AC 2007-2017: AN INTEGRATED APPROACH FOR ENGINEERING MECHANICS AND DESIGN

James Klosky, U.S. Military Academy

Decker Hains, U.S. Military Academy

Timothy Johnson, Department of Civil and Mechanical Engineering, USMA

Jakob Bruhl, US Military Academy, Dept of Civil & Mechanical Engineering

Jared B. Erickson, U.S. Military Academy

John Richards, D/CME, USMA

An Integrated Approach for Engineering Mechanics and Design

Abstract

As part of a major curriculum update undertaken over the last three years, the United States Military Academy at West Point has implemented a new course sequence in statics, mechanics and material science. This sequence involves teaching an introductory engineering course, CE300, to both engineering majors *and* non-majors, followed by CE364, a mechanics + material science course that is taken by those students majoring in Civil or Mechanical Engineering. The sequence integrates statics, mechanics of materials and a lesson block on material science; information that is traditionally separated across two or more courses, making it difficult for students to form the key connections between statics, mechanics and materials that are the bread-and-butter of the working engineer. Through tight coordination of these two courses, significant advances have been made in student attitudes, capabilities and, perhaps most importantly, engineering perspective.

This sequence, CE300 + CE364, was created in response to curriculum changes arising from the Department of Civil & Mechanical Engineering's slow-loop assessment process and a desire on the part of the Academy to implement a complete revision of the undergraduate engineering experience for non-engineering majors. CE300 – Fundamentals of Engineering Mechanics and Design became the first course in engineering for both majors and non-majors. This large change in the earliest part of the student's engineering experience suggested two questions - could this course truly serve both engineering and non-engineering students and could the tight coordination of the two-semester pair of courses be effectively implemented? This paper explores these questions, the answer to which we believe is a resounding "yes!" CE300 is now the first course of a two-course sequence in basic statics and solid mechanics and builds the foundation in mechanics and design for all civil and mechanical engineering majors.

The key finding of this effort, expanded on in this paper, is that by combining statics with introductory mechanics of materials, CE300 now includes exciting elements of design that are not generally taught in a traditional statics course. For instance, where students were previously constrained to answer only what forces acted on the members of a truss, they can now attach something more physical to that computation and get the feeling of accomplishment that comes with actually designing something by choosing an appropriate a material type and size for the truss member based on stress and/or deformation requirements. The second course in the sequence was originally CE364 – Mechanics of Materials and although it maintained its original name, the content now includes a more in-depth coverage of mechanics of materials and an introduction to material science, content that had previously been simply missing from the civil engineering curriculum. The result is a well-blended sequence of courses that provides an exciting introduction to engineering and gives engineering students the opportunity to begin the exciting process of design within the first five weeks rather than waiting for follow-on courses. This paper discusses the approaches and content of both courses as well as the linkage between the two. Assessment data related to student achievement and perceptions is also analyzed, and suggestions for further improvement of the sequence are included.

CE300 – Fundamentals of Engineering Mechanics and Design- The First Course in the Sequence

CE300 was originally developed in 2002 as part of a dramatic revision of the undergraduate engineering experience for non-engineering majors. In its original form, this course provided an introduction to engineering fundamentals which students would build through two additional courses in a civil or mechanical engineering sequence. The course developers used "careful material selection, . . . , a balance of theory and practical application, enthusiastic instruction, and continuous student feedback" to design and subsequently teach fundamentals of engineering mechanics and design to non-engineering students[1].

After successful implementation teaching non-engineers, it became apparent that the integration of statics and mechanics of materials into a single course could have tremendous benefits for students majoring in engineering disciplines. With this in mind, the traditional first-course for civil and mechanical engineering majors, CE302 – Statics and Dynamics, was replaced with CE300 and a separate dynamics course developed, enabling students to gain a deeper and more rigorous understanding of dynamics. Our students now begin their engineering education with an integrated two-course sequence: CE300 followed the next semester by CE364. Because these two courses share the teaching of topics in mechanics, tight coordination of content and careful decisions regarding the placement of that content, e.g. what to teach and when, had to be made.

In order to make this change effective, the content of CE300 was reexamined in conjunction with CE364, now somewhat mistitled Mechanics of Materials. Topics were selected and moved into the most appropriate course with the basic premise that the fundamentals be developed in CE300 and depth gained in CE364. One of the primary intents of CE300 is to introduce students to the exciting world of design as early as possible in their engineering education. Additionally, creating a course rigorous enough to challenge engineering students and build a solid foundation upon which to base the remaining two years of engineering education while keeping it applicable and exciting enough to maintain the interest and enthusiasm of non-engineering students was a significant issue that had to be addressed.

CE300 Structure and Content

The primary goal of CE300 is to provide students with a foundation in the theory and principles of statics and mechanics of materials. This is achieved through an emphasis on the Engineering Design Process, shown in Figure 1, throughout the course.

