Road Builders - Integrating Transportation and Construction Engineering

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Road Builders
Integrating Transportation and Construction Engineering through Experiential Learning

The United States Military Academy (USMA) seeks to educate and inspire their civil engineering students through a rigorous and realistic academic program. In the program's constrained course environment, course topics typically addressed with multiple courses at other institutions are combined into a single course at USMA. One particular composite course is a Heavy Highway Design and Construction Course, which integrates basic highway design elements with planning for heavy highway construction. Students in this elective have already been introduced to the basic fundamentals of highway geometric design in a site design course and have completed a general construction management course. Although the composite course was developed due to relatively constrained academic program at USMA, the authors feel a similar approach could benefit other civil engineering programs.

The evolution of this composite course began with the deliberate development of an Introduction to Highway Engineering course, which included experienced based learning elements. This elective course was taught for several years, and was well subscribed and received by the students. Concurrent with this original transportation course development was the evolution of the program's general construction management course. Through course and program assessments, the faulty recognized that the transportation course did not culminate sufficiently. That is, students could design highways but lacked the opportunity to plan through highway construction. Additionally, the general construction engineering course provided a solid foundation of construction management topics, but failed to address adequately the heavy highway construction topic. The result of these assessments was the composite course proposal.

A key component of this composite course is a requirement for groups of students to conduct a preliminary highway design and a plan for its construction. The culminating event for this requirement is a briefing and oral exam. The intent is to simulate a realistic context for the project and a challenging environment for the group's presentation. Faculty members draw upon their engineering experiences to provide relevant challenges for this experience, which ensures the requirement is realistic.

The student's experience in the composite course, and specifically in the briefing and oral exam addressed several of the program's ABET student outcomes. These outcomes include: *Demonstrating creativity in the context of engineering problem-solving, Incorporating the knowledge of contemporary issues into the solution of engineering problems,* and *Speaking effectively*. The assessment of these specific ABET student outcomes include direct and indirect embedded indicators. Additionally, the impact on both the cognitive and affective developmental domains is considered with respect to educating and inspiring our future civil engineers.

Introduction

The mission of the United States Military Academy (USMA) has evolved since the institution's inception in 1802[1]:

To educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country, and prepared for a career of professional excellence and service to the Nation as an officer in the United States Army.

The Department of Civil and Mechanical Engineering is one of 11 departments at the Academy, and both the civil and mechanical engineering programs are ABET accredited. The mission of the Department of Civil and Mechanical Engineering parallels the Academy's mission, while focusing on educating and inspiring students in the fields of civil and mechanical engineering[2]:

To educate cadets in civil and mechanical engineering, such that each graduate is a commissioned leader of character who can understand, implement, and manage technology; and to inspire cadets to a career in the United States Army and a lifetime of personal growth and service.

The civil engineering program established 16 student outcomes to achieve the mission and meet the ABET accreditation requirements:

Our students upon graduation:

1. *Design civil engineering components and systems.*
2. *Demonstrate creativity, in the context of engineering problem-solving.*
3. *Solve problems in the structural, construction management, hydraulic, and geotechnical discipline areas of civil engineering.*
4. *Solve problems in math through differential equations, calculus-based physics, and general chemistry.*
5. *Design and conduct experiments, and analyze and interpret data.*
6. *Function effectively on multidisciplinary teams.*
7. *Describe the roles and responsibilities of civil engineers and analyze the issues they face in professional practice.*
8. *Use modern engineering tools to solve problems.*
9. *Write effectively.*
10. *Speak effectively.*
11. *Incorporate knowledge of contemporary issues into the solution of engineering problems.*
12. *Draw upon a broad education to anticipate the impact of engineering solutions in a global and societal context.*
13. *Are prepared and motivated to pursue continued intellectual and professional growth—both as Army officers and as engineers.*
14. *Explain the basic concepts of management.*
15. *Explain the basic concepts of business and public policy.*
16. *Are leaders of character.*

