AC 2007-1588: INTRODUCING STUDENTS TO CIVIL ENGINEERING

Jason Evers, United States Military Academy

Major Jason A. Evers, P.E., is an instructor in the Department of Civil and Mechanical Engineering at the U.S. Military Academy, West Point, NY. He earned a B.S. degree in Civil Engineering from Gonzaga University in 1995 and a M.S. degree in Civil Engineering from the University of Washington in 2005. He commanded an engineer company in Iraq and is a registered professional engineer in the State of Washington.

Chris Conley, United States Military Academy

Dr Christopher H. Conley is an Associate Professor and Director of the Civil Engineering Research Center at the U.S. Military Academy, West Point, NY. He earned a B.S. from the University of Massachusetts in 1978 and his M.S. and PhD in Structural Engineering from Cornell University in 1980 and 1983. He is active in research with various U.S. Army labs on testing and modeling blast loading.

James Klosky, U.S. Military Academy

Dr J Ledlie Klosky, P.E., is an Associate Professor and Director of the Mechanics Group at the U.S. Military Academy, West Point, NY. He earned a B.S. and M.S. degree from Virginia Tech in 1987 and 1989 and his PhD from the University of Colorado in 1997. He is the winner of the national ASEE 2004 Best Zone Paper award and is editor of the McGraw-Hill website www.handsonmechanics.com.

Introducing Students to Civil Engineering

Abstract

CE390 Civil Engineering Site Design can be an essential course for any undergraduate civil engineering (CE) program. It introduces the profession of civil engineering to students early in their development as engineers, providing them with both direction and purpose in their education. Through this course they are introduced to the wide range of career possibilities in civil engineering, and are also shown the logic behind the rest of the curriculum that leads up to the granting of their Bachelor of Science degree in CE.

The course was originally developed out of the recognition that even though a cadet had chosen to major in civil engineering, they probably knew little of the breadth of the profession. Further, in the confines of harmonizing an accredited civil engineering program with the extensive mandatory core curriculum at the United States Military Academy (26 courses of shared content unified across all majors), all of which MUST be completed in four (4) years; there is not enough room to cover all of the major disciplines of civil engineering. CE390 provides at least an introduction to several topics in CE that are not otherwise presented in the CE curriculum, nor are available through electives.

CE390 is used to educate cadets about civil engineering through an exploration of civil engineering site development and design, and in the process demonstrates how the CE curriculum works to give the students the background needed to design and develop this infrastructure. The course is used to introduce students to visualization through hand sketching, and to introduce Computer Aided Drafting and Design (CADD) modeling and engineering calculation software. The basics of systems engineering are also presented as a problem solving approach useful in any engineering discipline. As there isn't room in our curriculum for a transportation engineering course, students are exposed to earthwork calculations, geometrical and structural issues of roadway construction, horizontal and vertical curves, site distances, and the basics of runway layout and design. Finally, basic surveying focusing on Global Positioning Systems (GPS) technology and an introduction to Geographic Information Systems (GIS) are provided as necessary background for understanding modern CE practice.

Through the evolution of this course, two other benefits are coming to light. First, by framing this course around site design it can provide the common link through which a student's capstone design experience can be incorporated throughout the curriculum. The United States Military Academy (USMA) is currently experimenting with conducting initial site design for a project in CE 390, then using soil from the actual site for testing in the geotechnical engineering course, and conducting a hydrological study of the same site in the hydraulics/hydrology course. This work will be extended and integrated with structural engineering, construction management and other aspects of the project as the students work to complete their capstone experience.

The other useful feature of the course is that it is also proving to be a convenient vehicle for discussing or incorporating advances in technology and discussing current events. CE390 is an excellent method for introducing and evaluating some of the American Society of Civil Engineers developed Body of Knowledge outcomes that are more difficult to judge performance in with more traditional CE courses.

Why teach a Site Design course?