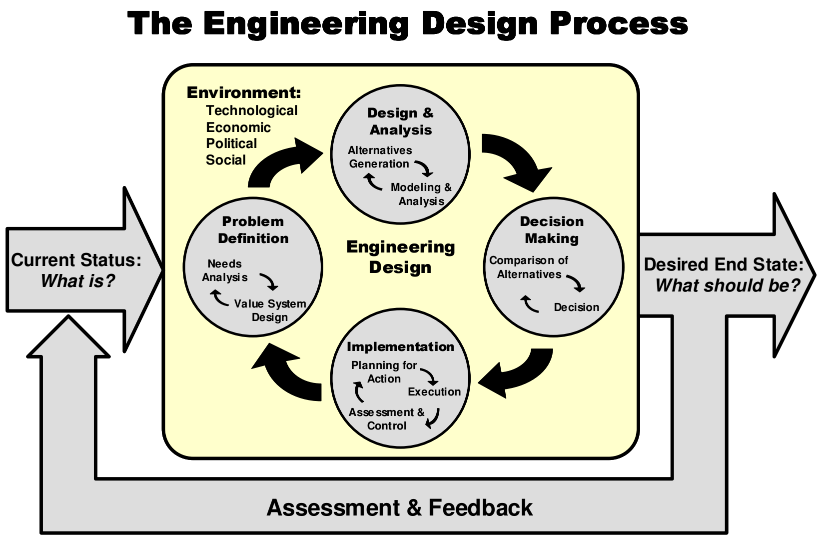

Figure 1. The Engineering Design Process utilized in CE300

At this fundamental level of education a great deal of emphasis is placed on the problem solving process, and much of the material is presented through focused example problems worked on the board by the instructor, who models the structured problem solving process expected of the student. The course maintains focus through a series of course objectives. The course objectives for this course, detailed in Table 1, are more numerous and specific than might be expected in a typical course. This is driven by the broad nature of the course, the need for tight and specific coordination with CE364, and the need for detailed assessment of each student's ability to meet each objective.

Table 1. Course Objectives

CE300 Course Objectives
Understand and use the Engineering Design Process; solve engineering problems utilizing a methodical problem solving approach.
Apply equations of equilibrium to calculate external support reactions for determinate 2D and 3D rigid bodies.
Analyze and design trusses.
Calculate internal pin reactions in frames and machines.
Analyze and design axial members based upon normal stress, shear stress and deformation criteria.
Develop and explain a material's stress-strain curve and associated material properties.
Analyze and design beams in bending based upon normal stress, shear stress, and deflection criteria.
Analyze problems of impending motion by conducting slip or tip analysis.
Analyze and design solid and hollow shafts subjected to torsional loading.
Apply Euler's buckling equation to analyze and design a column given an axial load, support conditions, and bracing configuration.
Recognize axial, bending, and torsional loading; draw the corresponding stress distribution, and determine where the stress is a maximum.
Calculate the effect of loads on a member using the concepts of tributary area and load path analysis.

We use graded performance on problem sets and exams in conjunction with web-based feedback as a gage of student attitudes about their ability to meet each course objective. Historically, this data mirrors closely their graded performance. It should be noted, however, that this data is only good in the aggregate; that is that each individual may do only a fair job in predicting his or her own abilities within a given topic, but the group predicts the performance of the group well. Two objectives, addressing friction and stress distributions for various loading conditions, were added after the first two semesters and an objective on load path analysis was added to the course in the first semester of the 2005-2006 academic year. Over the life of the course, several objectives were deleted and several others were combined into more succinct objectives. The course objectives are reviewed annually by the department leadership and updated as appropriate.

As the first engineering course our students take, a critically important aspect of this course is the intellectual excitement brought to the classroom by our instructors. This excitement and enthusiasm for engineering is facilitated through a course structure that shows applications of fundamental engineering concepts shortly after they are introduced, and makes heavy use of classroom demonstrations[2]. This is accomplished by interweaving statics, mechanics of materials, and design topics using a "just-in-time" approach. For example, after learning the basics of two-dimensional equations of equilibrium, students are introduced to truss analysis. After learning the method of joints and method of sections, they are then introduced to normal and shear stresses in axial members. After quickly moving into discussions about factor of safety and stress and strain relationships, students are able to analyze stresses and deformations in axial members and thus have all of the basic tools needed to properly design an axially loaded member. This is accomplished within the first 14 lessons of the course. So, within five weeks into their first engineering course, our students are designing basic structural elements.

Using the "just-in-time" approach described, CE300 is organized into three distinct blocks of instruction: axial loading and material properties; transverse loading and beam design; and special topics (friction problems and introductions to both column buckling and torsion). Table 2 includes the primary topics contained in each block. Each block begins with the statics content necessary to analyze the force system in question, then covers applicable mechanics of materials information, and ends by tying them together with design problems. The 40-lesson course is broken down as follows: 14 lessons focusing on statics, 16 lessons on mechanics of materials, 8 devoted to design, and 2 for mid-term examinations. However, this breakdown is only a rough index to assist the reader in judging the relative content of this course versus traditional courses. A real effort is made throughout to ignore the traditional boundaries between statics and mechanics with the aim of linking the broad ideas of force systems, stresses and design.

Table 2. CE300 Course Structure

CE300 Structure and Content					
			Number of Lessons Devoted to:		
		Topics	Statics	Mechanics of Materials	Design
The Engineering Design Process	Axial Loaded Members	Design and the Design Process Statics Fundamentals: Forces, Moments, 2D Equilibrium Truss Analysis Axial Loading: Normal and Shear Stress, Strain, Deformation Material Properties (σ - ε curve) Design of Structural Members: Trusses, Cables and Pulleys	6	6	5
	Beams	Centroids Distributed Loads Frame Analysis Shear and Moment Diagrams Elastic Bending Transverse Shear Stress Deflections Beam Design	5	6	2
	Special Topics	Column Buckling (application of Euler's Buckling Equation) 3D Equilibrium Torsion (circular cross-sections) Friction (slip and tip analysis)	3	4	1

Nearly all lessons include some sort of physical model or demonstration. Many of these demonstrations are or will be available at www.HandsOnMechanics.com[3]. A few of these are elaborate, requiring significant preparation time in the classroom – such as a free body demonstrator complete with the use of torches and chainsaws to emphasize the importance of "isolating" the body of interest or the full-scale construction and load testing of a 4' x 8' platform from dimensioned lumber after the students design it. Others are very simple and require little to no preparation time – for example, the use of a 10-pound weight held out by a student to show that the moment arm of a force is the perpendicular distance between the force's line of action and the point of rotation or foam beams to demonstrate plane sections remaining plane in elastic bending.

