Session # 2549

Showing Non-Engineers the Ropes: An Introductory Engineering Course for Future Army Officers

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Introduction

"Army Leaders must be sophisticated users of advanced technologies and comfortable in employing scientific, mathematical, and engineering concepts to solve national security problems." [1]

- Excerpt from the Operational Concept for the Academic Program of the United States Military Academy

The complexity and ever-changing nature of the world in which our future army officers will be leading soldiers' demands that each graduate of the United States Military Academy at West Point be a disciplined problem solver who has internalized the engineering thought process. In fact, *Engineering and Technology* is the first of six domains of knowledge listed under the Academy's Academic Program Goals (Page 6 – Educating Future Army Officers for a Changing World[1]). As such, every future "army leader" at West Point must take an engineering sequence, or "track," as part of their academic program regardless of major or field of study.

The Department of Civil & Mechanical Engineering offers two of the six available engineering sequences at the Academy: civil and mechanical engineering. Historically, these sequences consisted of five, semester-long courses which were also taken by CE and ME majors in the department. However, in 2002, this changed. In response to rapid changes in technology, the Academy conducted a review of its academic program which resulted in the addition of two information technology courses to the core undergraduate curriculum. Consequently, the Department of Civil & Mechanical Engineering surrendered two of the five courses in both engineering sequences and conducted a complete revision of the undergraduate engineering experience for non-engineering majors (Table 1).

Former CE Sequence	Restructured CE Sequence	Restructured ME Sequence	Former ME Sequence
Statics & Dynamics	CE300 Fundamentals of Engineering Mechanics & Design		Statics & Dynamics
Thermodynamics	Design of Wood and Masonry Structures	Mechanical Engineering I: How Army Systems Work	Strengths of Materials
Strengths of Materials			Thermodynamics
Structural Analysis	Infrastructure Development and Construction Management	Mechanical Engineering II: Design of Army Systems	ME Design I
Steel Design			ME Design II

Table 1: Restructuring of engineering sequences for non majors from 5 to 3 courses

As a result, CE300 - Fundamentals of Engineering Mechanics and Design, became the first course in a completely restructured three-course engineering sequence feeding both the Civil and Mechanical tracks taken by non majors. This restructuring brought about the challenge of how to consolidate a proven five-course experience into three courses. West Point's time constrained environment, coupled with students from a variety of non-engineer related majors and fields of study, demanded a course that could convince the student that the material was relevant, practical, and important. Through careful material selection, the refinement of engineering program objectives, a balance of theory and practical application, enthusiastic instruction, and continuous student feedback, CE300 was successfully taught for the first time during the autumn semester, 2003.

CE300 Structure, Content & Presentation

CE300 synthesizes the essential concepts from statics, mechanics of materials, and member design while continually reinforcing the Engineer Design Process (Figure 1).

