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Leveraging the ASCE ExCEEd Modelto Design a Course on Sustainable Infrastructure Development

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Abstract

Environmental, social, and economic considerations, commonly called the “triple bottom line” of sustainability, are critical components of a civil engineering education. Currently, civil engineering programs typically teach sustainability indirectly, generally as a theme accompanying more conventional disciplines or through select embedded lessons within traditional courses. Some universities employ upper-level electives, clubs, or even independent study experiences to teach sustainability principles to undergraduates. Many courses dedicated to sustainable development are limited to graduate programs. In this paper, we present the results of a faculty team’s efforts to design a new course on sustainable infrastructure development as a part of undergraduate civil engineering curricula. We conduct benchmarking with existing programs that teach infrastructure and sustainable development as explicit courses within civil engineering. We crosswalk the pedagogical framework within the American Society of Civil Engineers (ASCE) Excellence in Civil Engineering Education (ExCEEd) Model to the draft syllabus and specific elements of the new course, to include a structured organization with appropriate learning objectives for each lesson, in-class activities, and proposed out-of-class assignments. We further map specific learning objectives and learning activities to requirements for program accreditation by ABET. The resulting course syllabus schedule, learning objectives, and crosswalk to accreditation criteria can serve as a model for faculty seeking to expand their course offerings within the civil engineering program.

Introduction

Civil engineering programs seeking accreditation by the Engineering Accreditation Commission (EAC) of ABET are required to include application of sustainability. Criterion Three of the EAC General Criteria requires seven Student Outcomes, describing expectations for students’ abilities at the time of graduation from an accredited engineering program. Student Outcome #2 requires “an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors” and Student Outcome #4 requires “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts” [1]. Clearly embedded within these two outcomes are the triple bottom line of sustainability. Furthermore, Program Criteria from the American Society of Civil Engineers (ASCE) requires that curriculum include application of the “principles of sustainability, risk, resilience, diversity, equity, and inclusion to civil engineering problems,” application of “an engineering code of ethics,” and application of “professional attitudes and responsibilities of a civil engineer” [1]. The importance of these criteria is reflected directly within the preamble to ASCE’s Code of Ethics, which provides four fundamental principles for engineers to govern their professional careers, the first being to “create safe, resilient, and sustainable infrastructure” [2]. The importance of sustainability, both within civil engineering education and the civil engineering profession, is well established.

Literature Review

As global demands on resources and the environment continue to increase due to such factors as increasing population, the sustainability theme continues to grow in importance. Educators are regularly developing or updating courses to tackle related issues. More specifically, educators in engineering disciplines continue to weave sustainability themes into their respective curricula, or develop stand-alone courses, to inspire the next generation of engineers to develop creative solutions to complex problems.

As this issue continues to be a global in its nature, many programs in the United States seek to build their courses with international partners in mind. There are examples of programs at Colorado State University that have partnered with universities in Asia in a sustainability course focused on resilient infrastructure in the water resources sector [3], while another program at the University of Utah built a distance-learning course looking at sustainable infrastructure of the host nation during a study abroad program [4]. Additionally, programs both inside and outside of the United States have built engineering courses based on the United Nations Sustainability Development Goals. As an example, educators at the National University of Kaohsiung in Taiwan mapped the Sustainable Development Goals throughout numerous courses in their program [5], and educators at the Stevens Institute of Technology in New Jersey incorporated the Sustainable Development Goals with the Institute for Sustainable Infrastructure's Envision Rating System in a senior capstone design course [6]. These examples of international partnership demonstrate the potential support network for educators in the United States as we adjust or build courses in support of ABET Student Outcomes and ASCE Program Criteria.

Recent work in the development of sustainability threads and courses has shown that many programs are using problem-based and project-based learning approaches for delivery of course materials. Educational researchers at the University of North Carolina at Charlotte found that students not only had a generally favorable perception of problem-based learning, but that they were more aware of and confident in their ability to address associated ill-defined problems [7]. As another example, educational researchers at the Virginia Polytechnic Institute and State University used a problem-based learning approach related to a wastewater project [8]. Their work combined engineering and behavioral science to provide their students with a deeper understanding of complex problems related to sustainability. In comparison, educators at the University of Puerto Rico used project-based learning across a curriculum on sustainable and resilient infrastructure [9]. The implementation of this effort was motivated by recent devastation to the local infrastructure resulting from hurricanes.

While these examples of partnership opportunities and delivery methods for course materials demonstrate flexibility in course development in sustainability, it should also be pointed out that the course audience does not have to be restricted to engineering students. While many of the courses were focused on senior level engineering classes [8] or a mixture of STEM-based students [3], [9], other courses were successful teaching the principles to interdisciplinary teams comprised of engineer and non-engineer students alike [4], [7]. Given the triple bottom line of sustainability, the nature of ABET Student Outcomes (specifically #2 and #4), and the framework of the ASCE Program Criteria, it is promising to see demonstrated success in this topic area via a diverse range of student disciplines. This factor is especially important at the authors' institution, which requires non-engineer academic majors to participate in the three-course core engineering sequence.

This paper proposes a new undergraduate course in Sustainable Infrastructure Development for a mixture of STEM and non-STEM students at the United States Military Academy (USMA) at West Point, New York. USMA requires all graduates to complete a three-course core engineering sequence that complements their academic major and interests. Options include Infrastructure Engineering, Cyber Engineering, Robotics Engineering, Environmental Engineering, Nuclear Engineering, and Systems Engineering. This proposed course would serve as the introductory course in the Infrastructure Engineering core engineering sequence. Although the primary instructors would be from the Civil Engineering faculty, students could be majoring in everything from Civil Engineering to English and Philosophy. This diverse mix of students presents a unique opportunity for broad perspectives and thoughtful discussions on a topic that relates to all of society.

