AC 2010-1925: A "GLOBAL" CURRICULUM TO SUPPORT CIVIL ENGINEERING IN DEVELOPING NATIONS: THE FINAL RESULT

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A "Global" Curriculum to Support Civil Engineering in Developing Nations: The Final Result

Abstract

At the 2008 ASEE Conference in Pittsburgh, we reported on our initial plans to overhaul the West Point Civil Engineering curriculum based on initial constituent survey results and faculty focus group efforts. Following an ABET visit in the fall of 2008, we were able to again focus on refining our initial plan. Further efforts involved more detailed planning to ensure all identified subjects were included, all ABET requirements were satisfied, and that the resulting plan made sense from a pedagogical perspective. The end result of this process is a revised CE program that better meets the needs of our constituents. Along with providing a strong foundational basis for the study of civil engineering and for continued lifelong learning, the program now addresses aspects of infrastructure that our graduates need as Army Officers—deployed overseas as well as assigned within the United States. In addition, the program makes great strides at satisfying the requirements of the ASCE Body of Knowledge (BOK), in many cases beyond those listed as being required at the bachelor's degree level. This paper reports on development efforts since 2008 and provides the final result submitted to the USMA Curriculum Committee for approval. Background on specific decisions is provided as well as other pertinent information relevant to curriculum development. The paper provides a very brief summary of previous efforts; additional detail on initial development efforts is available in the 2008 paper.

Background

The Civil Engineering (CE) program at the United States Military Academy (USMA) at West Point has been a traditional structures-based program emphasizing the foundations of civil engineering for almost three decades. The program typically has about 50 students enrolled per year; about 65 percent of the students select to serve in the Army Corps of Engineers following graduation. To ensure that programs maintain relevance, ABET requires that all programs identify their constituencies and demonstrate that the program meets the constituents' needs; the US Army and the US Army Corps of Engineers are our two principal constituents. Over the last eight years, the US Army has been engaged in ongoing conflict in Iraq and Afghanistan that has required the development of proficiencies related to the identification, protection, assessment, maintenance, rebuilding, and development of infrastructure as a means to shape success and bring future stability to both countries. Within the United States, the issue of our deteriorating infrastructure has been brought to light by ASCE and our Nation's leaders. Substantial government funding has been focused on repairing infrastructure as a means to improve economic conditions.

In the early stages of curriculum development, a survey was sent to constituents of the USMA CE program.[1] The survey posed seven questions focused on identifying which CE topics are most useful to graduates. Those surveyed were Army officers, many of whom were recent graduates of the program, and civilians. Many of those surveyed had over 20 years experience working in or around the field of civil engineering. Survey results showed that many topics

currently covered in the USMA CE program are highly relevant, while some new topics should be added to the current curriculum to improve its relevance and help it better meet the guidelines established in the ASCE BOK.[2] Graduates of the USMA admittedly serve a unique role upon graduation. However, it can be argued that the skill set they need to be successful as civil engineering leaders in Iraq and Afghanistan is much the same as civil engineers working in other developing nations having limited infrastructure. As a note, the basics of infrastructure are applicable anywhere in the world, not just in developing nations.

The Current CE Program

The current CE program at the USMA is a traditional program emphasizing the foundations of civil engineering with a focus on structural engineering. Students join our program in their 4th term and Table 1 depicts the remaining five terms for a typical program of study with a focus on structures.

Table 1. Current CE Program of Study

Term 4	Term 5	Term 6	Term 7	Term 8
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
MA206 Probability and Statistics	**MA364** Engineering Math	**CE371 (R)** Soil Mechanics	**CE483 (R)** Design of Concrete Structures	**CE492** Design of Structural Systems
PH202 Physics II	**ME311 (L)** Thermal Fluid Systems I	**CE380 (R)** Hydrology and Hydraulic Design	_____ **Elective**	_____ **Elective**
LX20_ Foreign Language	**CE390 (R)** CE Site Design	**SS307 (R)** International Relations	_____ **Elective**	**CE460** Construction Management
SS201/2 Amer. Politics/ Economics	**PL300 (L)** Military Leadership ← →	**EN302** Advanced Composition	**LW403 (L)** Constitutional & Military Law	**EE301 (R)** Electrical Engineering
EV203/PY201 Phys. Geography/ Philosophy	**HI301** History of the Military Art I	**HI302** History of the Military Art II		**CE400** CE Seminar

The four major areas of study included in the program are structural engineering, construction management, geotechnical engineering, and hydrology and hydraulics. Students have several elective choices that allow them to develop depth, predominantly in the structures area. The shaded boxes show the CE program specific courses taken by students typically beginning in their fourth term at the USMA. Other courses shown (not shaded) are part of the USMA core curriculum that is taken by all students. An elective in geotechnical engineering is available

within the CE program, and several electives in environmental engineering are also available from outside the program. The program currently offers no additional course in construction management or hydrology and hydraulics.