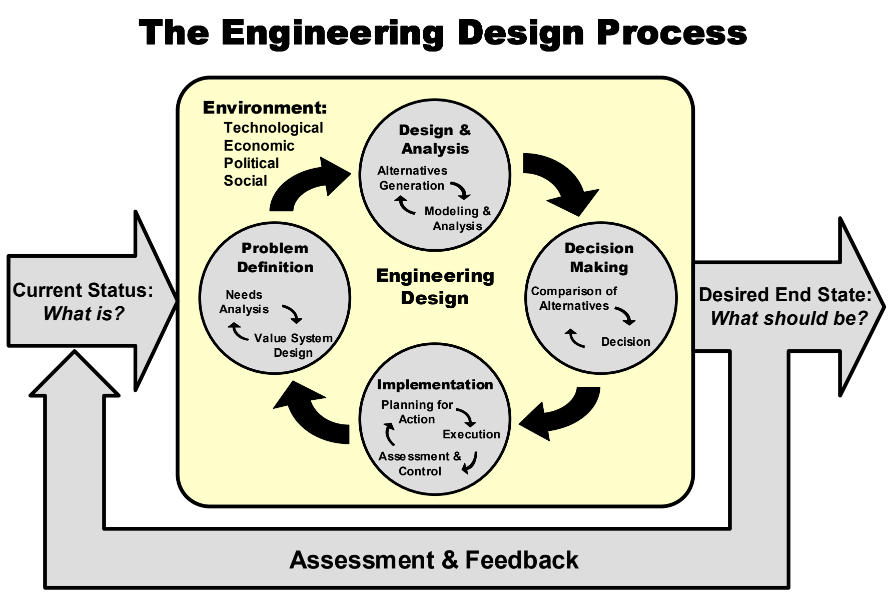

Figure 1: The engineering design template utilized in CE300

The course begins with forces in two dimensions, introduces the concept of static equilibrium, and then develops how external loads and forces are carried by internal forces for axial and flexural loading cases. Resulting stresses, strains, and deflections are examined and utilized for member analysis and design. Throughout the course, emphasis is placed upon structured problem solving while reinforcing the theory and engineering principles that support codes and software utilized in the follow on sequence courses where the cadets will design temporary structures and basecamps. More specifically, topic areas include:

CE 300 Structure & Content			
The Engineering Design Process	Axial Block	Design & the Design Process	1 Lab & 2 Classroom Design Challenges
		Statics: Forces, 2D Equilibrium, Moments and Couples	
		Trusses	
		Axial Loading: Stress, Strain, Deformations and Compatibility	
		The σ–ε Curve	
		Material Properties	
	Bending & Special Topics	Frames	1 Lab & 1 Presentation on Selected Material
		Shear & Moment Diagrams	
		Flexural Stress & Shear Stress	
		Deflections	
		Beam Design based upon stress and deflection	
		Torsion	
		Buckling	

Table 2: CE300 lesson content

For completeness, course content was driven by the following course goals and objectives.

CE300 Course Goals and Objectives
Apply the Engineering Design Process to solve problems
Apply equilibrium equations to calculate external reactions for determinant 2D rigid bodies
ID two-force or multi-force members in structures
For Axial Loading - Determine internal member forces - Determine stresses and strains due to internal forces - Determine deformations due to internal forces
For Beams in Bending - Determine internal member forces - Determine normal and shear stresses due to internal forces - Draw member shear and moment diagrams - Determine the deflections for a given loading configuration
Design axial and flexural members based on stress and deflection
Become familiar with torsion, buckling, and combined loading

Table 3: Goals and objectives

Developing lesson content from these objectives was a difficult, drawn out process involving a panel of senior and junior faculty members. Consolidating two existing well-organized courses demanded consolidation and/or elimination of topics and raised difficult questions such as "Can torsion effectively be presented in one 55 minute class?" or "Can member design or combined loading effectively be covered without a discussion of Mohr's Circle and principle stresses?" Topics such as 3-dimensional analysis, fatigue, and pressure loading were excluded to enable greater depth and reinforcement of the content selected for presentation. The final criteria utilized to determine lesson content were the course goals and objectives, the target audience of non-engineering majors resulting in the elimination of some theory, and ensuring that the course served the prerequisite demands of both the civil and mechanical engineering sequences. Of note, these follow on courses were also new and were being developed in parallel. The model utilized for course development is depicted in Figure 2.

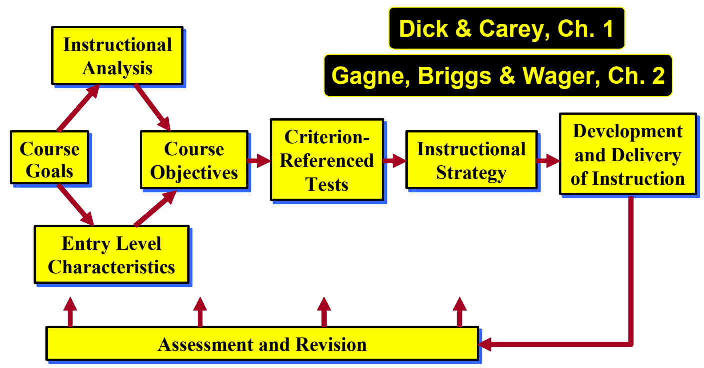

Figure 2: Systematic design of instruction [2, 3]