The authors have developed a draft course syllabus/schedule based on concepts presented in the ExCEEd Model in Figure 1 [10]. Special attention has been given from the start to create a highly structured organization with lesson learning objectives that nest to course learning objectives that further nest to university-level Academic Program Goals, ASCE Program Criteria, and ABET Student Outcomes. In-class and out-of-class activities are designed to be varied and appeal to different learning styles as would be expected in such a diverse group of students and academic majors. Course projects will leverage appropriate technology to ensure students are conversant and capable in the latest related software and data. Department policies, faculty development, and culture will facilitate engaging presentation, positive rapport with students, and frequent assessment of student learning.

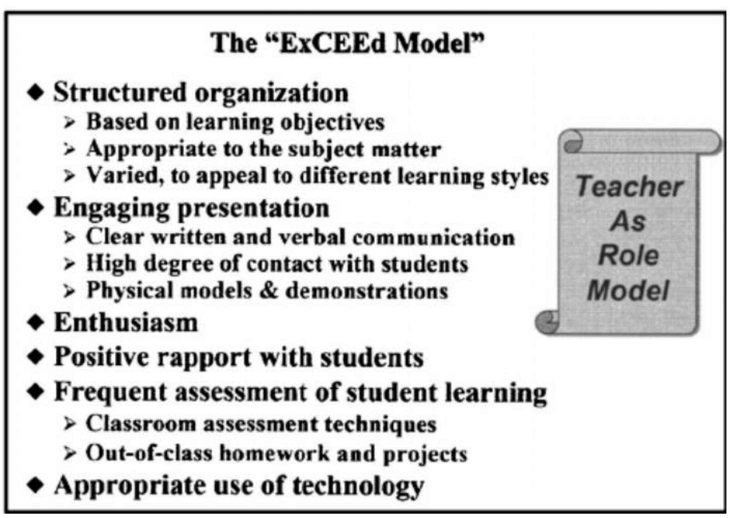

Figure 1: The ExCEEd Teaching Model by Estes, Welch, & Ressler [10]

The proposed course, CE300X: Sustainable Infrastructure Development, must first nest within the Infrastructure Engineering core engineering sequence. Table 1 details the course objectives for the two courses that would follow the course proposed in this paper, CE350: Infrastructure Engineering and CE450: Construction Management. The purpose of the Infrastructure

Engineering core engineering sequence is to focus "on the design, analysis, and construction of the built environment, (i.e., man-made structures and facilities used to accommodate societies' activities). Cadets learn about the importance of the infrastructure sectors, such as water, power, and transportation, and their interrelationships" [11]. The integrative experience for the Infrastructure Engineering core engineering sequence is the designing, planning, and presenting of a construction management plan for a contingency base camp within a combat theater of operations.

Table 1: Sequence of courses and course objectives in the Infrastructure Core Engineering Sequence

CE350: Infrastructure Engineering (offered since 2011)	
1.	Identify, assess, and explain critical infrastructure components and cross-sector linkages at the national, regional, and municipal levels.
2.	Calculate the demand on infrastructure components and systems.
3.	Assess the functionality, capacity, and maintainability of infrastructure components and systems.
4.	Evaluate infrastructure in the context of military operations.
5.	Prioritize and recommend actions to improve infrastructure resilience.

CE450: Construction Management (current form offered since 2011; lineage 100+ years)	
1.	Develop, refine, and manage the triple constraints of a project (Scope, Budget, and Schedule) throughout the Project Life Cycle Phases.
2.	Plan, organize, estimate, schedule and control a construction project (Project Imperium)
3.	Design a base camp and plan its construction.

This series of course objectives must nest with the university-level Academic Program Goals and "What Graduates Can Do" statements. Top-level Academic Program Goals for USMA are shown in Table 2 and support USMA's overarching academic goal that "graduates integrate knowledge and skills from a variety of disciplines to anticipate and respond appropriately to opportunities and challenges in a changing world".

Table 2: Top-level Academic Program Goals at USMA

1.	**Communication**: Graduates communicate effectively with all audiences.
2.	**Critical Thinking & Creativity**: Graduates think critically and creatively.
3.	**Lifelong Learning**: Graduates demonstrate the capability and desire to pursue progressive and continued intellectual development.
4.	**Ethical Reasoning**: Graduates recognize ethical issues and apply ethical perspectives and concepts in decision making.
5.	**Science/Technology/Engineering/Mathematics (STEM)**: Graduates apply science, technology, engineering, and mathematics concepts and processes to solve complex problems.
6.	**Humanities and Social Sciences**: Graduates apply concepts from the humanities and social sciences to understand and analyze the human condition.
7.	**Disciplinary Depth**: Graduates integrate and apply knowledge and methodological approaches gained through in-depth study of an academic discipline.

Each of the top-level Academic Program Goals have supporting "What Graduates Can Do" statements. Depending upon if a program is an academic major or a core engineering sequence, each "What Graduates Can Do" statement is assigned the role of either "introduce" or "reinforce" [12]. Those meant to introduce must facilitate students attaining a minimum acceptable level of achievement, whereas those meant to reinforce must support students attaining a higher level of achievement. If a "What Graduates Can Do" statement is assigned to the core engineering sequence, then it must be clearly mapped to course and lesson learning objectives and activities. In a collective effort toward continuous improvement, these "What Graduates Can Do" statements must be annually assessed and reported through executive summaries (EXSUMs) to the university's Associate Dean for Curriculum and Assessment. The supporting "What Graduates Can Do" statements assigned to the core engineering sequence are shown in Table 3.