Recent history has seen both a reduction in the number of credit hours available for civil engineering courses, and growing aspirations for what civil engineering graduates know and can do at the completion of their undergraduate program. The reduction in credit hours appears to have come about as a result of cost cutting measures in some university systems, and a desire, sometimes legislatively driven at state schools, to bring civil engineering in line with the number of credit hours required for most other majors. According to the American Society of Civil Engineers' (ASCE) Body of Knowledge (BOK) Committee[1]:

"Students earn at least 20 fewer credits than did their counterparts in the 1920s. While they take comparable proportions of mathematics, science, and general education, today's students complete, on average, 18 fewer credits of engineering topics. That is a whole semester less of technical education at a time when, by almost universal agreement, the complexity of the modern engineering project escalates."

At the same time, many now see a need for civil engineering graduates who are more rounded in the sense that they have been introduced to global issues and are capable of using modern engineering tools. [2,3] The ability to move civil engineering work around the globe is affecting the practice of civil engineering, and graduates need to know how to work and compete in such a world. Sustainability and the maintenance of our physical environment are issues that graduates also need to be conversant in, and they should be prepared to practice civil engineering in a fashion that supports these initiatives.

As a result of the above, and probably for other reasons, some civil engineering programs are facing a real challenge in scheduling all the necessary courses in a reasonable time frame. Many civil engineering programs have managed to implement courses that contribute to the major as early as first semester freshman year and are thus getting civil engineering to fit into a 4 to 5 year program.

The United States Military Academy (USMA) offers an Accreditation Board of Engineering and Technology (ABET)[4] accredited civil engineering major that must be completed in 4 years, and that does not allow for engineering specific courses within the curriculum until the 4th semester of the 8-semester program. To do this, courses such as surveying and computer-aided drafting and design are offered as electives. Further, geotechnical engineering is limited to one course, and transportation engineering was not covered at all. As part of the implemented slow-loop assessment program the faculty decided to revise the curriculum to make room for an additional civil engineering course, CE390 Civil Engineering Site Design, which would address these shortcomings, and also serve as an introduction to the profession of civil engineering.

Many cadets have little or no knowledge of civil engineering when they are tasked to choose a major during the first semester of their sophomore year. It appears that most civil engineering programs have a similar concern as evidenced by the growth of introductory courses in the freshman year, but as noted the USMA curriculum cannot accommodate such a course. So although cadets cannot get an introduction to the civil engineering profession until their sophomore year, they will have upperclassman in their dormitories who have been thoroughly

introduced to the profession in CE390 and who will, hopefully, promote the civil engineering major.

This introduction to civil engineering represents one of the main purposes behind this course as summarized in the course goals: "At the conclusion of CE 390, you should be able to defend/justify your choice of CE as a major. You should also be able to diagram and explain the CE curriculum, and be able to describe how the components of the curriculum fit into the design and construction of the elements of civil engineered infrastructure. Finally, assuming you can justify your choice of CE as a major, you should be able to formulate a tentative plan as to how you will use the knowledge gained in CE390 to further yourself in the Army, and beyond."

Further motivation for creating CE390 was the recognition of the lack of breadth of the CE program at West Point and the desire to better align the program with what the majority of the cadets who chose to join the Corps of Engineers branch were doing in the Army. It also came from a recognition of the changes in society that were bringing high school students to college with little or no knowledge of engineering, and little or no experience that would help them visualize how objects in the physical world interact with one another and how systems work.

A brief course outline and curriculum comparison with other institutions

The civil engineering curriculum at USMA has many competing demands. As such, the decision outlined above to add another required course to the civil engineering curriculum was not taken lightly. Based on these competing demands, the course was added to the curriculum in academic year 2005-2006 for students graduating in the year 2007. The course objectives will be discussed later, but the major topics covered by the course are listed in the left column in Table 1. The right column of this table shows a summary of the results of a recent survey of civil engineering program curriculum at various institutions. This informal survey was conducted in part to support the most recent slow-loop assessment of the USMA civil engineering program, and in part to reaffirm the content of the CE390 course.