Methods of Assessment

In Teaching Engineering, Wankat & Oreovicz discuss the nature and benefits of both formative (during the course) and summative (at course completion) evaluations. [3] Both methods were utilized in CE300 with the following results/impact.

Type	Assessment Mechanism	Impact / Resulting Changes
Formative	**Web based study** of incoming students GPAs and performance in physics for low incoming GPAs	**Useful:** Immediately (and accurately) identified potential challenged students
	Student Data Sheets on LSN 1 including the question, "What are your expectations of CE300?"	**Useful:** Gained visibility on students perceptions about the department. Many had heard of large homework loads and expressed the desire/hope only of passing
	Comment Cards: One positive, One negative on lesson 5, and LSN 15 (of 40 lessons)	**Very Useful:** Brought up points about pace of note taking, questioning techniques, and the need for more practice problems
	Survey on Bridge Design software utilized in class and on one homework assignment	**Useful:** Program was well received, reinforced use of the program in the course for next year.
	Comment Cards on Exam #1 (50% course completion) and Exam #2 (80% course completion)	**Marginally Useful:** Equal amount of "test was unfair and impossible" vs. "test could have been more challenging, easily completed within time alloted. Resulted in no restructering of exam #2 or the Term End examination.
Summative	**In class end of course survey** containing course related questions, instructor related questions, comments on good / bad points of the course and instruction.	**Marginally Useful:** Students did not respond well to generic 1-5 bubble course related questions. **Extremely Useful**: Students want to provide written feedback on quality of instruction / course content
	Web based end of course survey containing course related questions, instructor related questions, and general comments	**Extremely Useful:** Provided an unbiased barometer against other courses.

Table 4: Assessment mechanisms utilized in CE300

All assessments were anonymous in nature. Of note were the summative, web-based surveys. These surveys were completed by the students in their rooms, at their leisure, with no consideration of identity recognition. This survey system is administered every semester by the academy and data is provided to instructors which can easily be uploaded into excel and manipulated as needed. The two graphs presented in the later sections are from this system.

Implementing, Instructing, and Assessing the Course

The most challenging and rewarding aspect of CE300 was exciting students from a wide range of disciplines about the world of engineering and the engineering thought process. However; strikingly, shockingly, and somewhat surprisingly to the instructors of the course, for some of the students (perhaps those not convinced of the necessity of an engineering sequence) engineering wasn't their favorite subject of study. Regardless, these students immediately found themselves engaged by questions and provided with challenges from an instructor bursting with energy. Two priceless quotes from an end of course survey which asked what was disliked about the manner of instruction provides a insightful view into the course:

"Some days, I was just in a bad mood and your extreme happiness to be in class upset me even more, but then again that's my fault."
- anonymous, mildly disgruntled CE300 student

"You're very animated, it's great. Somehow, you made this class fun."
- anonymous, converted CE300 student

As a benchmark to gauge success, this paper utilizes Lowman's[5] two dimensional model of teaching effectiveness. In this model, Lowman states that the effectiveness and quality of instruction can be measured by the degree of intellectual excitement and interpersonal rapport generated among students. With this benchmark, a look into how each dimension was achieved and assessment of each dimension is now presented.