Recognizing that the Department's mission statement includes educating and inspiring, the civil engineering faculty have sought to develop their program appropriately along a set of commonly accepted educational taxonomies; that is, Bloom's Taxonomy. These widely known taxonomies are based on the seminar work of the 1950's educational committee chaired by Benjamin Bloom. The committee established a set of taxonomies in three domains of learning: cognitive, affective and psychomotor. The cognitive domain taxonomy is widely accepted in many fields and has been identified as, "arguably one of the most influential education monographs of the past half century."[3] The taxonomies are a language that describes the progressive development of an individual in each domain and are defined as follows[4]:

- Cognitive: of, relating to, being, or involving conscious intellectual activity.
- Affective: relating to, arising from, or influencing feelings or emotions.
- Psychomotor: of or relating to motor action directly proceeding from mental activity.

A set of development levels for each domain are shown in Table 1 based on work by Bloom (1956)[5], Krathwohl et al. (1973)[6], and Simpson (1972)[7], respectively. Each column shows the levels in each domain, from the simple at the top, to the more complex at the bottom.

Table 1. Domain Levels.

Cognitive Domain[5]	Affective Domain[6]	Psychomotor Domain[7]
Knowledge	Receiving	Perception
Comprehension	Responding	Set
Application	Valuing	Guided Response
Analysis	Organization	Mechanism
Synthesis	Characterization by a Value Complex	Complex Overt Response
Evaluation		Adaptation
		Origination

The authors recognized that their institutional mission statement expects both education (cognitive domain) and inspiration (affective domain) in their program. Furthermore, the authors believe that the engineering education profession is setting an expectation for student development in both of these domains. In particular this trend is evident in the American Society of Civil Engineers (ASCE) Body of Knowledge 2 (BOK2)[8] and has been studied in detail by the third author [9-13]. As such, courses in the Academy's civil engineering program strive to develop their students in both domains.

The purpose of this paper is to present the structure and assessment of a learning experience in one of the civil engineering program courses (CE495 – Transportation Engineering) at the United States Military Academy. The experience is a road design and construction briefing, and oral exam. The briefing and oral exam is intended to simulate a realistic environment typical of recent graduate military engineer officers, and with a project that is based on the real-world experiences of the faculty. The paper will detail the course, the road design and construction project, and the briefing and oral exam. An assessment will then be presented with respect to the CE495 Transportation Engineering course objectives, civil engineering program student outcomes, and department mission to educate and inspire.

Literature Review

The original concept of the experienced based learning in the CE495 – Transportation Engineering was presented in the 2010 ASEE Conference Paper – "Development of an Introduction to Transportation Engineering Course - Using experience-based learning to bring Afghanistan into the classroom [14]." This initial offering recognized that the program's graduates would likely deploy to challenging environments where road design and construction includes security concerns, cultural and social considerations, material availability (or lack thereof), limited contractor expertise and availability, military operational concerns, and commander expectations. As such, the course was well suited for a learning experience that required students to engage in developing and communicating solutions for complex problems. Furthermore, the authors believe that such a learning experience energizes the students directly, and also the faculty indirectly – resulting in a more inspiring classroom environment. Simply stated by Harold Hongju Koh, "Theory without practice is as lifeless as practice without theory is thoughtless [15]."

It is well researched and documented that problem based learning is well suited for engineering programs for students to engage in complex, ill-suited, and open-ended problems to foster flexible thinking and support intrinsic motivation [16]. These characteristics in turn can increase opportunities for group discussion over potential solutions, provide opportunity for critical instructor feedback, and essential self-reflection of the learning.

A. Kolb and D. Kolb define Experiential Learning Theory as the "process whereby knowledge is created through transformation of experience. Knowledge results from the combination of grasping and transforming experience. [17]" As defined, students undergo experiential learning through experiences in a concrete fashion (actual personal experiences) and abstract conceptualizations (simulations). Through reflective observations and feedback, the students gain a deeper understanding and ultimately knowledge.

Andresen et. al. outlines the student development in EBL as process as follows[18]:

1. Students engaged in EBL are involved through their senses, feelings, and intellect, at varying levels,
2. Students can recognize and relate lessons to personal learning experiences,
3. Students can reflect upon earlier experiences and transform them into deeper understanding.