Table 3: "What Graduates Can Do" statements assigned to the required "Core Engineering Sequence"

2.1	Identify the essential aspects of a situation and ask relevant questions. (Reinforce)
2.4	Reason both quantitatively and qualitatively. (Reinforce)
2.5	Think innovatively and accept risk to pursue solutions in the face of ambiguity. (Introduce & Reinforce)
4.2	Recognize ethical components of problems and situations. (Reinforce)
5.1	Apply mathematics, science, and computing to model devices, systems, processes, or behaviors. (Reinforce)
5.4	Apply an engineering design process to create effective and adaptable solutions.
5.4.1	In an environment of uncertainty and change, identify needs that can be fulfilled via engineered solutions.
5.4.2	Define a complex technological problem, accounting for its political, social, and economic dimensions.
5.4.3	Develop appropriate alternatives to solve an engineering problem.
5.4.4	Apply mathematics, basic science, and engineering science to model and analyze potential solutions to engineering problems.
5.4.5	Communicate an engineering solution to both technical and non-technical audiences and recommend an engineering solution to a decision maker.
5.4.6	Demonstrate basic-level technical proficiency in an engineering discipline that is relevant to the needs of the Army.
7.4	Synthesize knowledge and concepts from across their chosen disciplines. (Introduce)
7.5	Contribute disciplinary knowledge and skills as a part of a collaborative effort engaging challenges that span multiple disciplines. (Reinforce)

Because this course may ultimately serve the Civil Engineering major as well, the faculty are taking steps to ensure the lesson and course learning objectives also support the ASCE Program Criteria to become effective for the 2024-2025 Accreditation Cycle (Table 4) and ABET EAC's General Criterion 3 Student Outcomes effective for the 2023-2024 Accreditation Cycle (Table 5) [1].

Table 4: ABET EAC General Criterion 3: Student Outcomes [1]

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Table 5: ASCE Program Criteria [1]

1. Curriculum

The curriculum must include:

1.a. Application of:

1.a.i. mathematics through differential equations, probability and statistics, calculus-based physics, chemistry, and either computer science, data science, or an additional area of basic science

1.a.ii. engineering mechanics, materials science, and numerical methods relevant to civil engineering

1.a.iii. principles of sustainability, risk, resilience, diversity, equity, and inclusion to civil engineering problems

1.a.iv. the engineering design process in at least two civil engineering contexts

1.a.v. an engineering code of ethics to ethical dilemmas

1.b. Solution of complex engineering problems in at least four specialty areas appropriate to civil engineering

1.c. Conduct of experiments in at least two civil engineering contexts and reporting of results

1.d. Explanation of:

1.d.i. concepts and principles in project management and engineering economics

1.d.ii. professional attitudes and responsibilities of a civil engineer, including licensure and safety

2. Faculty

The program must demonstrate that faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience.

Benchmarking

Civil engineering programs seeking ABET accreditation are required to include application of sustainability. Individual programs, however, have significant latitude in how and when to introduce students to the subject. The authors are members of the faculty at an undergraduate-only, four-year institution with approximately four thousand students in the Northeast United

States. The authors conducted an initial benchmarking of sixteen civil engineering programs in which a doctorate is not offered to assess the nature of sustainability's inclusion in the programs.

The original intent of the benchmarking was to identify common course themes, course wide objectives, block/lesson titles, and learning activities employed by other institutions, using that information to shape the proposed course. However, publicly-available course information generally included only the course number, title, and a brief description – information insufficiently detailed to use as a basis for course and syllabus design.

Consequently, the authors chose to benchmark the extent to which civil engineering programs dedicated courses to sustainability topics and themes. The secondary objective was to identify when within a student's academic experience they might take these courses and whether they were required or elective experiences. The authors explored the public course catalogs of each civil engineering program to answer the following questions:

- Does the program offer a "title-level" course on sustainability or sustainable development?
    - If so, is it a required or an elective course?
    - If not, does the program offer other courses that include significant themes or sub-topics concerning sustainability?
- What is the target student level for these courses? Are they intended as introductory undergraduate courses (100/200-level), junior/senior undergraduate courses (300/400-level) or graduate courses (400/500-level)?

Benchmarking of the sixteen civil engineering programs showed that "title-level" courses devoted to sustainability as the primary topic were rare. Those that existed were almost entirely 300- and 400-level elective courses targeting senior undergraduates and graduate students. Most courses instead addressed sustainability or sustainable infrastructure only as a theme or lens for analysis of other topics in the course (e.g., a "transportation engineering" course with a course description indicating consideration of sustainability during discussion of planning road networks).

Only two of sixteen universities benchmarked taught introductory-level courses focused on sustainability as a title-level topic. Teaching such a course to students early in their academic careers is a powerful assertion of the importance of dedicated instruction in sustainability. The authors offer the course objectives, lesson topics, and learning activities below as a detailed example of a "title-level" course in sustainability that could be adapted by any civil engineering program as an introductory experience for students.

Course Objectives

In order to codify CE300X course objectives (Table 6), the authors conducted a deliberate crosswalk informed by the ASCE ExCEEd Model and Program Guidance, University Academic Program Goals, and ABET Student Outcomes pertaining to sustainability. With this guidance as the framework, the authors independently drafted three to five course objectives and deliberated verbiage, content, and focus areas to arrive at the proposed result. The objectives identified in

Table 6 are also tied to graded assignments the authors will employ to evaluate the effectiveness of teaching and learning course material.

Table 6: CE300X Course Objectives

1.	Describe principles of sustainable infrastructure development.
2.	Identify and assess societal, environmental, and economic implications of infrastructure development options.
3.	Apply data and engineering science to quantify risk and resilience.
4.	Apply Life Cycle Assessment and the Engineering Design Process to recommend infrastructure solutions.
5.	Communicate technical solutions through effective writing and presentation.

Next, the authors established major blocks of content to support the five course objectives. Within each block, lesson objectives were matched to the appropriate subject matter and subsequent learning activities that appeal to varied learning styles.