Assessing CE300

This course has been through several iterations now and assessment has been critical to developing it into its current state. Indicators of student performance (primarily grades) throughout the semesters have forced instructors to examine the amount of time devoted to particular topics. This has resulted in a few things being removed from the course after it was decided that there simply was not enough time to adequately cover the topic as well as adding more time to existing topics in order to provide a more thorough coverage. For instance, the course originally contained thermal deformations but not pulleys or transverse shear of pins. Thermal deformation was moved to CE364 and both pulleys systems and simple shear on pins were introduced in CE300. Without very tight coordination between CE300 and CE364, such fine-grained but important changes would simply not be possible. A truly collaborative approach is taken, and the two courses are literally coordinated and deconflicted on a lesson-by-lesson basis.

One of the most valuable sources of assessment data comes in the form of web-based feedback provided by the students at the end of the semester. This anonymous feedback consists of a number of questions for which the student provides an answer on a scale as well as a few questions for the students to provide written comments concerning the course. Other assessment data is acquired through the course of the semester (such as minute papers or muddiest point papers) to gage student attitudes and perceptions during the course, but these are more useful for individual instructors while the course-wide numerically-based feedback is extremely useful for the improvement of the course.

Since its inception, CE300 has been one of the most highly rated courses in both the department and the Academy in terms of intellectual excitement and interpersonal rapport. Figures 2 and 3 show the average feedback for the course over its six semester life and demonstrate that CE300 is consistently rated above average. As one of our department's largest enrollment courses, CE300 typically has between three and seven instructors per semester. The data included in the figures is the average for all instructors. A rating of 5 means that the students "Completely Agree" while a 1 means they "Completely Disagree".

Student feedback clearly indicates that they appreciate the effort put into the organization of the course, the enthusiasm of the instructors, and the extensive use of physical models and demonstrations. Figure 4 depicts the attitudes of the students about the various learning and teaching methods utilized in CE300. Because of the feedback the instructors continue to use in-class problems to demonstrate engineering principles nearly every lesson. In response to numerous student feedback indicating a desire for more in-class group work, this semester the instructors are incorporating additional in-class group problem solving opportunities.

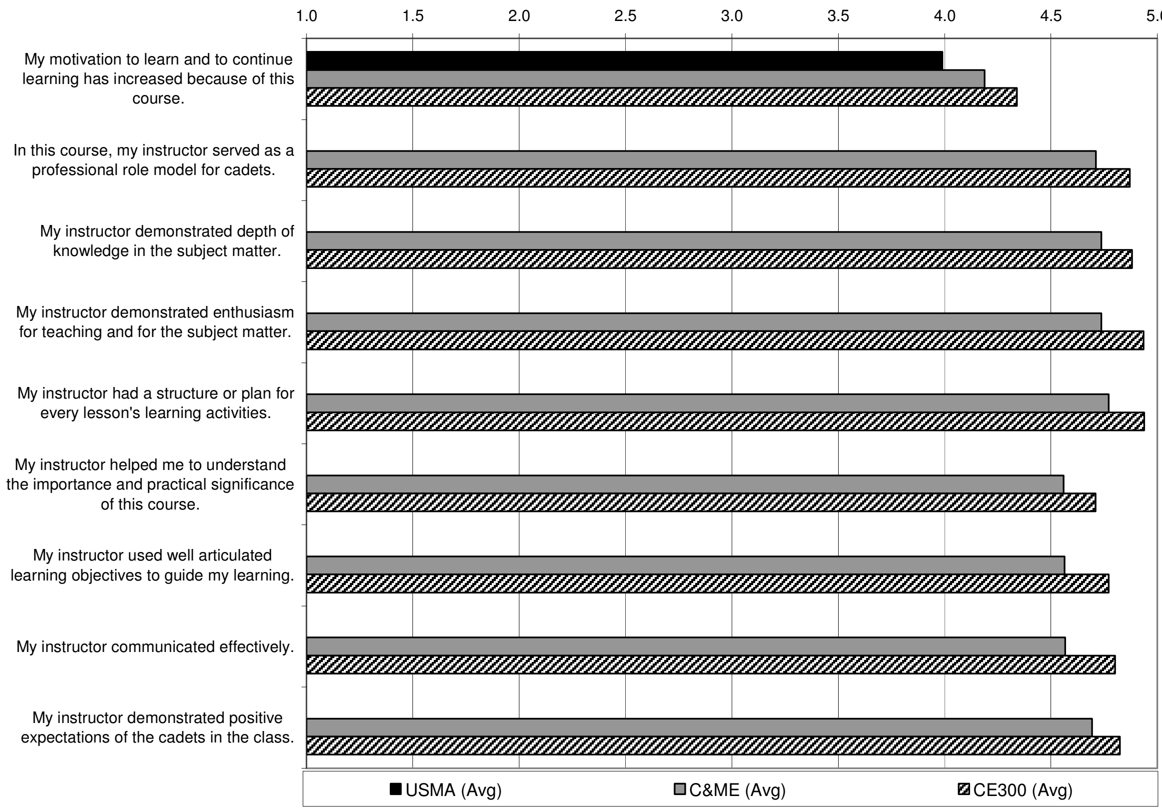

Figure 2. Assessment results for intellectual excitement.