Constituent Feedback

Reports from the field indicated that CE graduates were adequately proficient in the traditional areas of civil engineering, but lacked additional expertise in areas like project management, power generation and distribution, geomatics, transportation, and infrastructure assessment. Constituent survey results showed that topics could be categorized into three groupings to include "essential," "necessary" and "nice to have." Tables 2 and 3 below specify the "essential" and "necessary" topics, respectively. The "percent responding" column lists the percentage of respondents that felt the topic fit into the specific category.

Table 2. Essential Topics for CE in Developing Nations

Rank	Civil Engineering Topic	Percent Responding
1	Construction & Project Management	94%
2	Infrastructure Assessment	76%
3	Structural Engineering	60%
4	Infrastructure Maintenance and Management	50%

In examining the data in Table 3 for topics considered "necessary," there is only a 14 percent spread from the top-ranked to the bottom-ranked item; not a significant variation, indicating that all topics were considered similarly necessary. The placement of urban and regional planning above wastewater, transportation, and power generation and distribution showed the need for initial planning to enable efficient and correct placement and operation of other critical infrastructure items.

Table 3. Necessary Topics for CE in Developing Nations

Rank	Civil Engineering Topic	Percent Responding
1	Geotechnical Engineering	84%
2	Hydraulics and Hydrology	82%
3	Water Resources Engineering and Management	80%
4	Urban and Regional Planning	80%
5	Geomatics (Surveying, GPS and GIS)	78%
6	Wastewater (gray/black) and Solid Waste Management	76%
7	Transportation Engineering	74%
8	Power Generation and Distribution	74%
9	Information Technology	70%

Guidance for Developing a Solution

The following requirements were to be satisfied in developing the new CE curriculum.

- The CE Program must maintain ABET accreditation. In addition, it must offer flexibility and be forward-thinking enough to satisfy the requirements of the ASCE BOK.

- The curriculum must seek to satisfy needs identified in the survey.
- The curriculum must offer students options in the four major areas of study other than just the structures area.
- The curriculum must be efficient. With a relatively small faculty and recent losses due to faculty reallocation, the program cannot offer large numbers of electives, but must concentrate on fewer high quality electives in major areas of study.
- The CE curriculum, along with the core curriculum, must provide students solid CE foundational skills that will enable them to take and pass the Fundamentals of Engineering (FE) exam.
- The combination of courses that have traditionally been stand-alone bellwether CE courses is acceptable to free space for other curricular material.
- Finally, there can be no increase in the number of credit hours required for a BSCE.

The Resulting Solution

Comparison with the initial proposed curriculum solution in the 2008 paper shows some similarities; however, the curriculum in Table 4 satisfies the developmental guidance much more effectively and requires less faculty effort.[1]

Table 4. The Final Result: CE Program of Study

Term 4	Term 5	Term 6	Term 7	Term 8
CE300 (L) Mechanics and Design	**CE364 (L)** Mechanics of Materials	**CE403** Structural Analysis	**CE404 (L)** Design of Steel Structures	**CE492** Design of CE Systems
MA206 Probability and Statistics	**CE350** Infrastructure Engineering	**CE371 (R)** Soil Mechanics	**CE483 (R)** Design of Concrete Structures	**CE400** CE Professional Practice
PH202 Physics II	**ME311 (L)** Thermal Fluid Systems I	**CE380 (R)** Hydrology and Hydraulic Design	_____ Elective 1	_____ Elective 2
LX20___ Foreign Language	**CE390 (R)** CE Site Design	**CE450** Construction Management	**LW403 (L)** Constitutional & Military Law	_____ Elective 3
SS201/2 Amer. Politics/ Economics	**M&BS** Elective	**EN302** Advanced Composition	**HI301** History of the Military Art I	**EE301 (R)** Electrical Engineering
EV203/PY201 Phys. Geography/ Philosophy	**PL300 (L)** Military Leadership	**SS307 (R)** International Relations		**HI302** History of the Military Art II

Within Table 4, some boxes are shaded. The shaded boxes show the CE program specific courses taken by students typically beginning in their fourth term at the USMA. Other courses shown (not shaded) are part of the USMA core curriculum that is taken by all students. Student performance in the four dark gray shaded courses is included when calculating their standing based only on the core curriculum. In addition, the (L) following a course designation indicates the course is blocked for two hours whereas the (R) indicates the course has a separate two-hour laboratory period offered eight times during the course.