Block 1: Introduction & Environmental

Table 7: CE300X Block 1 Lesson Objectives

Lesson 1: Introduction to Infrastructure & Sustainable Development	
1.A	Define infrastructure.
1.B	Define sustainable development.
1.C	Explain the "triple bottom line" as it relates to sustainability.
1.D	Discuss ASCE Policy Statement 418 and the Priciples of Sustainable Development (https://www.asce.org/communities/institutes-and-technical-groups/sustainability/asce-sustainability-policies/), do the right project, and do the project right.
Lesson 2: Environmental Considerations I: Global Warming Potential & Carbon	
2.A	Explain what global warming is and its impacts.
2.B	Identify the major contributors to global warming, their relative impacts, and their primary sources.
2.C	Describe positive and negative radiative forcing.
2.D	Discuss international conventions and global warming limit targets.
Lesson 3: Environmental Considerations II: Calculations in Carbon Emissions	
3.A	Describe the nexus between energy and the atmosphere with regard to carbon.
3.B	Explain the concepts of embodied carbon and embodied energy.
3.C	Quantify carbon emissions resulting from common infrastructure materials and components.
Lesson 4: Environmental Considerations III: Development & Pollution	
4.A	Describe various sources of pollution from civilization.
4.B	Explain the human development index and ecological footprint.
4.C	Use an online tool to estimate your personal ecological footprint (https://www.footprintcalculator.org/home/en).
4.D	Discuss global, political, and cultural considerations with regard to sustainable infrastructure development.
Lesson 5: Environmental Considerations IV: Quantifying Human Health Impacts from Pollution	
5.A	Define mortality and quantify the Value of Statistical Life using EPA values and inflationary adjustments based on the Consumer Price Index.
5.B	Define morbidity and quantify its contributory factors.
5.C	Describe the connection between pollution and human health impacts.
5.D	Calculate the negative impact of pollution on human health using World Health Organization statistics.
Lesson 6: Environmental Considerations V: Quantifying Environmental Impacts from Pollution	
6.A	Describe the sources and impacts of the following emissions: sulfur dioxide, nitrogen oxides, particulates, heavy metals, and fly ash.
6.B	Quantify emissions of the above from various sources of energy and transportation.
6.C	Discuss ways in which new or renovated infrastructure can reduce pollution.
Lesson 7: Case Study I – Water	
7.A	Discuss the causes and results of the municipal water system failures in Flint, Michigan.
7.B	Explain quality of life and stakeholder interests within this case study.

The introductory block of Sustainable Infrastructure Development provides students with fundamental definitions (infrastructure, sustainability, the Triple Bottom Line) while also conducting a thorough overview of environmental impact considerations surrounding infrastructure development. Proposed lessons on global warming potential calculations, carbon emission calculations, and land development requirements will facilitate student understanding of tradeoffs within the Triple Bottom Line. Lastly, the course will quantify both human health and environmental impacts from pollution, providing calculation methods that allow students to examine pollution concerns with sound analysis techniques.

Block 1 will draw on several documents and key resources. First, ASCE Policy Statement 418 "The role of the civil engineer in sustainable development" will support all lesson objectives in addition to providing the guiding principles of "do the right project and do the project right [13]." The course will also leverage www.footprintcalculator.org to provide an opportunity for students to estimate their personal ecologic footprint, either with our university location or by using their hometown to provide a wider aperture of diverse ecologic impacts.

The culminating case study for this block will be an analysis of the Flint, Michigan water system failure. Through examination of both the human health and infrastructure impacts of this disaster, the students will also discuss the concept of stakeholder interests.

Block 2: Social Considerations

Table 8: CE300X Block 2 Lesson Objectives

Lesson 8: Social Considerations I: Global & Cultural	
8.A	Discuss the United Nations' 17 goals of sustainable development (https://sdgs.un.org/goals).
8.B	Discuss the history and output of the United Nations' Intergovernmental Panel on Climate Change.
8.C	Define leapfrogging in terms of infrastructure development.
8.D	Compare and contrast development contemporary strategies of countries using the United Nations' Global Sustainable Development Report (https://sdgs.un.org/gsdr/gsdr2023).
Lesson 9: Social Considerations II: Politics & Policy	
9.A	Describe the genesis and implications of the Clean Water Act, National Environmental Policy Act, Rivers & Harbors Appropriation Act, Endangered Species Act, and Waters of the United States.
9.B	Describe how the US Army Corps of Engineers Regulatory Program enforces these laws in infrastructure development, operations, and maintenance.
Lesson 10: Social Considerations III: Public Health, Safety, & Welfare	
10.A	Identify potential impacts of infrastructure development on public health, safety, and welfare.
10.B	Discuss how historic and cultural resources, views and local character, and community wellbeing impact the design of sustainable infrastructure development.
10.C	Discuss the American Society of Civil Engineers' Code of Ethics (https://www.asce.org/career-growth/ethics/code-of-ethics).
Lesson 11: Social Considerations III: Diversity, Equity, & Inclusion	
11.A	Define the concepts of diversity, equity, and inclusion.
11.B	Discuss how these concepts apply to sustainable infrastructure development.
11.C	Discuss how leadership, collaboration, and stakeholder involvement contribute to sustainable infrastructure development.
Lesson 12: Case Study II – Transportation	
12.A	Discuss the impacts of transportation infrastructure development decisions as evidenced in Jane Jacobs v Robet Moses in NYC.
12.B	Explain quality of life and stakeholder interests within this case study.

Block 2 of Sustainable Infrastructure Development highlights social considerations pertinent for students to consider when evaluating the efficacy and impacts of proposed development decisions. Lessons include global and cultural awareness, politics and policy, and the concepts of diversity, equity, and inclusion applied to infrastructure development.

The Social Considerations Block will rely on several documents and key resources. First, the UN Sustainable Development Goals are central to providing students the full spectrum of sustainable development, facilitating thought beyond the build environment. The UN Global Sustainable Development Report adds assessment mechanisms to this objective by allowing comparison between countries. Next, the course will examine the U.S. Army Corps of Engineers role in federal policy enforcement, as well as where the ASCE Code of Ethics overlaps with responsibilities of engineers in development.

The culminating case study for this block explores Jane Jacobs' and Robert Moses' conflicting attitudes towards urban development in New York City. Through numerous examples of proposed or completed projects, students will apply stakeholder analysis to understand the implications construction can have on people and communities.