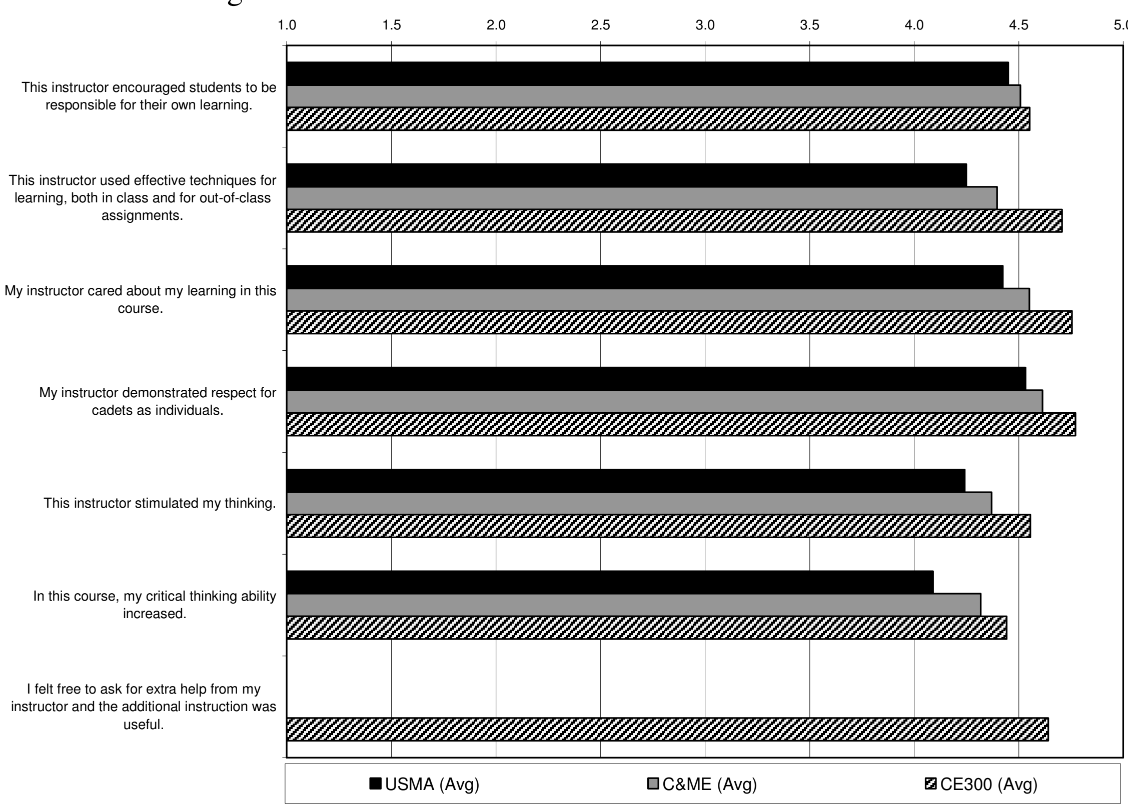

Figure 3. Assessment results for interpersonal rapport

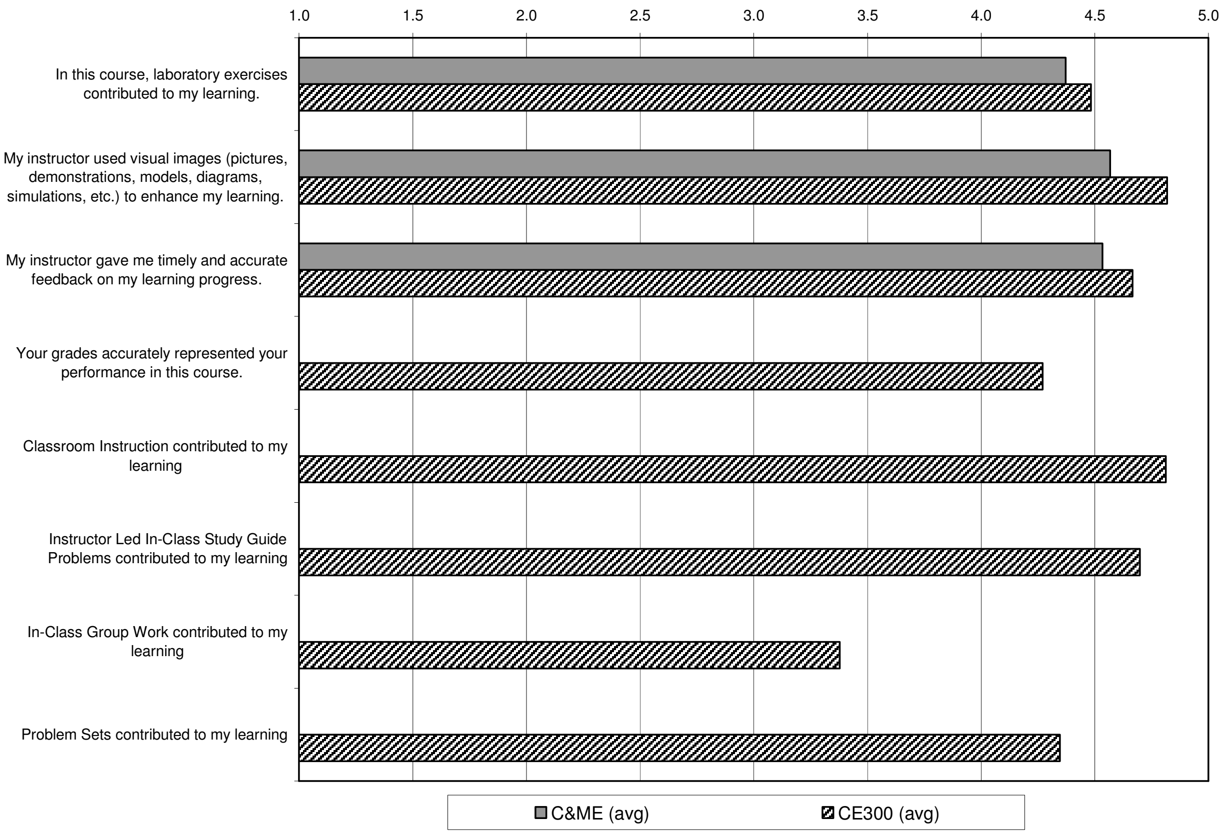

Figure 4. Assessment results for learning and teaching methods

In addition to numerical assessment data, written feedback is enlightening. In the aggregate, most written comments are favorable with the majority of negative comments mirroring closely the numerical data submitted. Majors and non-majors alike respond very positively to CE300 as these quotes from the end-of-course anonymous survey suggest:

> ”I loved the enthusiasm. If the instructor cares, then the cadets will care too . . . my instructor legitimately seemed like he wanted us to succeed.”

> “I liked how class was centered around the study guide problems. Through class, I was able to understand the [material] which helped me with the problem sets.”

> “The in-class [demonstrations] were very helpful to me. I could picture the different forces when viewing these real life examples.”

> “The instructors were always willing to help and ensured that everyone had the ability to ask for help when necessary. The devotion by the department as a whole to the student body surpasses that of any other department.”

Setting CE364 up for Success

CE300 is a foundational course for both the civil and mechanical engineering sequence students (non-majors) and engineering majors. CE300 is uniquely and deliberately linked to CE364 – Mechanics of Materials, which follows in the next semester for engineering majors. To assist in linking the two courses, both have adopted the same textbook, Statics and Mechanics of Materials – 2nd Ed.[4] which integrates statics and mechanics of materials. In this way, the terminology and notation remains consistent between the courses eliminating unnecessary confusion by the students.

The course content has also been integrated to prevent "re-teaching" the same lessons in CE364. Instead, CE364 can, in many instances, pick up where CE300 left off and begin to build a deeper understanding of the material. An example is the elementary development of torsion in CE300. In CE300, students are provided with the equation for shear stress in a circular cross-section subjected to elastic torsion with a brief explanation and then use it in a number of simple design examples. In CE364, instructors build on this understanding with a more rigorous development of torsional theory by quickly reviewing how the equation is used for simple cases and deriving the equation to help students gain a better understanding of the assumptions and limitations inherent in the underlying theory. Other examples include load, shear, and moment relationships and the elastic flexural stress equations. These relationships and equations are introduced in CE300 and then used in simple applications. CE364 then focuses on underlying theory and more complex applications, like combined loading; something that was impossible before the deliberate linking of the two courses. Furthermore, the students come into the theory-heavy portions of CE364 having a basic understanding of the stress and design implications of the applicable equations, making it much easier to tease key points out of the derivation process.