Table 1. CE390 Topic Areas comparison with other Institutions

CE390 Topic Area	Number of Institutions requiring a full term course in this topic
Introduction to Civil Engineering	12
Computer Aided Drafting and Design or Modeling and Visualization	16
Surveying or Geomatics	10
Engineering or Civil Engineering Systems	9
Transportation Engineering	12
Civil Site Engineering	2

Data from twenty civil engineering programs, not including West Point, is presented. It should be noted that although a course in a certain topic area may not be required, it may still be offered as an elective at these schools. On average, these CE programs at other institutions had 6 engineering electives. In the CE program at USMA there are only 3 electives.

With only three electives, many CE majors at West Point were graduating with no surveying experience at all, though surveying is one of the possible electives (taught by the Department of Geography and Environmental Engineering). Likewise, many CE majors were graduating with limited experience with Computer Aided Drafting and Design (CADD), though they could take an elective in the Mechanical Engineering major that would give them significant exposure to a popular mechanical engineering CADD package. Finally, Transportation Engineering is not available as an elective course at all at USMA, and prior to CE390 the cadets had no exposure to this aspect of the profession.

The three other major topic areas in CE390, an introduction to CE, systems engineering, and site engineering, are relatively new in the history of most CE programs. As noted earlier, many schools have introduced courses in the freshman year that help prospective majors understand what civil engineering is. Systems engineering is also somewhat new, at least as a topic area in a civil engineering course. Surely civil engineers have been exercising systems engineering for some time, but the general applicability of the principles of systems engineering is more widely recognized now. Somewhat similarly, civil engineers have been doing site engineering for some time, but this area has now grown to the point that many civil engineering firms do most of their work in this area. Given the amount of billing in CE firms associated with site engineering[5], it is quite interesting that the data shows only 2 of the 20 programs surveyed have a course on site engineering.

The civil engineering curriculum at USMA and where CE390 fits into it is detailed in Table 2. The course was added to the second year of civil engineering instruction, which occurs in the first semester of a students' third (junior) year at the academy. This situation is not ideal and as will be discussed later, the course might better be offered in a student's first semester civil engineering curriculum (an option currently being investigated).

Table 2. Civil Engineering Curriculum at USMA

2nd Semester Sophomore	*1st Semester Junior*	*2nd Semester Junior*	*1st Semester Senior*	*2nd Semester Senior*
CE 300 (L) Mechanics and Design	**CE 364 (L)** Mechanics of Materials	**CE 403** Structural Analysis	**CE 404 (L)** Design of Steel Structures	**ME 306 (L)** Dynamics
MA 206 Probability and Statistics	**MA 364** Engineering Math	**CE 371 (R)** Soil Mechanics	**CE 483 (R)** Design of Concrete Structures	**CE 492** Design of Structural Systems
PH 202 Physics II	**ME 311 (L)** Thermal Fluid Systems I	**CE 380 (R)** Hydrology and Hydraulic Design	_____ **Elective**	_____ **Elective**
LX 20_ Foreign Language	**CE390 (R)** Site Civil	**SS 307 (R)** Intl. Relations	_____	**CE 460** Construction Management

			Elective	
SS 201 Economics or **SS 202** American Politics	**PL 300 (L)** Military Leadership	**EN 302** Advanced Composition	**LW 403 (L)** Const. & Military Law	**EE 301 (R)** Fundamentals of Electrical Engineering
EV 203 Physical Geography or **PY 201** Philosophy	**HI 301** History of the Military Art I	**HI 302** History of the Military Art II		**CE 400** CE Seminar

Since the course was supposed to provide breadth within the civil engineering discipline, it essentially had limitless material to draw from. The following course objectives were finalized after presenting the course for two complete semesters:

1. Able to describe what civil engineering is to someone outside of the profession.
2. Able to communicate ideas/designs through sketches, drawings and models created by hand, and created with computer-aided drafting and design (CADD) software.
3. Able to use/apply the systems engineering approach to solve problems.
4. Able to plan and execute surveys using global positioning system (GPS) equipment.
5. Able to use/apply geographic information systems (GIS) technology in the solution of engineering problems.
6. Able to select the best site for a given purpose, and devise the modifications to the site required to prepare it for that purpose.