Block 3: Economic Considerations & Risk / Resilience

Table 9: CE300X Block 3 Lesson Objectives

Lesson 13: Economic Considerations I: How Projects Get Funded	
13.A	Describe the differences between the fiscal year President's Budget and Congressional authorizations and appropriations.
13.B	Summarize the federal processes that fund US Army Corps of Engineers civil works projects (https://www.usace.army.mil/Missions/Civil-Works/Budget/#!).
13.C	Discuss the influences upon government decision-making in funding infrastructure projects.
Lesson 14: Economic Considerations II: Social Cost of Greenhouse Gas	
14.A	Discuss the impacts of the Environmental Protection Agency's 2023 Report of the Social Cost of Greenhouse Gases (https://www.epa.gov/environmental-economics/scghg).
14.B	Compare the 2023 Social Cost of Greenhouse Gases to previous government estimates and other academic estimates (Table ES.1 of https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf & Table 4 of https://web.mit.edu/rpindyck/www/Papers/SCCRevisitedJEEM2019.pdf).
14.C	Explain the concept of a discount rate and the illustrate the impact on the Social Cost of Greenhouse Gases.
14.D	Calculate the Social Cost of Greenhouse Gases from a military installation.
Lesson 15: Economic Considerations III: Calculations in Mortality, Morbidity, and Value of Statistical Life	
15.A	Calculate mortality costs resulting from the effects of a component of infrastructure using the value of statistical life.
15.B	Calculate the morbitity costs resulting from the effects of a component of infrastructure.
Lesson 16: Case Study III – Energy	
16.A	Discuss historical examples of proposed and built power production facitilites in the Hudson Valley (https://omeka.hrvh.org/exhibits/show/rescuing-the-river/powering-the-hudson).
16.B	Identify stakeholders and their positions on the various types of proposed energy infrastructure.
Lesson 17: Field Trip - SUNY New Paltz Green Infrastructure Tour	
17.A	Observe and appraise the effectiveness of example sustainable infrastructure development projects. (https://www.newpaltz.edu/sustainability/view-programs-and-progress/green-infrastructure/)
Lesson 18: Characterizing and Quantifying Risk	
18.A	Define risk per ASCE Policy Statement 437.
18.B	Explain how the variablity and uncertainty of natural and manmade hazards impose risk to infrastructure systems.
18.C	Use the Monte Carlo Method to conduct a basic stochastic simulation and numerically estimate risk to an infrastructure system.
Lesson 19: Characterizing and Quantifying Resilience	
19.A	Define resilience per ASCE Policy Statement 518.
19.B	Discuss ways to characterize resilience.
19.C	Define reliability and quantify failure probability per Hashimoto (1982).
19.D	Calculate the resilience of a component of infrastruture based on reliability and failure probability.
Lesson 20: Written Partial Review (Mid-Term Exam)	
20.A	Demonstrate the required level of achievement in learning objectives from Lesson 1 thorugh Lesson 19.

Economic Considerations & Risk / Resilience (Block 3) draws parallels between both environmental and social considerations of development by quantifying them through economic costs. Topics include federal project funding, greenhouse gas impacts, and statistical life analysis. Risk and resilience are introduced in independent lessons; risk focuses on mitigation while resilience presents students with a method to numerically estimate risk to an infrastructure system.

Documents key to Block 3 learning objectives include the EPA's Report on the Social Cost of Greenhouse Gases, ASCE Policy Statement 437 (Risk), and the U.S. Army Corps of Engineers civil works project funding process summary.

Block 3's case study focuses on power generation infrastructure in New York's Hudson Valley region. Students will examine proposed versus operating energy production facilities and conduct a stakeholder analysis to better understand the system. In addition to the case study, a field trip to the State University of New York (SUNY), New Paltz introduces students to a wide array of Leadership in Energy & Environmental Design (LEED) facilities, campus operating practices, and energy sourcing decisions.

Block 4: Life Cycle Assessments

Table 10: CE300X Block 4 Lesson Objectives

Lesson 21: Life Cycle Assessment I - Overview	
21.A	Describe the purpose of a life cycle assessment using the ISO 14040 framework (https://www.lifecycleinitiative.org/resources/training/lca-life-cycle-assessment-training-kit-material/).
21.B	Compare the concepts of cradle-to-grave and cradle-to-cradle.
21.C	Investigate the inputs and outputs characteristic of life cycle assessments.
Lesson 22: Life Cycle Assessment II - Goal, Scope, and Boundary Definition	
22.A	Define the goal of a life cycle assessment.
22.B	Define an effective scope for a life cycle assessment.
22.C	Define an effective boundary for a life cycle assessment.
Lesson 23: Life Cycle Assessment III - Inventory Analysis	
23.A	Using an example, conduct an inventory analysis and quantify the elementary flows of resource extractions and substance emissions crossing the system boundary.
23.B	Using an example, establish the energy and carbon balance for products in order to identify the dominant stages in the product's life cycle.
23.C	Discuss existing databases and life cycle assessment approaches.
Lesson 24: Life Cycle Assessment IV - Impact Assessment & Interpretation	
24.A	Using an example, conduct an impact assessment to include slection and definition of impact categories, characterization, normalization/equivalency, and aggregation/weighting.
24.B	Prepare a graphical representation to help interpret and communicate results.
Lesson 25: Life Cycle Assessment V - Software Tools & EIO-LCA Lab	
25.A	Download and gain experience using open-source Economic Input-Output-Life Cycle Assessment (EIO-LCA) Software (https://www.openlca.org/).
25.B	Conduct a basic EIO-LCA.
Lesson 26: Life Cycle Assessment VI - EIO-LCA Lab In-Class Working Session	
26.A	Conduct a basic EIO-LCA.
26.B	Communicate technical results of the EIO-LCA through a report that is clear, concise, precise, purposeful, and consistent.
Lesson 27: Guest Lecture	
27.A	Engage with a Senior Leader to discuss how sustainable infrastructure development can contribute to current policy.
27.B	Receive EDP Team Assignments.

CE300X Block 4 is entirely focused on Life Cycle Assessments. First, the concepts of cradle-to-cradle versus cradle-to-grave are examined. Subsequently, assessment scope, boundaries, and goals are understood prior to conducting example problems and practical exercises.

Documents key to Block 4 learning objectives include the International Organization for Standards (ISO) 14040 Life Cycle Assessments and current government policy. Additionally, instructors will provide local infrastructure project data to feed student analysis of competing alternatives.

Block 4's case study leverages www.openlca.org to complete a basic Economic Input-Output-Life Cycle Assessment (EIO-LCA) for a building construction component or system.