Instructors also play a key role in these learning experiences; Hmelo-Silver states that they should be considered facilitators, serving as motivators, guiding students through various stages of the experience, monitoring the group experience, and aiding in self-reflection through well-directed questioning to individual students [16].

The current configuration of CE495 has evolved the experienced-based learning event over several iterations and leverages the well-established motivations for complex engineering problems. The course and the project of interest is presented in what follows.

CE495 – Transportation Engineering

Course Scope, Objectives, and Structure. The course covers a wide variety of transportation engineering topics in similar courses: highway geometric design, pavement design, traffic flow analysis, queuing, road level of serviceability, and signalized intersection design. The culminating exercise requires students to design and plan the construction of a road in a deployed combat setting overseas, thus enhancing the students' level of understanding of the general field of transportation engineering. The course has three primary objectives:

1. Design a road, to include vertical and horizontal characteristics of a curve, and establish layer depth and materials to use when developing a rigid or flexible pavement road.
2. Design the width of a road in terms of lanes by considering road characteristics, traffic flow, queuing, and level of serviceability.
3. Design a road and follow its construction process under deployment constraints in Afghanistan.

A portion of the composite course is focused on road and highway design and the other portion of the course is focused on applying the highway design fundamentals to a road construction project. The primary topics associated with the highway design portion of the course are listed in the course scope and are covered during the first two-thirds of the course and the road construction project encompasses the final third of the course.

Road Design and Construction Project. The CE495 road construction project is related to a need of creating a bypass around a small village in southern Afghanistan. The existing route through the village is narrow and there is concern with damaging buildings in the village during retrograde operations as several forward operating bases and other tactical infrastructure are being closed. The project is completed in groups of three to four students and accounts for nearly 20% of the overall graded requirements. The project itself has six different graded portions:

1. **Preliminary Centerline and Reconnaissance Plan:** The project is open-ended and students select an initial bypass route, while considering cultural, political, and social impacts. The instructor provides feedback, answers requests for information, and works with each group to determine an acceptable bypass route.
2. **Road Geometry and Earthwork:** Students design the geometric layout of the road, including horizontal and vertical curves, a typical cross-section, and earthwork.
3. **Pavement Design:** Students design a flexible pavement surface to carry the loads anticipated during operations and for sustained use by the local Afghanistan population.
4. **Drainage Design:** Students design culverts to ensure the road does not flood, nor does it negatively impact the nearby agricultural fields.
5. **Construction Plan and Schedule:** Students develop a construction plan, given horizontal construction assets such as scrapers, loaders, dump trucks, graders, rollers, etc. Teams build a project schedule that includes the critical path, limiting factors, and resources required to crash the project. Security must also be incorporated into the construction plan.
6. **Briefing and Oral Exam:** Each team briefs their roadway design, construction plan and schedule, and security plan to the instructor. The instructor then asks individual questions to all members of the team to assess their understanding of the overall project.

Assessment

The course is assessed with respect to the CE495 course objectives, the department mission, and the civil engineering program student outcomes. The third course objective in Table 2 is focused specifically toward the experiential activity, the road design and construction project.

CE495 Course Objectives: Course objectives are assessed annually as part of the civil engineering program's course assessment process. Course directors apply a standardized rubric based on student performance on graded requirements as shown below. The definition of "meeting a course objective" is achieved by a "C" level (70%) on the graded requirement.

- **1= Objective Not Met**. Most (75%) of the students did not achieve it.
- **2= Objective Marginally Met**. Objective met by half the students or minimally by most.
- **3= Objective Satisfactorily Met**. Objective clearly met by a majority (70%) of the students.
- **4= Objective Solidly Met**. Objective clearly met by the vast majority (90%) of students.
- **5= Objective Clearly Met**. All students achieved the objective.

The CE495 course assessment for spring academic term in 2015 is shown below in Table 2 and demonstrates the course solidly met the objectives. The percentages in the "Assessment Event and Average Score," pertain to the average score achieved by students across the course. Although not listed in the table below, the number of students achieving less than 70% is also incorporated into the assessment ratings of 1-5 as defined above.