The sixth objective encompasses the context for the entire course, the ability to be able to conduct a site analysis and design. The common theme for the course was an engineering design project to reconnaissance, research, and design modifications for an undeveloped site for a specific use. This design project was taken from a variety of future building projects the academy is currently investigating. In order to design the site, knowledge was required in a variety of the major topics listed in Table 1. Table 3 summarizes the specific blocks of material that were presented during a 40 lesson, 8 lab semester, in order to complete this design. Lessons at the USMA encompass 55 minutes, while Labs are 2 hours in length.

Table 3. Course Syllabus

Lesson	Topic
1-3	Introduction to CE 390 and Civil Engineering practice, contracting and communication
4-6	Intro to Systems Engineering
7-9	Site selection and analysis
10-14	Geotechnical Engineering and Earthwork

15	Introduction to the CE390 Engineering Design Project (EDP)
16	EXAM I
17-18	Surveying and Global Positioning System (GPS)
19-22	Roadway design
23-24	Runway design
25-27	Hydraulics and hydrology
28-31	Environmental considerations
32	EXAM II
33-35	Sustainable engineering
36-38	Case study – Base camp site engineering
39	Guest Speaker
40	EDP Oral and Written Presentations

Lab	**Topic**
1-3	Sketching & CAD
4-5	Surveying & GPS
6-7	GIS
8	EDP Help/Work Session

As one of the first engineering courses in our curriculum, many software applications were still unknown to most students. This course lends itself to introducing various software applications useful in solving engineering problems. The following programs were introduced and used in this course: SketchUp [6], Bentley MicroStation [7] and ArcGIS[8]. The idea has also recently been entertained that this course should be the students' first introduction to the use of MathCAD[9] in solving engineering problems.

The course begins with a 3 lesson block containing an introduction to civil engineering practice, contracting, and communication. The concept of engineering as a profession is introduced and what that means. This concept is covered in a solemn manner that takes into account that many students have probably not thought of engineers as having an important obligation to society. Here the student is first introduced to the concept of licensure and the important role played by professional organizations is discussed, in that they define the steps to achieving licensure and police the profession internally. The sub-disciplines of civil engineering are introduced and reinforced during each block, so that students begin to gain an appreciation of the breadth of their chosen profession. These early lessons, combined with the site selection block in the course lend themselves well to the establishment of an "engineering vocabulary", meaning the students' first introduction to a variety of civil engineering terms. By being introduced to these terms early in their academic program it is hoped that when they encounter them again later they will get more out of the subsequent courses. For instance, as a result of CE390, students are introduced to the notion of a drainage basin and do some rational method runoff calculations which allows us to quickly review the rational method in the subsequent hydraulics and hydrology course, then move into other methods for predicting runoff, like the Soil Conservation Service method.

Another main area of emphasis for this course is an introduction of the world of modeling, simulation and visualization. Through the first few labs, in the context of both hand

sketching and CADD projects, a vocabulary for modeling and visualization is introduced. The vocabulary is reinforced throughout the semester through the use of a variety of software packages, with the goal that students understand the process (concepts) and are less concerned about the means (specific software)[10], which is more important as technology is constantly changing. The desired end state is that students have the ability to pick up any CADD package and teach themselves how to use it with relative ease. Students are also taught how to get programs to interact with each other, and the larger concept of Building Information Modeling (BIM) is introduced as the next generation of modeling for civil engineers.