Intellectual Excitement

Classrooms and class conduct are consciously set up to be charged with energy and to appeal to the senses. On any given lesson, the student is likely to "hear" the classroom before entering. Music, or a video clip linked to the lesson content are playing. Items of interest, such as developments in Iraq or the failure of a structure are posted on the back boards. The lesson title and any administrative announcements are posted. Directly next to this board are 3-5 lesson objectives that let the student know exactly what they are responsible to learn for that day which are also available in their course syllabus. One-to-two review boards are posted to reinforce key points from prior/supporting lessons. Training aids for the current block of instruction are positioned around the room. Physical models that represent the lesson's example problems are positioned in the front or center of the class. Then, class starts. Exactly 55 minutes in length starting and ending on time. Introduction, theory, physical demonstrations, example problems, and review of the lesson objectives are common to almost every lesson. This setup and conduct is supported by Lowman's assertion that the classroom is a dramatic, emotionally charged arena with the instructor as a focal point of energy and motivation.[5]

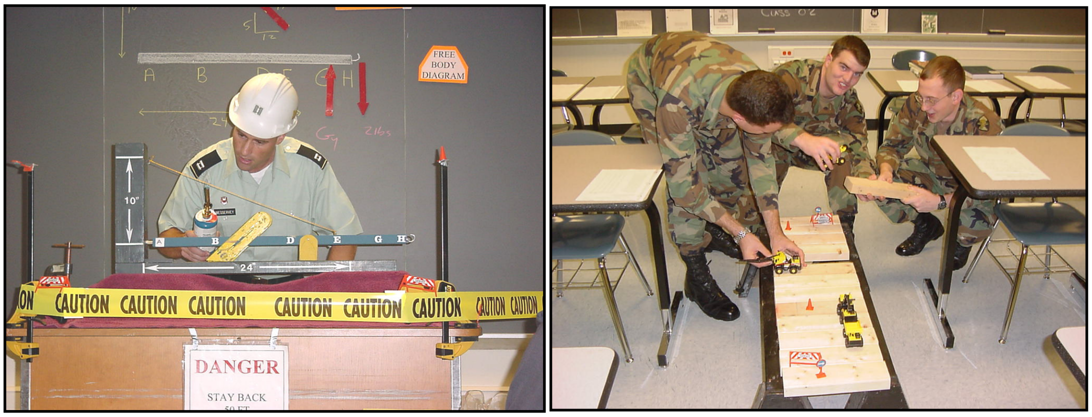

Figure 3: Using physical models to generate intellectual excitement

Intellectual Excitement was also obtained through lesson content, delivery, and method of instruction. In developing the course important concepts were routinely given one lesson for theory and one lesson for example problems and student in-class exercises. To start the lesson, each topic is made practical, relevant, and important to the students through a personal example or item from the news at the beginning of class. For example, a "war story" about a tank stuck in the mud provides an excellent motivation for the topic of forces and equilibrium. Additionally, the class never settled into a predictable routine. Cognizant of Felder's dimensions of learning styles which simply state that different people learn best differently, each block of instruction was approached utilizing complimentary techniques.[6] The following methods of instruction were applied:

- Theoretical derivation and lecture
- Instructor led example problems
- Problem Solving Sessions: Groupwork and individual work at the blackboards
- Laboratories
- In class design challenges
- In class "jeopardy" (game show)
- In class student presentations on material of choice

