 Introduction 1.2 Examples of materials selection. A. Price and availability.Â No engineer attempts to learn or remember tables or lists of data for material properties. But you should try to remember the broad orders of magnitude of these quantities. All foodstores know that â€˜â€˜a kg of apples is about 10 applesâ€™â€™ â€” they still weigh them, but their knowledge prevents them making silly mistakes which might cost them money.Â To the lecturer This book is a course in Engineering Materials for engineering students with no previous back-ground in the subject. It is designed to link up with the teaching of Design, Mechanics, and Structures, and to meet the needs of engineering students for a rst materials course, emphasizing design applications. International Technology and Engineering Educators Association - Technology. Buildings generally contain a variety of subsystems. (Grades 6 - 8) More Details.Â (Ask students to share their experiences in which they used available materials to create a bridge between two places.) Have you ever looked at a bridge and wondered what it was made of and where the materials came from?Â Sometimes, engineers must design bridges with as few materials as possible. One example of a bridge system with minimal use of materials that provides important links between people, communities and resources is the wire bridge technology used in rural Nepal â€" called eco bridges. Strength of materials, also called mechanics of materials, deals with the behavior of solid objects subject to stresses and strains. The theory began with the consideration of the behavior of one and two dimensional members of structures, whose states of stress can be approximated as two dimensional, and was then generalized to three dimensions to develop a more complete theory of the elastic and plastic behavior of materials. An important founding pioneer in mechanics of materials was Stephen Timoshenko. This textbook is intended for students of materials science, of different branches of engineer-ing and of related disciplines who need to re-activate their English language skills. Using au-thentic materials and figures selected from scientific texts, students will improve their reading, writing and speaking skills in a context relevant to their specialist studies.Â Professor Seshadri in particular introduced me to the field of materials science and directed me to my most valuable source, Materials Science and Engineering: An Introduction, by William D. Callister Jr.Â The discipline of materials science and engineering includes two main tasks. Materials scientists examine the structure-properties relationships of materials and develop or synthesize new materials.