In addition to the integration of the course content, the emphasis on fundamentals assists CE364 and all other subsequent courses. Professional standards for submitted work are communicated to students and enforced in CE300. This includes topics such as the format for problem set solutions, expectations related to quality of work and supporting diagrams, and standards for the format of documenting assistance received on an assignment. CE300 instructors emphasize the importance of reporting complete answers, maintaining consistent units, doing work neatly, as well as developing the beginning of engineering judgment – teaching students to always do a "sanity check" of their answers ("Does this answer make sense?"). All of these things help students as they begin their second engineering course and it helps the instructors to reinforce standards previously set in CE300.

CE364 – Mechanics of Materials- The Second Course in the Sequence

With the integration of CE300 into the engineering curriculum, it was clear that changes needed to be made in CE364, the traditional Mechanics (Strengths) of Materials course. The impact of students being exposed to mechanics and strength of materials topics in their first engineering class was that those topics, in order to prevent redundancy, needed to be eliminated or significantly reduced in the follow-on course, CE364. This actually turned out to have a positive impact on the early curriculum of engineering majors at the Academy since the elimination of those topics allowed CE364 to expand its breadth and gave students a one-semester jump on design; an important advantage in an ABET sequence that lasts only five semesters.

With flexibility to expand the breadth of CE364, we decided that including a significant block on material science would be the optimal choice. This decision was based in part on the fact that civil engineering undergraduate majors had no exposure to material science. Secondly, the mechanical engineering majors benefited from an introduction to material science, which they see in much more depth in a required full semester course in material science, ME380. The impacts on ME380 are also positive, allowing that class to delve deeper into topics in which students already have a foundation. Perhaps more important, the combination of forces, stresses, deformations and material science integrated with design methodology over two semesters allows our students to take a truly holistic view of component design very early in their engineering studies. The benefits of this are clearly enormous, giving even the best students a strong sense of accomplishment and a keen awareness of the key elements of good engineering. The sequence clearly answers the key student concern of "Why should I care about this?"