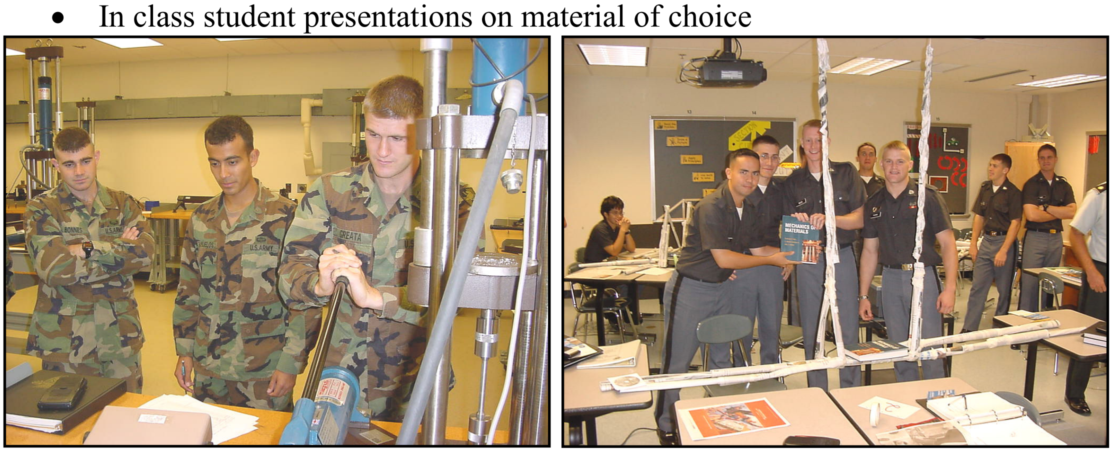
Figure 4: Captivating students with the tension test lab and newspaper bridge design challenge

The last element of generating intellectual excitement was essentially a degree of propaganda. Referring to other courses and electives in the department, talking about ongoing faculty research, and using newfound knowledge and skills to enthusiastically relate to common life experiences excited the students. For example, something as simple as exposing that a lugwrench (couple which induces no shear) is a much better choice than a cheater bar (moment of a force which induces shear) provided motivation for a target audience who had recently earned the privilege of having automobiles on campus.

The chart below shows web-based student feedback on questions pertaining to different facets of generating intellectual excitement. The questions posed in this survey were specific in nature to the Department of Civil and Mechanical Engineering so the department is utilized as the only comparison other. Only the questions relating to intellectual excitement are presented.