Table 2. Spring 2015 Course Assessment of CE495 Course Objectives.

Course Objective	**Assessment**	**Assessment Event and Average Score**
1. Design a road, to include vertical and horizontal characteristics of a curve, and establish layer depth and materials to use when developing a rigid or flexible pavement road.	4	Associated Homework Exam I: 81% Exam II: 88%
2. Design the width of a road in terms of lanes by considering road characteristics, traffic flow, queuing, and level of serviceability.	4	Associated Homework Exam I: 81% Exam II: 88% Final Exam: 90%
3. Design a road and follow its construction process under deployment constraints in Afghanistan.	4	Project submissions Average: 87%

Department Mission: Indirect indicators, such as anonymous student course end feedback are also used to assess the course, particularly with regard to the department mission, "*To educate cadets in civil and mechanical engineering, such that each graduate is a commissioned leader of character who can understand, implement, and manage technology; and to inspire cadets to a career in the United States Army and a lifetime of personal growth and service.*"

Students from across the United States Military Academy answer 11 common questions in a mandatory course-end feedback system and results from the course (CE495) are compared to aggregated course data for the Civil Engineering Division (CE Div), the Department of Civil and

Mechanical Engineering (C&ME), and the academy (USMA). Figure 1 illustrates the course was positively received by the students as the course received higher ratings for each of the 11 questions. Of note, students in CE495 reported that their "motivation to learn and to continue learning increased" and their "critical thinking ability increased" at a higher rate.

Students also provided positive remarks as part of the course end feedback, such as:

- "This was one of the most enjoyable courses I have taken at the academy."
- "The class was very well organized, allowing the students to learn and understand the different processes of road design."
- "The road project was fair and useful."
- "This was one of the most structured courses I have taken at the Academy, which I think is why I found the material so digestible. Always had learning objectives and stuck to the plan. Highly organized."
- "Awesome course."