Block 5: Engineering Design Process & Project

Table 11: CE300X Block 5 Lesson Objectives

Lesson 28: Engineering Design Process I – Overview	
28.A	Explain the term engineering design.
28.B	Discuss the stages of the engineering design process.
28.C	Understand the role of design thinking for Professional Engineers and Army Officers.
Lesson 29: Engineering Design Process II – Team Dynamics and Project Management	
29.A	Discuss the stages of team development.
29.B	Discuss different methods and tools for project management.
29.C	Outline team roles and responsibilities using a Team Charter.
Lesson 30: Engineering Design Process III – Project Requirements & In-Class Working Session	
30.A	Identify client, customers, and/or stakeholders for a proposed design.
30.B	Describe the need which a proposed design will satisfy.
30.C	Use the STEEP-C framework of Safety, Technological, Economic, Environmental, Political/Legal, & Cultural to conduct a stakeholder analysis and develop project requirements.
30.D	Develop objectives and constraints for a proposed design.
30.E	Conduct a literature review to frame the problem and define sustainability in terms of the triple bottom line.
Lesson 31: Engineering Design Process IV – Problem Statement & In-Class Working Session	
31.A	Organize design objectives using an objectives tree.
31.B	Prioritize primary objectives using pairwise comparison.
31.C	Incorporate needs, objectives, and constraints into a well-crafted problem statement.
Lesson 32: Engineering Design Process V – In-Progress Review & Out-of-Class Working Session	
32.A	As a team, communicate progress in the Engineering Design Process to date and the way ahead to your instructor in 10 minutes or less.
Lesson 33: Engineering Design Process VI – Engineering Specifications & In-Class Working Session	
33.A	Develop engineering characteristics associated with project requirements.
33.B	Use the House of Quality tool to correlate and prioritize engineering characteristics.
33.C	Conduct benchmarking to assess state-of-the-art and set sustainability goals.
Lesson 34: Engineering Design Process VII – Functional Analysis & In-Class Working Session	
34.A	Explain the difference between functions and means.
34.B	Develop a comphehensive list of functions for an infrastructure project.
34.C	Arrange functions hierarchiacally using Functional Decomposition.
Lesson 35: Engineering Design Process VIII – Generating Alternatives & In-Class Working Session	
35.A	Describe different ideation techniques.
35.B	Use ideation techniques to develop multiple means for established functions.
35.C	Organize means and functions using a morphological chart.
35.D	Combine means into coherent concepts.
35.E	Communicate concepts using concept sketches.
Lesson 36: Engineering Design Process IX – Decision Making & In-Class Working Session	
36.A	Use decsion support tools to objectively compare alternatives.
36.B	Create utility curves to rate performance against engineering specifications.
36.C	Explore qualitative comparison methods.
Lesson 37: Engineering Design Process X – Preliminary Design Review	
37.A	Convey design decisions and receive feedback through a preliminary design review.
Lesson 38: Engineering Design Process XI – Detailed Design	
38.A	Convey design intent using plans and specifications.
Lesson 39: Course Review	
39.A	Create a mind map to organize your learning in CE300X this semester.
Lesson 40: Term-End Exam (Final Exam)	
40.A	Demonstrate the required level of achievement in learning objectives from Lesson 1 thorugh Lesson 39.

CE300X Block 5 facilitates a team-based, course-culminating opportunity through the Engineering Design Project (EDP). Key to this block is establishing the team charter, project framework, and objective analysis, criteria weighting, and iterative project design.

The Safety, Technological, Economic, Environmental, Political / Legal, & Cultural (STEEP-C) framework is introduced as a method for teams to conduct project stakeholder analysis, aiding their scoping and deliverables organization. The intent is the EDP is presented to a panel of Senior Faculty to receive feedback beyond just the students' individual instructor.

Conclusion and Future Work

Given the guidelines and requirements from ABET EAC, ASCE Program Criteria, and the institutional Academic Program Goals, this research has demonstrated the crosswalk from requirements to course objectives to lesson objectives for a semester-long course in sustainable infrastructure design. The course differs from those taught at many institutions in that its titular focus is sustainable design of infrastructure, as opposed to a theme woven throughout related topics in civil engineering. While there is nothing inherently wrong with filling requirements via a thematic approach to the topic of sustainability, the authors feel that the creation of a sustainability course eases assessment of its effectiveness and mapping its content to external requirements.

The program at the United States Military Academy is in a unique position to present an engineering course to a student population of engineer and non-engineer majors, alike. As many universities have demonstrated the efficacy of combined academic backgrounds in the classroom, the teaching team for this course is looking forward to the opportunity to implement recommendations and lessons learned. Overall, given the continually growing importance of sustainability, the authors expect that the blend of backgrounds will create an ideal learning environment for the students.

Given the specific institutional requirements and the intention to implement this course as part of the core engineering sequence, it is expected that the composition of the population will mostly be second year students. This arrangement presents a phenomenal opportunity reinforce the principles of sustainability earlier in the academic career, thus carrying over into other aspects of their respective academic disciplines. The presence of this opportunity highlights the importance of creating a strong and well-developed course to present to the future students.

As the authors continue the curriculum development process, we intend to expand our benchmarking sample size, in order to compare our course curriculum against other undergraduate sustainability courses. Most importantly, we look forward to the constructive feedback from colleagues as they offer insight and critique into the efficacy of our block structure, lessons objectives, and learning activities. Last, we anticipate conducting a pilot course and assessment process within the next one to two academic years.

Disclaimer

The views expressed in this work are those of the authors and do not necessarily reflect the official policy or position of the United States Military Academy, Department of the Army, DoD, or U.S. Government. Reference to any commercial product, process, or service by trade name, trademark, manufacturer, or otherwise neither constitutes nor implies endorsement, recommendation, or favor.

