Highlighting Cultures, Civilizations, and Diversity in Historical Civil Engineering Achievements

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Abstract

Technical advances throughout history provide a pathway to investigate diverse cultures and their global impact within the context of Civil Engineering. While the Virginia Military Institute (VMI) requires undergraduates to take two writing-intensive courses and two humanities courses (referred to as civilization and cultures courses), no current course explores the historical contributions of Civil Engineering to society as a whole. The following work seeks to fill this gap by developing a new course investigating the contributions of diverse cultures through the lens of technology appropriate for both STEM and non-STEM students. This paper defines an approach based mainly on case studies to educate and engage students using historical turning points in Civil Engineering. Topics in transportation, environmental, water resources, structural, geotechnical, and military engineering are integrated into this writing-intensive course, as students reflect on both time and place throughout the history of humankind.

Keywords

Civil Engineering, History, Humanities, Writing Intensive

Introduction/Background

Humanities courses are required for engineering majors, but the type, subjects, and requirements vary. Some curriculums may include engineering history, but this is typically included in a survey or seminar class. The rich history of civil engineering (CE) provides insight into how diverse cultures posed intellectual challenges, which CE answered, a topic typically absent from non-technical humanities curricula. Examining this history is beneficial to engineering students and non-STEM students.

Like most universities, the core curriculum of VMI requires an undergraduate student to take two humanities courses referred to as civilization and cultures courses (designated as "C&C") and two writing-intensive courses (designated with the suffix "W")[1,2]. At least one of the W courses must be in the cadet's major, while C&C courses may be taken from any department on campus. Every academic department offers these courses, which may not be STEM-based or technical in content. The courses are each worth three credit hours and are offered every semester, including summer school. While not required, typically, over 50% of C&C courses are also a W course.

The C&C classes do, however, support the ABET Criterion 5(c) to have a "broad education component that complements the technical content of the (engineering) curriculum…" [3]. Appropriately, these courses are listed as humanities courses, not as engineering technical electives, even if they are taught in an engineering department. While there are generally

sufficient C&C and W courses available at VMI, no course broadly discusses the historical advancements of CE's various subdisciplines in a non-technical way with student writing requirements. The following work endeavors to fill this gap by developing an inspiring CE writing-intensive humanities course that discusses diverse cultures' contributions in worldwide civil engineering achievements. This paper identifies the approach and rationale to educate and engage students through case studies and historical turning points in civil engineering. Weaponry and military advancement in infrastructure are envisioned as a part of this course to foster interest and feedback among students from all academic majors at VMI, a military school.

Additional benefits are envisioned for students who might select this course. The schedule at VMI is tightly constrained with little opportunity for flexibility beyond required courses, and this course would provide an additional option within the existing framework. This course could be especially beneficial for those students who transfer significant credits before matriculating into VMI. There are very few 200-level courses (sophomore level) currently available for them to take in engineering. For freshman and sophomore CE students who take this course, it would be especially beneficial to help them identify their preferences for the various CE subdisciplines earlier in their academic experience.

Course contents

The core contents of this course will discuss innovations within the CE's subdisciplines as well as applications of those innovations over time. Initially, the total syllabus will be split into sections based on CE's subdisciplines, i.e., structures and materials, environmental, water resources, geotechnical, transportation, and weaponry/military advancement in infrastructure. Under each section, topics will be introduced based on their significance in the time period they were invented. These inventions are associated with diverse cultures based on their implementation in a given time period, region and CE subdiscipline (Figure 1). More details for each CE subdiscipline, including a tentative lesson plan (Table 1) and proposed activities, can be found below.

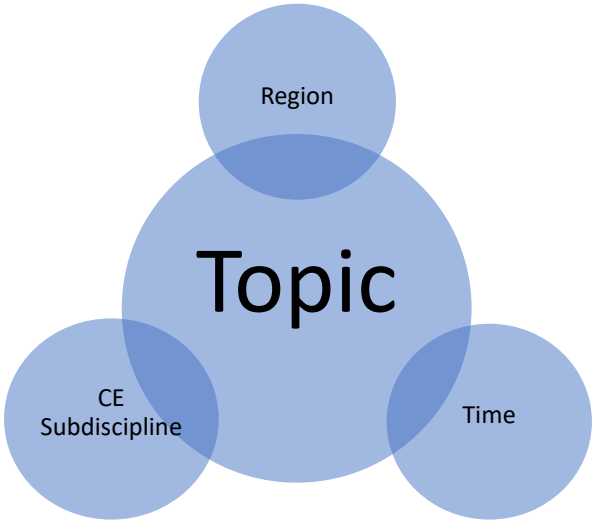

Figure 1: 3-Dimensional course contents for this W and C&C course

Section 1: Structures and Materials

The structural engineering and materials section will mainly focus on the use of iron throughout civilization. Many engineered materials have been essential to civilization, but the development of the use of iron can be traced back for at least 3000 years. One of the most prized materials since antiquity, iron was used for agriculture, weapons, and bridges in limited applications because of its rarity and value. Once mining and blast furnace techniques were developed, the price decreased, and its use increased astronomically. Early exploration in America led to iron mining and eventually the development of metallurgy in the 1800s[4]. This section's lessons will include the history of the steel-making industry, the development of the processes to make alloys, current uses of alloys in the military and space programs, and the applications of Corten/Triton for exposed structures. The history and construction of some iconic structures would include the Eads Bridge, the Home Insurance Building, and the Golden Gate Bridge.