While none of the topics covered in the course are in depth enough to allow students to gain complete expertise, there is a lot of room for what the authors' like to call the "intangibles," items that do not neatly fit into other courses in the curriculum. New advances in technology are an excellent example of these "intangibles." Most schools (West Point included) do not have the leniency to include a GIS course as a requirement in the civil engineering curriculum and where it is offered, it is typically as an elective. Most of our students were able to, after limited training, produce 3-dimensional renderings of their project site, draped with an orthophoto, and a 3-dimensional model of their proposed design. Given the current state of the art (and the rapid advances) of GIS technology, it would be a shame for a student to complete their undergraduate education without having at least seen some of these capabilities. Specifically, for our students, who will shortly become Army officers (possibly serving in a theatre of war in the Middle East), knowledge of GPS and GIS is essential. Similar to a senior year seminar course, we were also able to include on a very frequent basis the latest updates in technology and projects being undertaken both in the United States and abroad, through our inclusion of various publications and web references. This additional effort provided both context for that day's lesson and a way to peak students' interest with cutting edge technologies.

Similarly, transportation was not in our curriculum, and we felt that our civil engineering graduates should have at least a basic understanding of the layout of horizontal and vertical curves, stopping and passing site distances, and the layout of parking lots. While the design and construction of new roads and highways may not be as active an area for civil engineers as it once was, the U.S. Army has been doing a lot of road building. Further, traditional surveying is not a required course for our civil engineers and it was originally not included in CE390. After the first semester of teaching the course, we realized that a lack of surveying knowledge led to difficulty understanding some of the basics of laying out horizontal and vertical curves. This realization caused us to include a very simple, one lab surveying exercise in this course. This exercise led to an opportunity to compare and contrast newer GPS methods of surveying a site with traditional surveying methods and dispel some preconceptions students had about the accuracy of GPS technology.

Finally, in today's social environment, some understanding of sustainable engineering and design is a necessity. This topic might be discussed in a required environmental engineering course, but such a course is not feasible given the academy's course constraints. Site design is the ideal forum to introduce this topic, though, because site design occurs early in the project life cycle, exactly when sustainable engineering concepts should be included. Early incorporation of sustainable engineering in a project life-cycle often reduces its' overall cost. One could likewise

argue that early incorporation of sustainable engineering in a student's education will result in more comprehensive solutions to engineering problems throughout their career.

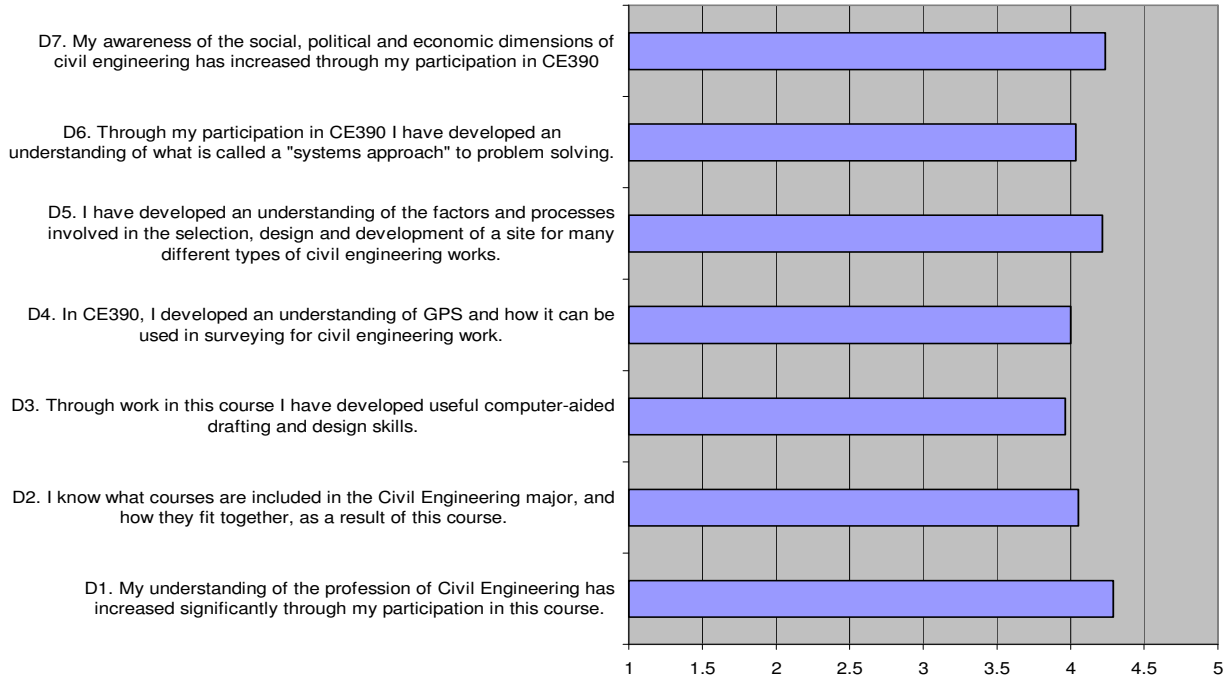
The final (and possibly, most convincing) argument for this course's inclusion in a curriculum is the fact that it allows for the integration of a program's curriculum through an overarching project. This idea is currently being investigated for the Class of 2008 at West Point. The concept behind the curriculum integration is the introduction of the senior design project during the site design course. In this course, the preliminary site design work can be completed, which includes the investigation of the site for existing utilities, some preliminary design with estimates to rule out some design options, and the early integration of sustainable engineering practices in the environmental assessment or environmental impact statement. This early site work can then be integrated through the curriculum with the site being the source of soil for soil site investigation and testing, and subsequent geotechnical designs for foundations and retaining walls. Similarly, the site can be further investigate in the hydrologic engineering course, in stormwater pollution prevention plans (SWPPP), and in any other areas of the curriculum that might use an "actual" project as a source of real-world problems. This early site design and analysis through the individual courses in the curriculum then culminates in the senior capstone design experience. The work done in previous semesters does not need to be maintained as is, but can hopefully be improved upon. If the work completed was of good quality, then the project can get into more in-depth analysis and include other elements, such as better integration of sustainable engineering concepts in the final design. If the work was of poor quality, then it can be reviewed in the capstone design process to get the students to the point where they demonstrate mastery of the concepts.