Explanation of Specific Curricular Changes

Comparing Tables 1 and 4 reveals several changes. Each change is identified below with a brief explanation provided.

Term 5 – Addition of CE350 Infrastructure Engineering. The addition of this course was predicated by significant comments received from the field about the need for infrastructure knowledge. CE350 is designed to be a "systems level" course that provides students with the background necessary to identify, analyze and assess built infrastructure. It is focused on providing coverage to augment many of the "necessary topics" listed in Table 3 above. The course is positioned early in the curriculum to serve as an initial exposure to infrastructure items, providing a framework for future studies. CE350 also serves as the second course in the Civil Engineering Three Course Sequence, one of seven possible engineering programs of study required for Wet Point's non-engineering majors. In order to add CE350, it was necessary to remove a course from the curriculum. After much dispute, the course removed was ME306 Dynamics, which will be discussed later in this paper. The scope of CE350 is:

> *This course identifies, analyzes, and assesses built infrastructure which is the foundation for modern society. The complex and interconnected nature of infrastructures is investigated and demands on critical components are calculated. Students explore the non-technical factors necessary for the functioning of infrastructure including supplies, trained personnel, and cross-sector dependencies. The course provides a basis for understanding the complexity and cost of maintaining, rebuilding and developing infrastructure. Major blocks of instruction include water, wastewater and solid waste, energy, transportation, and public administration. Several in-class scenarios are provided to synthesize the connectivity between the major items of infrastructure. Finally, as infrastructure is one of the six variables in the joint operating environment, the knowledge gained is employed to analyze infrastructure in the context of military operations.*

The four course objectives of CE350 are:

- Identify, categorize, and assess critical infrastructure and cross-sector linkages at the national, regional, and municipal levels.
- Calculate the demand on infrastructure components and systems.
- Assess the functionality, capacity, and maintainability of infrastructure components and systems.
- Analyze infrastructure in the context of military operations.

The syllabus for CE350 is listed in Appendix 1.

Term 5 – Math and Basic Science (M&BS) Elective. In the current curriculum, MA364 Engineering Math, is required of all CE majors in order to achieve the ABET minimum required 32 credit hours of M&BS. Since the content of MA364 was not required to successfully complete other coursework in the CE major, it was decided to offer students the option of taking other courses that satisfy the necessary M&BS credit hours while giving them additional elective options in their programs of study. Included in the list of possible elective courses are MA364 Engineering Math, MA371 Linear Algebra, PH365 Modern Physics, and SE375 Statistics for Engineers.

The removal of MA364 sparked significant discussion concerning the ABET requirement for CE students to "apply knowledge of mathematics through differential equations" as specified in Criterion 9, the CE Program Criteria.[3] However, the American Society of Civil Engineers (ASCE) commentary dated January 2008 states: "To comply with this criterion, the program must demonstrate that its graduates can apply concepts and principles from math and science to solve relatively straightforward problems. There is no requirement for a minimum number of credit hours or courses in any of these subject areas. The evaluation should be based principally on graduates' demonstrated ability to solve problems, not on curricular content."[4]

There was also discussion related to students being less prepared for the Fundamentals of Engineering (FE) exam. While this is a valid concern, the impact was felt to be minimal since students already receive adequate math preparation in the core math curriculum for successful completion of the vast majority of problems on the FE exam. We feel the risk is minimal; we will monitor student performance closely in the coming years to ensure our students are meeting the standard.

Term 6 – Repositioning CE450 from Term 8. Based on constituent feedback concerning the importance of construction management skills, CE450 was moved from Term 8 to Term 6 to provide our students exposure to this important topic earlier in their programs of study. By moving the course forward one year, students are now able to apply the principles of construction management to their senior-level CE courses. As a note, CE450 and CE460 (current version) are the same course. In the current curriculum, CE450 is a construction management course taken by non-engineering majors while CE460 is taken by CE majors. CE450 has replaced CE460 and is now the same course taken by both non-majors and CE majors.

Term 7 – Modification of CE404 and CE483. Constituent feedback indicated that structural engineering topics were essential for our graduates. In an attempt to satisfy that need while reducing the total number of structural engineering courses to enable coverage of other elective areas, modifications were made to CE404 Structural Steel Design, and CE483 Reinforced Concrete Design. Previously, an elective course in timber and masonry was offered; this hampered our ability to offer other non-structural electives. In CE404, seven lessons of steel design were replaced with lessons covering basic timber design. Since great similarities exist between the design of steel and timber, the substitution made sense. In CE483, seven lessons of reinforced concrete design were replaced with masonry design for the same reason. The

resulting substitutions were well received by students after the first iteration during the fall term of 2009.