Section 2: Environmental

The act of keeping the environment that humans inhabit clean and safe has been a priority to varying degrees since the development of cities and towns resulted in humans living closer to each other. As cities hosted more and more people in a confined setting, the removal of waste, provision of clean drinking water, and supply of clean air became an increasingly important and complicated issue. The environmental section of this course will focus on the development of drinking water treatment technologies such as coagulation, filtration, and disinfection. Additional topics will include the importance of having separate waste and water systems (John Snow and the cholera outbreaks in London, sewer development in Paris, Chicago River flow reversal), the proper disposal of industrial waste (Cuyahoga River fire, equity of waste disposal, and landfill construction), and the issue of smog and air quality (Los Angeles, CA, USA; Beijing, China; and New Delhi, India).

Section 3: Water Resources

The history and context of the water resources section will begin with the aqueducts and water infrastructure designed and built by the Roman Empire. It has been stated that "if water is essential to life, then water supply is essential to civilization" [5]. From the days of the Roman Empire and the growth of civilization, the cultural importance of protecting the water supply and working to ensure access for years to come is a valuable concept and lesson for young Civil Engineers to learn. In addition, examples of this lesson in early modern history include the construction of the qanats in Northern Iraq, the Greek canals in Troy and Athens, and the Grand Canal in China. This section will examine the worldwide trends in dam construction, the distribution of water from the Colorado River, and the stormwater and dyke system of the Netherlands, ending by comparing access to water across many geographic regions.

Section 4: Geotechnical

Until the 18th century, no theoretical basis for soil design had been developed, and the discipline was more of an art than a science, relying on past experiences. Humans have historically used soil as a material for flood control, irrigation purposes, building foundations, and as a construction material for buildings. This section will follow the water resources section because

they are related. The section will discuss the activities linked to irrigation and flood control, as demonstrated by traces of dykes, dams, and canals dating back to at least 2000 BC. Then it will discuss the Tower of Pisa's foundation problems, the history of the development of earth pressure, the creation of the soil classification system, and principles related to flow through a porous medium. From there, this section will cover the development of "modern geotechnical engineering," including the bearing capacity of foundations, earthquake engineering, and a description of soil behavior. The geotechnical section will conclude by briefly covering the mining of materials like saltpeter, sulfur, uranium, etc., and the extraordinary durability of Roman roads due to their geotechnical foundations.

Section 5: Transportation:

From horses and the earliest invention of the wheel to the first flight of the space shuttle, transport has a history over 5,000-years old. This section will begin in 4000 BC, when horses and camels were used for transporting people and goods. Gradually, lessons will introduce historical turning points in transportation, including the construction of paved roads by the Romans, the introduction of public transport, the invention of the bicycle, and modern transportation methods including steam-powered locomotive trains, airplanes, cars, and space travel. This section will compare the transportation facilities and development of infrastructure disparity between different regions of the world. Impacts of innovative, eco-friendly, and modern transportation facilities on people's lives will also be discussed.

Section 6: Military Systems:

Throughout history, military superiority has relied on and driven technological advances. While weaponry and armor are primary tools of war, military structures and machines illustrate technologies where civil engineering principles are widely applied. These lessons may be organized both topically and by direct connection to a dominant culture in each epoch. For example, fortress location, design, and construction elements are one structural module. The technology of sailing vessels is another important structural topic encompassing hull design, armor, and locomotion. A module focusing on machines will include battering systems, catapults, trebuchets, and siege towers, among others. A study of how technology impacted military dominance will include the Chinese (1750-100 BC), the Tartars/Mongols/Huns (400-500 AD and 1250-1400 AD), and Turks (1000-1100 AD and 1300-1600 AD). Finally, the course will conclude by investigating how Civil Engineering contributed to the Spanish, French, and English military might from 1500-1900 AD. Advances in the 20th and 21st centuries will be reserved for individual study and paper topics.