APPENDIX A

CE300X APG-ASCE-ABET Learning Objective Crosswalk (Part 1)

Crosswalk of Learning Objectives between Lessons, Course, University Academic Program Goals, ASCE Program Guidance, and ABET Student Outcomes

ABET SO	ASCE PG	APG	Course	Lesson	Learning Objective
				Lesson 1: Introduction to Infrastructure & Sustainable Development	
			1	1.A	Define infrastructure.
			1	1.B	Define sustainable development.
4	1.a.iii	5.4.1	1, 2	1.C	Explain the "triple bottom line" as it relates to sustainability.
4	1.a.iii	5.4.1	1	1.D	Discuss ASCE Policy Statement 418 and the Priciples of Sustainable Development (https://www.asce.org/communities/institutes-and-technical-groups/sustainability/asce-sustainability-policies/), do the right project, and do the project right.
				Lesson 2: Environmental Considerations I: Global Warming Potential & Carbon	
			2	2.A	Explain what global warming is and its impacts.
		7.4	2	2.B	Identify the major contributors to global warming, their relative impacts, and their primary sources.
		7.4	2	2.C	Describe positive and negative radiative forcing.
4	1.a.iii	2.1	2	2.D	Discuss international conventions and global warming limit targets.
				Lesson 3: Environmental Considerations II: Calculations in Carbon Emissions	
		7.4	2	3.A	Describe the nexus between energy and the atmosphere with regard to carbon.
		7.4	2	3.B	Explain the concepts of embodied carbon and embodied energy.
6	1.a.i	5.1	2	3.C	Quantify carbon emissions resulting from common infrastructure materials and components.
				Lesson 4: Environmental Considerations III: Development & Pollution	
	1.a.iii		1, 2	4.A	Describe various sources of pollution from civilization.
4	1.a.iii	7.4	1	4.B	Explain the human development index and ecological footprint.
	1.a.iii		1, 2	4.C	Use an online tool to estimate your personal ecological footprint (https://www.footprintcalculator.org/home/en).
2, 4	1.a.iii	2.1	1	4.D	Discuss global, political, and cultural considerations with regard to sustainable infrastructure development.
				Lesson 5: Environmental Considerations IV: Quantifying Human Health Impacts from Pollution	
		2.4	2	5.A	Define mortality and quantify the Value of Statistical Life using EPA values and inflationary adjustments based on the Consumer Price Index.
		2.4	2	5.B	Define morbidity and quantify its contributory factors.
		2.1	2	5.C	Describe the connection between pollution and human health impacts.
2	1.a.i, 1.a.iii	2.4	2, 3	5.D	Calculate the negative impact of pollution on human health using World Health Organization statistics.
				Lesson 6: Environmental Considerations V: Quantifying Environmental Impacts from Pollution	
		2.1	2	6.A	Describe the sources and impacts of the following emissions: sulfur dioxide, nitrogen oxides, particulates, heavy metals, and fly ash.
	1.a.i	2.4	2, 3	6.B	Quantify emissions of the above from various sources of energy and transportation.
1	1.a.iii	2.4	1	6.C	Discuss ways in which new or renovated infrastructure can reduce pollution.
				Lesson 7: Case Study I – Water	
4	1.a.iii, 1.a.v	4.2	2	7.A	Discuss the causes and results of the municipal water system failures in Flint, Michigan.
4	1.a.iii, 1.a.v	4.2	2	7.B	Explain quality of life and stakeholder interests within this case study.
				Lesson 8: Social Considerations I: Global & Cultural	
4	1.a.iii	5.4.1	1	8.A	Discuss the United Nations' 17 goals of sustainable development (https://sdgs.un.org/goals).
			3	8.B	Discuss the history and output of the United Nations' Intergovernmental Panel on Climate Change.
	1.a.iii		1	8.C	Define leapfrogging in terms of infrastructure development.
4	1.a.iii	7.5	2	8.D	Compare and contrast development contemporary strategies of countries using the United Nations' Global Sustainable Development Report (https://sdgs.un.org/gsdr/gsdr2023).
				Lesson 9: Social Considerations II: Politics & Policy	
4	1.a.iii		2	9.A	Describe the genesis and implications of the Clean Water Act, National Environmental Policy Act, Rivers & Harbors Appropriation Act, Endangered Species Act, and Waters of the United States.
2, 4	1.a.iii		2	9.B	Describe how the US Army Corps of Engineers Regulatory Program enforces these laws in infrastructure development, operations, and maintenance.
				Lesson 10: Social Considerations III: Public Health, Safety, & Welfare	
4		4.2	1, 2	10.A	Identify potential impacts of infrastructure development on public health, safety, and welfare.
4		4.2	1, 2	10.B	Discuss how historic and cultural resources, views and local character, and community wellbeing impact the design of sustainable infrastructure development.
4	1.a.v	4.2	1, 2	10.C	Discuss the American Society of Civil Engineers' Code of Ethics (https://www.asce.org/career-growth/ethics/code-of-ethics).
				Lesson 11: Social Considerations III: Diversity, Equity, & Inclusion	
	1.a.iii, 1.a.v	4.2	2	11.A	Define the concepts of diversity, equity, and inclusion.
2	1.a.iii, 1.a.v	2.4	1, 2	11.B	Discuss how these concepts apply to sustainable infrastructure development.
2	1.a.iii, 1.a.v	2.1	1, 2	11.C	Discuss how leadership, collaboration, and stakeholder involvement contribute to sustainable infrastructure development.
				Lesson 12: Case Study II – Transportation	
4	1.a.iii, 1.a.v	4.2	2	12.A	Discuss the impacts of transportation infrastructure development decisions as evidenced in Jane Jacobs v Robet Moses in NYC.
4	1.a.iii, 1.a.v	4.2	2	12.B	Explain quality of life and stakeholder interests within this case study.
				Lesson 13: Economic Considerations I: How Projects Get Funded	
			2	13.A	Describe the differences between the fiscal year President's Budget and Congressional authorizations and appropriations.
			2	13.B	Summarize the federal processes that fund US Army Corps of Engineers civil works projects (https://www.usace.army.mil/Missions/Civil-Works/Budget/#!).
2, 4	1.a.iii	4.2	1, 2	13.C	Discuss the influences upon government decision-making in funding infrastructure projects.
				Lesson 14: Economic Considerations II: Social Cost of Greenhouse Gas	
		7.4	2	14.A	Discuss the impacts of the Environmental Protection Agency's 2023 Report of the Social Cost of Greenhouse Gases (https://www.epa.gov/environmental-economics/scghg).
	1.a.iii	2.1	2	14.B	Compare the 2023 Social Cost of Greenhouse Gases to previous government estimates and other academic estimates (Table ES.1 of https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf & Table 4 of https://web.mit.edu/rpindyck/www/Papers/SCCRevisitedJEEM2019.pdf).
		7.4	3	14.C	Explain the concept of a discount rate and the illustrate the impact on the Social Cost of Greenhouse Gases.
4	1.a.i	2.4, 5.1	2, 3	14.D	Calculate the Social Cost of Greenhouse Gases from a military installation.
				Lesson 15: Economic Considerations III: Calculations in Mortality, Morbidity, and Value of Statistical Life	
4	1.a.i	2.4, 5.1	2, 3	15.A	Calculate mortality costs resulting from the effects of a component of infrastructure using the value of statistical life.
4	1.a.i	2.4, 5.1	2, 3	15.B	Calculate the morbitity costs resulting from the effects of a component of infrastructure.
				Lesson 16: Case Study III – Energy	
4	1.a.iii, 1.a.v	4.2	2	16.A	Discuss historical examples of proposed and built power production facitilites in the Hudson Valley (https://omeka.hrvh.org/exhibits/show/rescuing-the-river/powering-the-hudson).
4	1.a.iii, 1.a.v	4.2	2	16.B	Identify stakeholders and their positions on the various types of proposed energy infrastructure.
				Lesson 17: Field Trip - SUNY New Paltz Green Infrastructure Tour	
1	1.a.iii	2.1	1, 2	17.A	Observe and appraise the effectiveness of example sustainable infrastructure development projects. (https://www.newpaltz.edu/sustainability/view-programs-and-progress/green-infrastructure/)
				Lesson 18: Characterizing and Quantifying Risk	
			3	18.A	Define risk per ASCE Policy Statement 437.
		2.4	3	18.B	Explain how the variablity and uncertainty of natural and manmade hazards impose risk to infrastructure systems.
1, 6	1.a.i, 1.a.ii, 1.a.iii	2.5, 5.1, 5.4.4	3	18.C	Use the Monte Carlo Method to conduct a basic stochastic simulation and numerically estimate risk to an infrastructure system.
				Lesson 19: Characterizing and Quantifying Resilience	
			3	19.A	Define resilience per ASCE Policy Statement 518.
		2.4	3	19.B	Discuss ways to characterize resilience.
1, 6	1.a.i, 1.a.ii, 1.a.iii	5.1, 5.4.4	3	19.C	Define reliability and quantify failure probability per Hashimoto (1982).
1, 6	1.a.i, 1.a.ii, 1.a.iii	5.1, 5.4.4	3	19.D	Calculate the resilience of a component of infrastructure based on reliability and failure probability.
				Lesson 20: Written Partial Review (Mid-Term Exam)	
1, 2, 4, 6	1.a.i, 1.a.ii, 1.a.iii	2.1, 2.4, 2.5, 4.2, 5.1, 5.4.1, 5.4.4	1, 2, 3	20.A	Demonstrate the required level of achievement in learning objectives from Lesson 1 thorugh Lesson 19.