Term 8 – Removal of ME306. In conjunction with the addition of CE350 in Term 5, the removal of a course in the CE program was necessary to meet the Dean's intent of a one for one swap, a policy that has been in effect for many years to control the total number of courses offered at the Academy. The course chosen for removal was ME306 Dynamics. Much like MA364 Engineering Math, there was significant discussion about the selection of ME306 for deletion. Many felt that in a traditional civil engineering program that dynamics is a fundamental skill necessary for future learning and to be successful on the FE exam. Members of the program's ABET advisory board felt strongly about maintaining the course, but understood the desire to replace dynamics with a course in infrastructure. Since students already receive adequate coverage of basic particle dynamics in their second core physics course, it was felt that the risk associated with removing dynamics was minimal. In addition, benchmarking of similar programs showed that several other schools did not require dynamics unless students specifically concentrated in structural engineering within their program of study.

Term 8 – Coverage of Power Generation and Distribution in EE301. In Table 3, power generation and distribution was one of the "necessary topics" for coverage in the program. We initially considered offering a civil engineering course focused on power, but then were able to work with the Academy's Electrical Engineering Department to include additional coverage of power-related topics in the basic electrical engineering course, EE301. Students will receive an overview of power generation and distribution systems in CE350, then learn additional basic-level skills in EE301 that will enable them to solve straightforward generation and distribution problems they may encounter as Army officers.

Terms 7 and 8 – Electives. Students select three electives in addition to the M&BS elective as part of their program of study. In the current program, there are two structural engineering electives (CE471 Timber and Masonry; CE491 Advanced Structural Analysis) and one geotechnical engineering elective (CE472 Advanced Soil Mechanics and Foundation Engineering). In order to broaden the spectrum of electives available, three new electives (CE478 Structural Mechanics; CE490 Protective Design; CE495 Transportation) have been developed and will be offered to students starting in the spring term of 2010. CE471 Timber and Masonry will be discontinued since coverage of those two building materials is now included within the steel course, CE404, and the concrete course, CE483.

What about ABET?

Whenever making changes to an ABET accredited curriculum, it is vital to ensure that the result satisfies the requirements established in Criterion 1 through 9. In order to demonstrate that credit hours were satisfied in each category (Engineering Topics, ET; Math & Basic Science, M&BS), a spreadsheet was developed listing credit hour counts by category with the "worst-case" course selections examined with regard to each category. The spreadsheet is shown in Table 5. The abbreviation "GE" stands for "General Education" and "OTH" stands for "Other Topics" as would relate to courses like physical education and military instruction. In both the ET and

M&BS categories, the spreadsheet readily demonstrates compliance with the ABET credit hour requirements.

Table 5 – ABET Credit Hour Compliance

Course	M+BS	ET	GE	OTH
CH101	3.5			
EN101			3.0	
HI103			3.0	
MA103	4.0			
PL100			3.0	
PE11X				0.5
PE115/6				0.5
MS101				0.5
CH102	3.5			
EN102			3.0	
HI10X			3.0	
IT105		0.5	2.5	
MA104	4.5			
PE117				0.5
MS103				0.5
LX203/3XX (1)			3.0	
MA205	4.5			
PH203	3.5			
PY201			3.0	
SS201			3.5	
PE211				1.5
MS201				0.5
CE300		3.0		
EV203	2.0	0.5	0.5	
LX204/LX3XX (1)			3.0	
MA206	2.5	0.5		
PH204	3.5			
SS202			3.5	
PE112				0.5
MS203				0.5

Course	M+BS	ET	GE	OTH
CE364		3.5		
CE390		3.5		
CE350		3.0		
ME311		3.5		
HI301			3.0	
PL300			3.0	
PE311				1.5
MS301				0.5
CE371		3.5		
CE380		3.5		
CE403		3.0		
CE450		3.0		
EN302			3.0	
HI302			3.0	
MS302				0.5
CE404		3.0		
CE483		3.5		
LW403			3.5	
PE4XX				0.5
CE400		1.0		
CE492		3.0		
EE301		3.5		
SS307			3.5	
MS400				1.5
Total w/o Electives	31.5	45.0	53.0	10.0