Proposed Activities:

i. Visit local bridges and view the use of the 4 primary structural building materials on campus.

ii. Visit local flood control structures to understand risk control and the impacts on communities.

iii. Field trip to the second-largest pumped-storage project in the world to reflect on energy infrastructure.

iv. CE history scavenger hunt within the local area to identify and remind students of the invisibility of technology that surrounds us.

v. Visit the VMI museum to know more about civil engineering's contribution to the military system.

vi. Visit the VMI's heating plant to better understand the importance of water chemistry (softening), flow demand/capacity management, and sanitation.

vii. Visit the nearby historical Natural Bridge State park to see the intersection of transportation planning, water resources (creek and dam), and environmental engineering (wastewater treatment plant).

Table 1: A tentative lesson plan for the proposed course

Week	Topic/Subdiscipline*	Assessment
1	Introduction to the course, Civil Engineering overview, introduction to writing	Introduce technical paper and library resources
2	Section 1: Structures and Materials	
3		Reflection essay
4	Section 2: Environmental	Technical paper 1 draft
5		Reflection essay
6	Section 3: Water Resources	Technical paper 1 final
7		Reflection essay
8	Section 4: Geotechnical	
9		Reflection essay
10	Section 5: Transportation	Technical paper 2 draft
11		Reflection essay
12	Section 6: Military System	Technical paper 2 final
13		Reflection essay
14	Class Wrap up Discussion and Reflection	Discussion on students' technical paper(s)

*Field trips will be interspersed throughout.

Course evaluation

As this newly developed course will serve as both a W and C&C course, course outcomes will be evaluated by assigning a reflection essay (1-2 pages) on each of the major topics in the class and two technical papers (4-5 pages). The technical papers will require the students to resubmit their papers at least once after receiving feedback. For some of the assignments, the students will choose their own topics. For the rest of the assignments, instructors will assign the topics. Instructors will not look for the "correct answers", rather all the assignments will aim to push the students to connect engineering processes to human problems in the infrastructure. A broad category of topics will be assigned, including "fact check" and "what if" scenarios of civil engineering's histories.

A set of reflection essay topics could include:

i. Fact finding: Do all innovations have real value? (Example-3D concrete printing). Justify your choice.

ii. What if: What impacts could be expected if the widespread availability of electrical power had been delayed 10 years? Or a generation? What possible changes might we have experienced?

iii. Among the numerous theories proposing how the Pyramids were built, which one(s) seems most logical to you? Justify your choice.

iv. Among all the distinct civilizations (for example, Mesopotamia, Egypt, Rome, etc.), which one made the most significant contribution to shape the history of humankind or had significant impacts on the discipline(s) in CE to improve people's lives?

v. If you were a billionaire, what technologies would you strategically invest in to positively impact people's lives?

vi. Which current policy or application of technology would you propose changing in a developing country to make people's life better?

vii. What technology would you like to invent to improve one element of infrastructure? The proposal need not be technically possible, but must address a real problem.

viii. What technology will most significantly affect the future of transportation?

ix. How has the advancement within one element of infrastructure saved significant human lives?

x. Many mature technologies in current use remain effective. Research the opportunity for advancement in one of these and why these advances may be delayed. Does its effectiveness overshadow possible improvements?

Technical Paper Assignment topics:

Goal: to have the students choose a topic of interest, use the library resources to find peer-reviewed sources, and integrate those sources to support logical arguments or viewpoints.

i. Topic 1: Investigate the history and development of a particular piece of infrastructure.

ii. Topic 2: For the piece of infrastructure that was researched for topic 1, discuss whether this piece of infrastructure could be placed in another region or country of the world. What design considerations would have to change to meet the needs of the new location and the population that lives there? Use examples of existing infrastructure or the needs of the population in that area.

Conclusions

This paper discusses the development of a writing-intensive humanities course, open to any major, to inspire and engage students across different majors by exposing them to the diverse accomplishments of civil engineering throughout history. The course is based on case studies and historical turning points in technology with an emphasis on infrastructure and society. Topics in transportation, environmental, water resources, structural, geotechnical, and military engineering are integrated into this course, revealing how civil engineering has impacted and improved the quality of life for societies throughout history. Exploring advances in these fields within the framework of time and place adds a 3-dimensional aspect to technology. A tentative list of historic turning points and case studies, weekly lesson plan, and assessment methods, including possible topics for writing-intensive assignments, are briefly discussed.

The development of this course will shed light on how cultures advanced largely due to the civil engineering disciplines, a viewpoint lacking from the typical non-STEM curricula. Adding this history-based course to VMI's Civilization and Cultures (C&C) and writing-intensive (W) course collection would benefit STEM and non-STEM major students, especially those students who transfer significant credits before matriculating into VMI. Additionally, for freshman and sophomore students, this course will stimulate consideration of STEM fields in general and help declared engineering majors identify preferences for the various CE subdisciplines earlier in their academic experience.

As developed and presented, the authors hope other institutions will readily adopt this course to enrich their humanities course collection while simultaneously learning through the lens of the oldest engineering profession.

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