The CE300+CE364 sequence marked a drastic change in our engineering curriculum in general, pushing key design knowledge forward by a full semester. More specifically, CE364 has become an effective bridge to advanced topics in civil engineering and to the in-depth material science course taught to our mechanical engineering majors as shown in Figure 5.

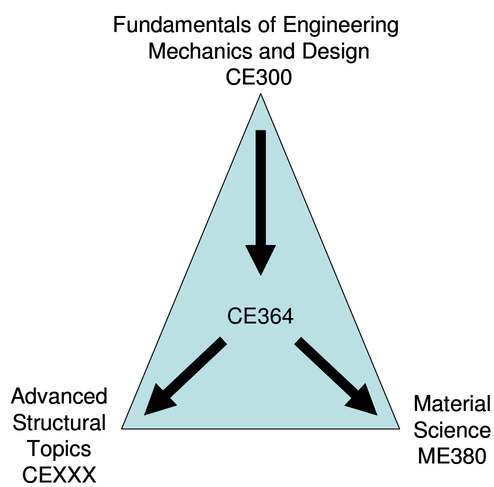

Figure 5. Integration of CE364 within the Curriculum

This change, implemented in the 2005 fall semester, resulted in CE364 becoming an integrated course of both mechanics of materials and material science, with the material science topics encompassing roughly one-third of the course. The performance of materials was integrated right into the design process.

CE364 Structure and Content

CE364 begins with a review of the fundamentals of stress, strain and design and builds on these basic concepts. A complete listing of the course objectives is listed in Table 3. Because the students are familiar with the basics of mechanics of materials, they are introduced almost immediately to the design of structural members and components. By the second lesson in a 40-lesson course students are designing structural members. The course is structured so that the typical loading conditions discussed in an undergraduate level mechanics course are covered. These typical loading cases include axial, torsion, transverse shear, bending, thin-walled pressure vessels, and column buckling. Furthermore, and at least partly because the fundamentals are covered in CE300, more advanced topics such as stress transformation, failure theories and special cases like combined loading effects, stress concentration, crack propagation and fatigue are also included in CE364.

Table 3. CE364 Course Objectives

CE364 Course Objectives
Calculate the internal forces, internal stresses, and deformations of centrically axially loaded members, circular members in torsion, thin-walled pressure vessels, prismatic beams in bending, columns, and members subjected to combined loading due to axial, torsional, internal pressure, or bending forces; and/or thermal effects.
Apply compatibility of deformations to analyze and design members of a statically indeterminate structure subjected to axial, torsional, bending, or combined loading and/or thermal effects.
Apply appropriate theories of failure to analyze and design thin-walled pressure vessels and members subjected to axial, torsional, bending, or combined loading and/or thermal effects.
Given strain data from a strain rosette, determine the state of strain and the state of stress.
Given a state of stress at a point, determine the principle stresses, the maximum in-plane shear stress, the angle to the principal plane, and the state of stress on any plane through the point.
Apply deformation—strain, strain—stress, and stress—force relationships to analyze and design structural members and machine components.
Describe the composition and general microstructure, properties, failure mechanisms, and application of ferrous alloys.
Apply materials science concepts and knowledge of material properties to the proper selection of materials for structural and machine components.
Analyze and design axially loaded members containing holes and/or fillets (stress concentrations), and members subjected to cracking, fatigue, corrosion and creep.
Conduct laboratory experiments to verify and apply methods, theories and scientific laws learned throughout the course, and prepare proper technical reports to clearly communicate the conduct and results of those experiments.

Because students enter the course with some basic fundamental mechanics of materials knowledge, CE364 course builds on these fundamental concepts quickly and proceeds in more depth. With more in-depth coverage, the student is better able to understand the various loading conditions as inter-related topics. Previously, combined loading was a separate lesson block at the end of the course. With the close coordination and link from CE300, combined loading is introduced early and integrated throughout the course. As each loading condition is explored, the students not only have a reference to what they have been taught in CE300, but are able to apply these engineering basics to real and more complex situations. Each loading condition is explored from the general view of stress and strain where the derivation of the equations and formulas are re-emphasized and then applied to actual conditions through the use of creative and realistic in-class problems. In each specific loading case the students are exposed to both elastic and inelastic theory. The students are also introduced to the analysis of indeterminate structures within each loading case. As each loading condition is presented, the students develop tools to apply what they have learned in combined loading situations.

The most significant change is the inclusion of a material science block. This lesson block exposes the students to material science and impacts on design considerations, on both a microscopic and macroscopic level. The material science portion of the course begins with a quick introduction into the history of materials, specifically ferrous alloys, and followed by lessons on phase diagrams, phase transformations, strengthening mechanisms and heat treatments of various materials. The major focus is on steel. The lesson block also examines the properties and phenomena of engineering materials, exposing students to fracture mechanics, stress concentrations, fatigue, corrosion, and creep and exploring how these mechanisms are applied to design of members and components.