Course	M+BS	ET	GE	OTH
Worst Case for M + BS				
M&BS Elect (2)	2.0	1.0	0.0	0.0
CE Field Elect # 1 (3)	0.0	3.0	0.0	0.0
CE Field Elect # 2 (3)	0.0	3.0	0.0	0.0
CE Engr Elect (4)	0.0	3.0	0.0	0.0
Total with Electives	33.5	55.0	53.0	10.0
ABET Minimum CH	32.0	48.0	NA	NA
	OK	OK		
Worst Case for ET				
M&BS Elect (2)	3.0	0.0	0.0	0.0
CE Field Elect # 1 (3)	0.0	3.0	0.0	0.0
CE Field Elect # 2 (3)	0.0	3.0	0.0	0.0
CE Engr Elect (4)	3.0	0.0	0.0	0.0
Total with Electives	37.5	51.0	53.0	10.0
ABET Minimum CH	32.0	48.0	NA	NA
	OK	OK		
If Cadet Takes 3 CE Field Electives				
M&BS Elect (2)(6)	2.0	1.0	0.0	0.0
CE Field Elect # 1 (3)	0.0	3.0	0.0	0.0
CE Field Elect # 2 (3)	0.0	3.0	0.0	0.0
CE Field Elect # 3 (4)	0.0	3.0	0.0	0.0
Total with Electives	33.5	55.0	53.0	10.0
ABET Minimum CH	32.0	48.0	NA	NA
	OK	OK		

NOTES

(1) Assumes 3.0 CH of GE for advanced foreign language option
(2) M&BS elective: SE375, MA364, MA371 or PH365
(3) Cadet must take 2 CE Field Electives minimum, but can take 3
(4) Cadet can take a maximum of 1 CE Engineering Elective, but can take 0
(5) Cadet must take 3 total CE electives
(6) Assumes a M&BS Elective with only 2.0 CH of M&BS credit since ET will be easily satisfied

Another fairly recent change from the ABET perspective involves the requirement to include coverage of an "additional area of science" as specified in Criterion 9, the CE Program Criteria.[3] The ABET requirement provides program directors with significant latitude by stating that the additional area of science must be consistent with the Program Educational Objectives (PEO). Geodetic science was identified as our additional area of science based on our graduates' need to work with maps, identify and analyze geospatial information, and work with sophisticated satellite-based technology as part of daily military operations in the global arena. Geodetic science is covered substantially in three courses; EV203 Physical Geography; CE390 CE Site Design; and CE492 Design of CE Systems.

Conclusion

Undertaking a major curriculum change is something that must be accomplished in a conscientious and systematic manner—it is not an activity that should be rushed and must not be

accomplished in a vacuum. Following the ABET slow loop process provides a good framework for such curricular changes. This process took longer than initially anticipated, but the final solution was well worth the time and effort. Comparison of the resulting curriculum in this paper with the initially proposed format in the 2008 paper demonstrates how the plan developed as the process moved forward.[1] The final step to complete the process is a thorough assessment of the changes and their results with regard to student performance. Following an assessment, the authors plan to present a final paper depicting the results of the new curriculum on student performance.

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4. American Society of Civil Engineers, "Commentary for Civil and Similarly Named Programs," Draft as of January 2008, accessed at http://www.asce.org/pdf/Revised_Civil_Draft_Commentary.pdf, January 7, 2010.

Appendix 1 – Syllabus for CE350 Infrastructure Engineering

CE350: Infrastructure Engineering

Lesson	Topic
1	Administration and Introduction to Infrastructure
2	Infrastructure Sectors and Key Assets and the Economy
3	Network Theory
4	Network Modeling
5	Network Modeling
6	Network Modeling
7	Introduction to Water Resources
8	US Water Treatment Models
9	Afghanistan Water Treatment Models
10	US Wastewater Treatment
11	Afghanistan Wastewater Treatment
12	Water Treatment and WW Treatment Plant Tours
13	Landfills (US and Afghanistan)
14	Written Partial Review 1
15	Introduction to the Energy Sector
16	Electrical System Overview and Terminology
17	Electrical Generation and Transmission
18	Electric Sub-stations
19	Distribution of Electricity
20	Electricity Consumption
21	Electrical System Assessment
22	Electricity in Afghanistan
23	Alternative Power Generation
24	Oil, Gas, and other Energy Sub-sectors
25	Transportation
26	Transportation
27	Transportation
28	Transportation
29	Transportation
30	Transportation
31	Transportation
32	Written Partial Review 2
33	Infrastructure in Doctrine
34	Infrastructure Reconnaissance and Assessment
35	Infrastructure Reconnaissance and Assessment
36	Infrastructure Reconnaissance Field Trip
37	Development—Engineering
38	Development—Governance
39	Stability and Support Operations
40	Stability and Support Operations