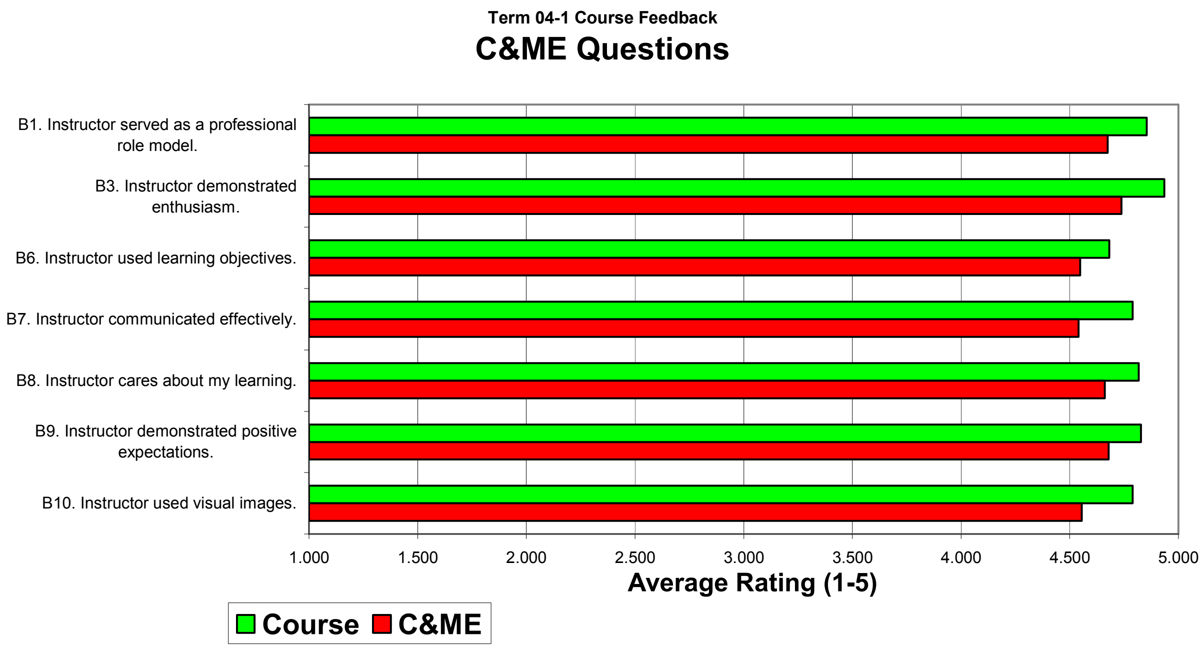

Figure 5: Assessment results for intellectual excitement

Interpersonal Rapport

During the first lesson, each student gets a biography of the instructor. This biography tells something about the instructor's family, previous military assignments and experiences, and lists the instructor's home phone number and contact information. Acceptable hours to call at home are established. One-on-one additional instruction (AI) or help on homework is readily available upon student request. Some representative comments from end of course feedback on the quality of additional instruction:

"I would have given up hope if not for AI."

"The session was very useful, you seemed to earnestly care about my success."

Timely feedback was also utilized to establish rapport with the students. As a rule, all homework assignments were returned the following lesson after turn-in and exams were returned the second lesson after taking the exam. Also as a rule, comments were written wherever points were cut.

Classroom setup and conduct also worked to build rapport. On many occasions, students commented on the quality and inherent preparation associated with models, training aids, video clips, and events that made the class enjoyable. Again, from anonymous survey comments:

"The time you spend in class preparation is evident in your performance and how smooth the class is run."

The last element of building Interpersonal rapport that will be addressed was an ongoing dialogue with the students through the use of formative assessment mechanisms. Aware that the course was being instructed for the first time, the students were eager to provide assessment and to help shape the course for future semesters. Additionally, the students could see the benefit of their assessments as requested topics were reinforced, several submission deadlines were adjusted, and discussions were frequently held about the value of different presentation techniques.

The following chart summarizes student feedback for questions pertaining to building Interpersonal Rapport. The questions posed are utilized across all departments at the academy so two comparisons are presented.