Course and Program Assessment

As a means of assessing the effectiveness of this course the students were asked a variety of questions at the end of the semester as part of the academy's course-end feedback system. Our most recent course assessment provided a variety of data points. The data was mixed.

The following table shows the Course specific feedback questions for CE390, with a range from 1-5, where a 1 indicates strong disagreement with a question and a 5 indicates strong agreement.

Table 5. CE390 Course-End Feedback Information



A broad range of data actually came in the form of the written feedback comments on the student's course assessment. Many students wrote very positive comments about the course and were generally understanding of the purpose of the course. Such feelings were embodied by the following comments:

"My cousin is a Civil Engineer and he said he wished he had something like the[CE390] EDP during college because thats actually what he is doing all the time now;"

"This course taught me more about CE than any other course;"

"I thought the course did a very good job of introducing you to a lot of aspects of engineering."

However, just as many students felt that the course was poorly structured and did not encompass topics in enough depth. Such feelings are demonstrated in the following student's remarks:

"This course was not structured well. There was never any clear picture of what was going on in ths course. Sometimes we learned random technical skills, and other times we looked at the big pictures. Nothing ever seemed to go together. When we were taught technical information, like calculated curves, we never went into depth enough or recieved enough instruction to successfully complete problems. There was way too much information put into one class."

While the students had mixed reactions to the course, the instructors feel confident that with a bit more revision, the majority of students will understand the importance of the course and see its value as they work their way through the rest of the curriculum. We also have plans to survey the graduating seniors to see what they think of the course after having seen the rest of the curriculum.

The course can become an integral part of the program assessment as well. The nature of this course (or one similar to it) allows for the inclusion of a variety of topics that support the previously discussed ASCE BOK. This course tends to be a convenient vehicle to include portions of these outcomes that do not neatly fit into the engineering curriculum in other courses. It also allows the insertion of program outcome indicators that can be used for ABET accreditation. Of the 15 program outcomes, CE390 was able to support no less than 11 in part or in full for the CE program, as shown in Table 4.