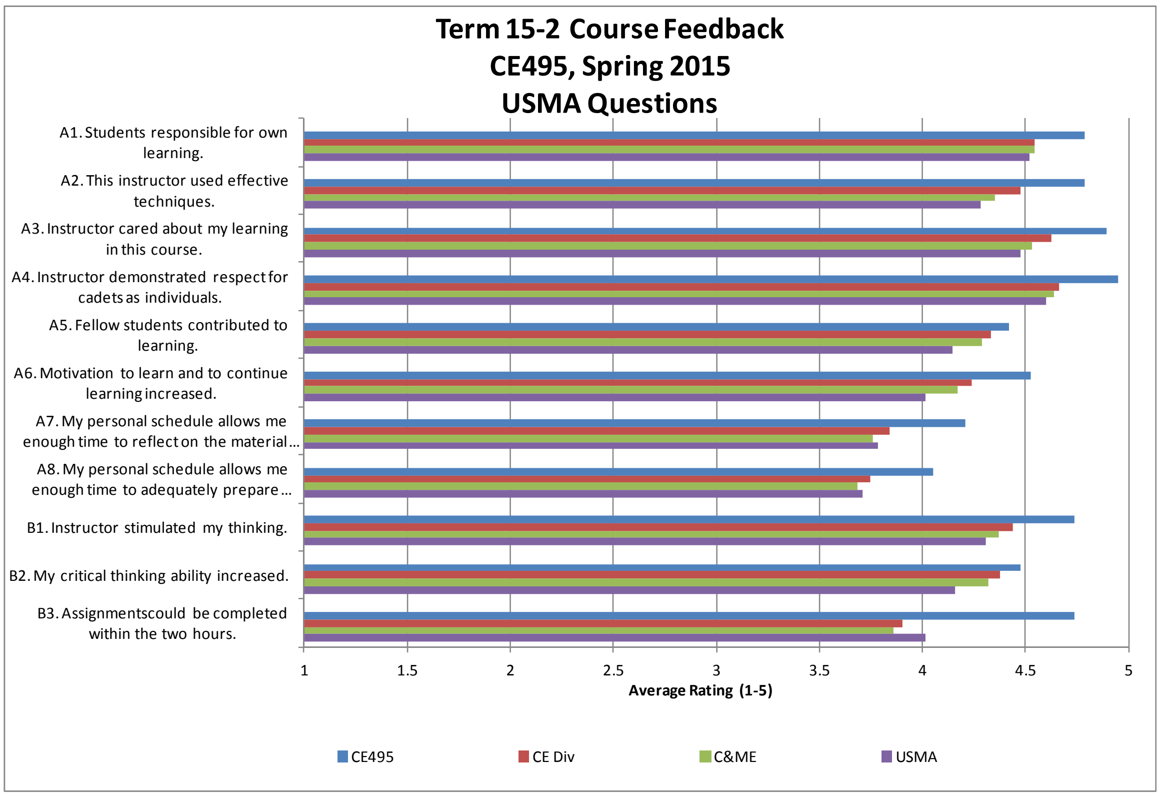

Figure 1. Course-End Feedback, CE495.

The authors feel this composite course serves to impact the cognitive development of students by educating them in aspects of both transportation engineering and construction management. The authors also feel the course impacts the affective development while contributing to the mission accomplishment of the Civil and Mechanical Engineering Department and inspiring our future civil engineers.

Civil Engineering Program Outcomes: Of the sixteen civil engineering program student outcomes, three outcomes are directly related to the project in CE495:

2. *Demonstrate creativity, in the context of engineering problem-solving.*
10. *Speak effectively.*
11. *Incorporate knowledge of contemporary issues into the solution of engineering problems.*

Similar to the assessment of the course object the student outcomes were assessed as follows:

Table 3. Civil Engineering Program Outcomes.

Course Objective	Assessment	Project Evaluation
2. Demonstrate creativity, in the context of engineering problem-solving.	4	Overall Project Grade Average: 87%
10. Speak effectively.	4	Briefing and Oral Exam: Average: 90%
11. Incorporate knowledge of contemporary issues into the solution of engineering problems.	4	Preliminary Recon Plan Average: 92% Briefing and Oral Exam: Average: 90%

Conclusion

To further assess the project in terms of realism and potential impact on the graduates, the third author assessed the project with respect to military engineering training and experience. His assessment is presented herein as a conclusion.

The benefit CE495 provides the young military engineer tasked with road construction in a combat theater of operations such as Afghanistan is invaluable. While the first military course for engineers during the Engineer Officer Basic Course at Fort Leonard Wood, MO, refreshes newly commissioned engineers on the basics of geometric design, earthwork, and developing a construction plan and schedule, the experience-based learning opportunity to test this knowledge in a combat construction setting is not afforded due to time constraints. Outside of a course geared towards military transportation engineering, the best option a young military engineer has to gain a deeper understanding of designing roads that meet performance specifications in a combat-oriented, time-constrained environment is tapping into the knowledge base of his veteran peers and non-commissioned officer corps as he plans his first mission.

While the course project scenario is different than the missions that platoons conduct in theater, the military engineer considers similar factors in the planning and design phase for a major road rehabilitation project. In several instances the course project scope actually extends beyond the typical expectations of an engineer platoon leader conducting combat construction in an austere environment. Having said that, while the scope of the mission may not include the new construction of a long segment of road, an engineer platoon leader still considers vertical and horizontal curve characteristics, layer depth and materials for pavement design, and the road characteristics, traffic flow, and level of serviceability required for the road width determination. The project scenario includes the unique challenges inherent to road construction projects, such as manpower, equipment, time, and resource constraints. These special considerations provide the student with a truly realistic experience-based learning scenario that challenges them as future military engineers to think critically through what they have learned and apply it within a simulated environment. Essentially, the experienced-based learning scenario provides the students with a useful practical application that prepares them as future military engineers tasked with planning, briefing, and executing road construction.

The CE495 road design and construction project has evolved over several years and is continually assessed with respect to course objectives, Department mission, and civil engineering program student outcomes. The authors believe the project is realistic and challenging, and meets the assessment goals as presented in this paper. The approach is being consider for other courses in the program and will hopefully inspire other engineering instructors to develop and execute similar projects in their courses.

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