Assessing CE364

The purpose of CE364 is to reinforce basic engineering mechanics, teach mechanics of materials and provide an introduction to material science, all in the context of engineering design. Although the course is very new, having only been taught twice, the course and student feedback has been very positive. Despite the close coordination with CE300, some perceived redundancy in material coverage remains. This overlap will continually be assessed. An examination of student work shows that significant progress has been made in increasing the student's ability to design components in a realistic setting. Standardized feedback from the first two offerings of the course is provided in Figures 6 and 7. The terms "2006-1" and "2007-1" represent the fall 2006 and 2007 semesters, respectively. As in CE300, the data included in the figures is the average for all instructors and rating of 5 means that the students "Completely Agree" while a 1 means they "Completely Disagree". The feedback from students has been relatively consistent and positive.

The feedback on the new material science portion of the class was also positive. This feedback came in the form of written responses from the students and indicated that students enjoyed being introducing to material science. Students also appreciated the continuity and integration with CE300. Student responses include:

"…I had a great instructor who made the course fun and I still learned a lot about materials"

"the actual metal strengthening [mechanism] lab was fascinating, and one of the single most beneficial classes during the course."

"Good continuation of CE300."

"Course was interesting…CE300 part II from my perspective."

"The course was a good continuation of what we learned in CE300."

"Great course. It had a good structure and went from topic to topic very smoothly."

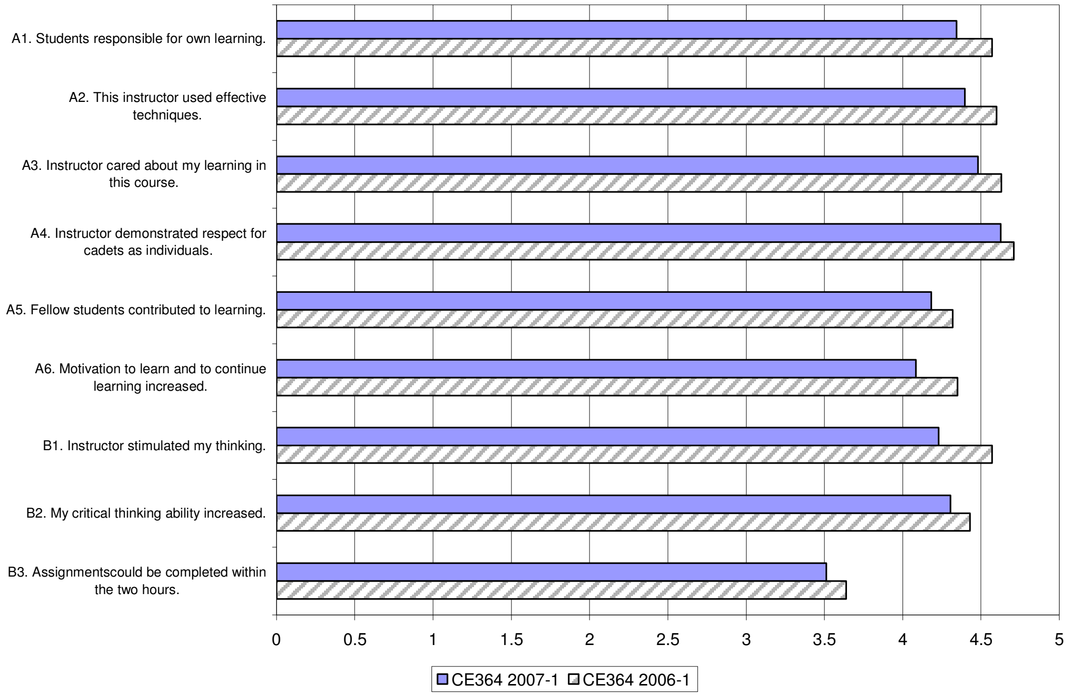

Figure 6. Assessment results for the USMA questions.