Table 4. BOK outcomes supported by CE390

Supported by CE390?	BOK Outcome[4]
Yes	1. an ability to apply knowledge of mathematics, science and engineering.
Yes	2. an ability to design and conduct experiments, as well as analyze and interpret data.
Yes	3. an ability to design a system, component or process to meet desired needs.
	4. an ability to function on multi-disciplinary teams.
Yes	5. an ability to identify, formulate and solve engineering problems.
Yes	6. an understanding of professional and ethical responsibility.
Yes	7. an ability to communicate effectively.
Yes	8. the broad education necessary to understand the impact of engineering solutions in a global and societal context.
Yes	9. a recognition of the need for, and an ability to engage in, life-long learning.
Yes	10. a knowledge of contemporary issues.
Yes	11. an ability to understand the techniques, skills, and modern engineering tools necessary for engineering practice.
Yes	12. an ability to apply knowledge in a specialized area related to civil engineering.
	13. an understanding of the elements of project management, construction, and asset management.
	14. an understanding of business and public policy and administration fundamentals.
	15. an understanding of the role of the leader and leadership principles and attitudes.

CE390 will be gathering data on these program outcomes during the record year (Academic Year 2008) in advance of USMA's ABET visit in October, 2008

So where do we go from here?

The restated outcome after taking the course was: "At the conclusion of CE 390, you should be able to defend/justify your choice of CE as a major. You should also be able to

diagram and explain the CE curriculum, and be able to describe how the components of the curriculum fit into the design and construction of the elements of civil engineered infrastructure. Finally, assuming you can justify your choice of CE as a major, you should be able to formulate a tentative plan as to how you will use the knowledge gained in CE390 to further yourself in the Army, and beyond."

Given this goal, the most immediate and important change that the instructors feel is necessary is for the course to truly become a student's introduction to civil engineering. As such, it should be in the first semester of a student's CE curriculum. This plan is currently being considered at USMA. Additionally, many other challenges are posed for future CE390 course administrators - in balancing student expectations with the proper amount of breadth and technical content across the spectrum of civil engineering. Despite these challenges, the authors are still convinced that this course has the correct goals and objectives to meet the needs of the civil engineering curriculum at West Point and other institutions. Any institution seeking to provide students with an early introduction to the civil engineering profession, looking for a way to present technical content that does not fit neatly into other more specific engineering courses, trying to incorporate a common theme throughout the civil engineering curriculum, and searching for a manner to present material that supports complex BOK objectives, would do well to include a course similar to CE390, Civil Engineering Site Design in it's curriculum.

Bibliography

1. Body of Knowledge Committee of the Committee on Academic Prerequisites for Professional Practice (2004), "Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future," ASCE, Reston, Va., 13.
2. Body of Knowledge Committee of the Committee on Academic Prerequisites for Professional Practice (2004), "Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future," ASCE, Reston, Va., 26-27.
3. Committee Science, Engineering, and Public Policy (2006), "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," The National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, Washington, DC, ES-8.
4. Accreditation Board for Engineering and Technology Home page, http://www.abet.org/ Accessed March 5th, 2007.
5. D.K. Rubin (2005), "Stantech Pushes Big Plans – Carefully – For Moving to the Front Row," *Engineering News-Record*, July 25, 2005, 31.
6. Google SketchUp Home page, http://www.sketchup.com Accessed March 5th, 2007.
7. Bentley Home page, http://www.bentley.com/en-us/ Accessed March 5th, 2007.
8. ESRI ARCGIS Home page, http://www.esri.com/software/arcgis/ Accessed March 5th, 2007.
9. MathSoft Home page, http://www.ptc.com/products/mathcad/mathcad14/promo.htm Accessed March 5th, 2007.
10. Rani, Whab, Shaarani, and Aziz (2000), "Facilitating Learning of Engineering Graphics Instead of Learning CAD System," *ICEE 2000, International Conference on Engineering Education [CD-ROM]*, Taipei, Taiwan.
11. Body of Knowledge Committee of the Committee on Academic Prerequisites for Professional Practice (2004), "Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future," ASCE, Reston, Va., 5-6.