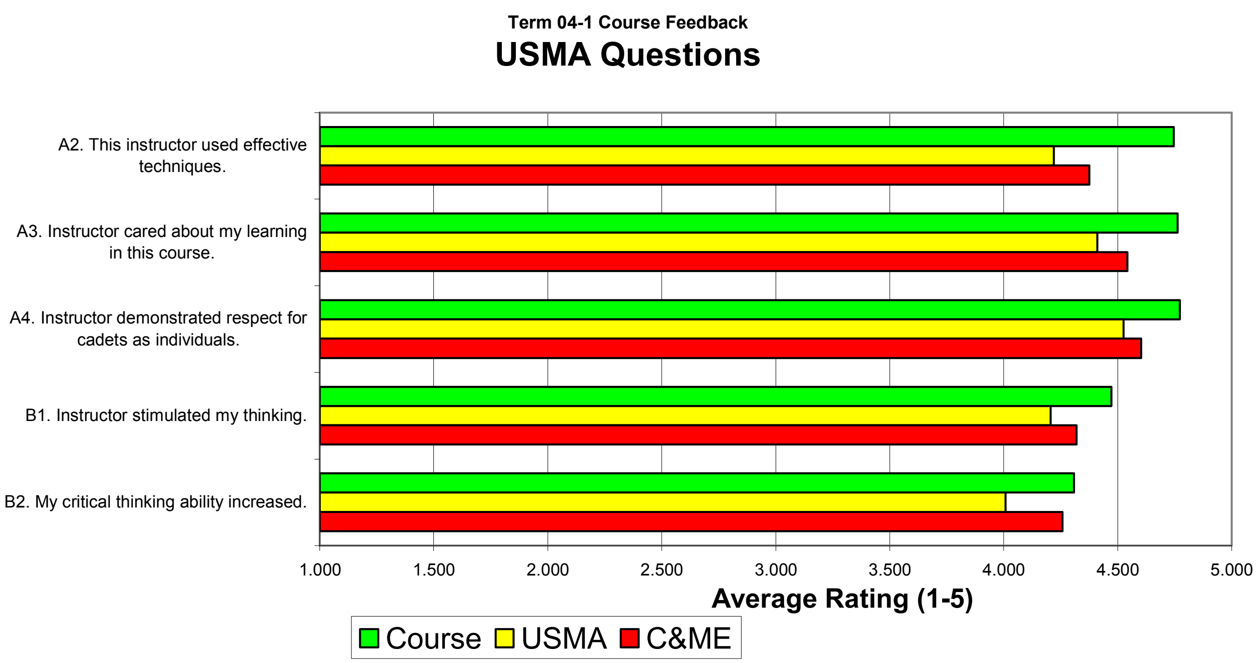

Figure 6: Assessment results for interpersonal rapport

Challenges and the Future of CE300

Now in the assessment phase of course development, several changes are being considered based upon student feedback and instructor course assessments. Two textbooks were utilized. This inevitably resulted in the incorrect book being brought to class when switching between statics and engineering mechanics related topics. An acceptable combined text is being researched. Next, time survey results, indicating time spent preparing for each lesson, spiked too sharply corresponding with homework submissions. Partial submissions or smaller, more frequent homework assignments are possible options. Removing one of the special topics, such as combined loading, is being considered in order to provide additional time to cover the topics of torsion and buckling. Lastly, the placement in the course of several activities such as the student briefings on selected materials and their properties may be adjusted to earlier lessons based upon student feedback about where it fit best in the course and how it related to other time demands they faced at that point in the semester.

A major change may be in store for CE300. As part of the ABET slow loop process, CE300 is being considered to replace CE302 - Statics & Dynamics as the first course in the engineering sequence for civil and mechanical engineering majors. This change could result in the elimination of Statics & Dynamics from the curriculum as currently offered. External to the department, this proposal is being staffed to determine if CE300 would meet the prerequisite demands of other departments and their programs. Currently, 50-60% of students enrolled in Statics & Dynamics are not civil or mechanical engineers. Internal to the Department of Civil and Mechanical engineering, the proposal is being staffed to determine if the current content of CE300 would be suitable for engineering majors as well as the non majors. Treatment of theory and derivations is of particular concern as is the ability to pace classroom instruction such as to keep majors fully challenged but not to overwhelm or discourage non-majors. Currently, CE300 focuses more on understanding how to utilize key formulas and relationships than on their derivation. This may not be the approach desired for the engineering majors. A possible answer to this challenge is the fact that the second course of the engineering program for majors is CE364 - Mechanics of Materials. Several of the lessons from CE364 were adopted by CE300 so there would be room to restructure the syllabus in CE364 to revisit any material not fully developed in CE300 and to add some new material science and advanced mechanics topics. For engineering majors, the exciting part of this proposal is that by covering mechanics of materials in CE300 as part of their first engineering course, follow-on courses become available one semester earlier than is currently possible. However, the treatment of dynamics is not covered at all in CE300 and the dynamics would need to become a separate course or get rolled up as part of the current vibrations engineering course. Mechanical majors would need this material immediately, whereas civil majors would likely take a newly restructured dynamics course in their senior year in preparation for the Fundamentals of Engineering Exam. Currently in the staffing process, this proposal and how the challenges are resolved will certainly be the topic of future study and papers.

Conclusion

CE300, Fundamentals of Engineering Mechanics and Design, was quickly developed in response to top driven changes in the Academic Program at the United States Military Academy. Combining essential elements of statics and strengths of materials with a variety of teaching techniques, the course reached out to excite non engineers about engineering. Accomplishment of course objectives, instructor feedback, and extremely positive student feedback show that goal was met. Currently in its first assessment loop after its first semester of instruction, course goals, objectives, and lesson content are being reviewed to implement changes for next year. Of interest, a larger question has emerged from the development and assessment of CE300, should this course be utilized for engineering majors and non-engineering majors? If so, CE300 will once again lead change to answer a distinct set of challenges at West Point.

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Biographical Information

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