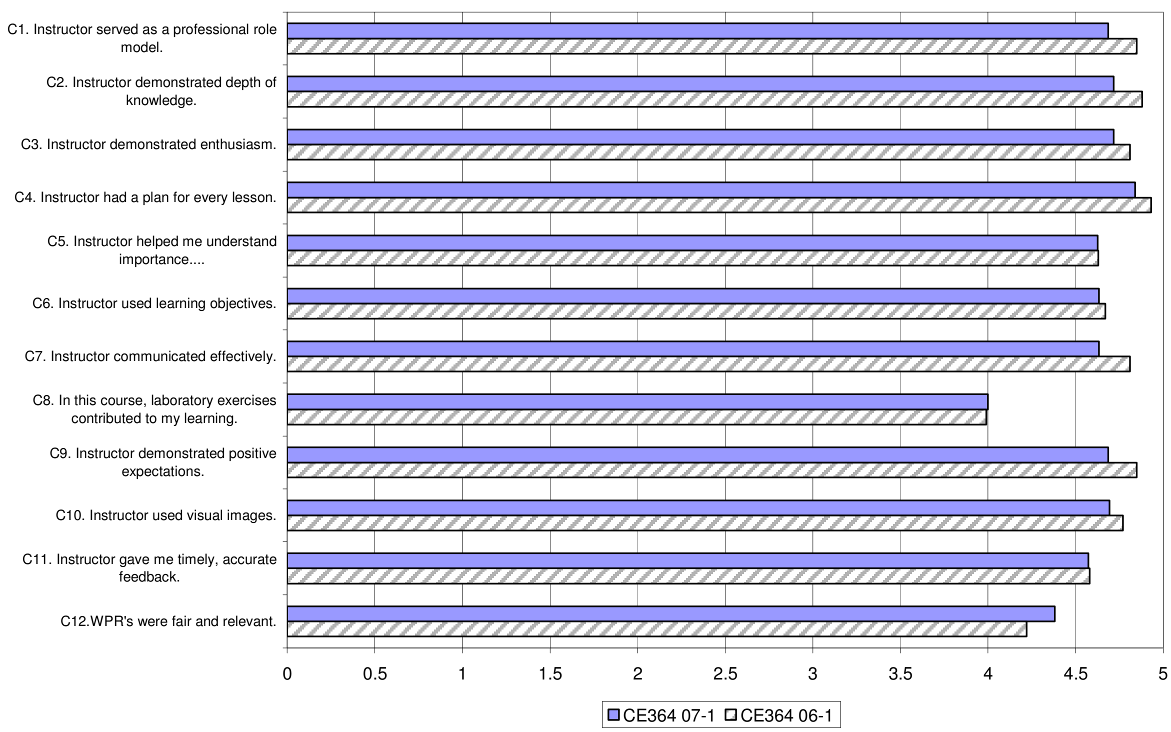

Figure 7. Assessment results for the Department of Civil & Mechanical Engineering questions.

CE300+CE364 Sequence Assessment

Two iterations of Civil and Mechanical Engineering majors (the classes of 2007 and 2008) have now completed the CE300+CE364 sequence. The web-based feedback from these two iterations and a comparison of the feedback to the previous Mechanics of Materials course provides some insight into the effectiveness of this new sequence.

As stated earlier, during the restructuring of this course sequence several concepts were moved from the old CE364 into CE300 to be used as an introduction to design and analysis. CE364 then builds on these concepts and goes into more depth. These common concepts, captured in four course objectives that were specifically assessed each semester, directly carried over from the old CE364, through CE300 into the new CE364. Looking at the Web-based feedback for how well students perceived their ability to accomplish these four course objectives for CE364 before and after restructuring provides some insight into the effectiveness of the new sequence.

At the end of each semester, students are asked via a web-based feedback system how well they think they can accomplish each course objective on a scale of 1, Strongly Disagree to 5, Strongly Agree. Although, this feedback is an indicator of student comfort with the material rather than actual achievement, the averages shown in Table 4 clearly indicate that students felt much more comfortable with the material after having taken the new sequence as compare to the old stand-alone course. The data for the Old CE364 Average covers the last two semesters it was taught (Fall 2004 and Fall 2005); while the data for the New CE364 Average covers the first two semesters it was taught (Fall 2006 and Fall 2007). Students taking the Old CE364 took CE302 (Statics and Dynamics) the previous semester, while students taking the New CE364 had taken CE300 the previous semester. The data show that students perceived their ability to accomplish three of the four course objectives increased slightly in the New CE364, having taken CE300.

Table 4. CE300 and CE364 Common Course Objectives

Course Objectives	Old CE364 AVG	New CE364 AVG	Delta
Analyze/design a centric axially loaded (2 force) member.	4.41	4.50	0.09
Analyze and design circular members in torsion, including calculating shear stresses (τ) and angles of twist (ϕ).	4.17	4.21	0.05
Design a prismatic beam.	3.65	3.57	-0.08
Analyze and design columns	4.15	4.39	0.24

Though this data may not be demonstrably correlated to achievement, the fact that there is a general upward trend in student perception of their ability indicates that this sequence is effective. The fact that students now see design and analysis of structural members and have repetition of key mechanics of materials concepts before moving on to higher level courses must not be ignored. A better method than looking at the feedback from individual courses may be to conduct exit interviews with the graduating students to find out how they think the linkage between the two courses improved their level of understanding of mechanics of materials in their higher level engineering courses, or to compare student achievement directly by giving term end questions identical to those used in the old CE364 at the end of the new CE364.

Course Integration Lessons Learned

The major lesson learned throughout this process was the importance of communication and coordination. The department leaders, to include the course directors for CE300 and CE364 as well as the course directors for follow on courses met several times to discuss what material should be covered in the two courses and in what order, long before the new CE364 was taught. After each semester, we conduct an extensive course assessment to examine the course and recommend better ways of integrating the courses. Specifically, we target areas of redundancy and gaps in the coverage of the topics presented in both CE300 and CE364. This process is very effective since both courses are under the supervisor of one senior faculty member who has taught both courses and has an intimate knowledge of the sequence and the flow of the major concepts between the two courses. These efforts significantly help refine the material taught in each course and make close integration of this sequence possible.

Conclusion

The CE300+CE364 sequence provides our students with both a solid foundation in mechanics and design and an introduction to material science. We gained efficiencies in our curriculum by integrating these courses and our students are better able to draw connections among mechanics, mechanics of materials and material science all within the context of design The well-blended two-course sequence provides students an exciting introduction to engineering and prepares them well for follow-on courses in both civil and mechanical engineering. We will continue to assess this two-course sequence to balance redundancy and depth of coverage.

References

[1]Messervey, T. et.al. 2004 “Showing Non-Engineers the Ropes: An Introductory Engineering Course for Future Army Officers”, *Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition*.

[2]Vander Schaaf, R., and J.L. Klosky. 2005. “Classroom Demonstrations in Introductory Mechanics.” *Journal of Professional Issues in Engineering Education and Practice*, 131(2), 83–89.

[3]Welch and Klosky. 2006. “An Online Database and User Community for Physical Models in the Engineering Classroom.” American Society for Engineering Education, 2006 National Conference, Chicago, IL.

[4]Riley, Sturges and Morris. 2002 Statics and Mechanics of Materials – 2nd Ed. John Wiley and Sons.