APPENDIX A
CE300X APG-ASCE-ABET Learning Objective Crosswalk (Part 2)

Crosswalk of Learning Objectives between Lessons, Course, University Academic Program Goals, ASCE Program Guidance, and ABET Student Outcomes					
ABET SO	**ASCE PG**	**APG**	**Course**	**Lesson**	**Learning Objective**
					Lesson 21: Life Cycle Assessment I - Overview
			4	21.A	Describe the purpose of a life cycle assessment using the ISO 14040 framework (https://www.lifecycleinitiative.org/resources/training/lca-life-cycle-assessment-training-kit-material/).
			1	21.B	Compare the concepts of cradle-to-grave and cradle-to-cradle.
6			4	21.C	Investigate the inputs and outputs characteristic of life cycle assessments.
					Lesson 22: Life Cycle Assessment II - Goal, Scope, and Boundary Definition
		2.1, 2.4	4	22.A	Define the goal of a life cycle assessment.
		2.1, 2.4	4	22.B	Define an effective scope for a life cycle assessment.
		2.1, 2.4	4	22.C	Define an effective boundary for a life cycle assessment.
					Lesson 23: Life Cycle Assessment III - Inventory Analysis
	1.a.iii	2.1, 2.4	4	23.A	Using an example, conduct an inventory analysis and quantify the elementary flows of resource extractions and substance emissions crossing the system boundary.
	1.a.iii	2.1, 2.4	4	23.B	Using an example, establish the energy and carbon balance for products in order to identify the dominant stages in the product's life cycle.
			4	23.C	Discuss existing databases and life cycle assessment approaches.
					Lesson 24: Life Cycle Assessment IV - Impact Assessment & Interpretation
6	1.a.iii	2.1, 2.4	4	24.A	Using an example, conduct an impact assessment to include slection and definition of impact categories, characterization, normalization/equivalency, and aggregation/weighting.
3		5.4.5	4, 5	24.B	Prepare a graphical representation to help interpret and communicate results.
					Lesson 25: Life Cycle Assessment V - Software Tools & EIO-LCA Lab
6			4	25.A	Download and gain experience using open-source Economic Input-Output-Life Cycle Assessment (EIO-LCA) Software (https://www.openlca.org/).
6	1.a.iii, 1.c	5.1, 5.4.6	4	25.B	Conduct a basic EIO-LCA.
					Lesson 26: Life Cycle Assessment VI - EIO-LCA Lab In-Class Working Session
6	1.a.iii, 1.c	5.1, 5.4.6	4	26.A	Conduct a basic EIO-LCA.
3	1.a.iii, 1.c	5.4.5	4, 5	26.B	Communicate technical results of the EIO-LCA through a report that is clear, concise, precise, purposeful, and consistent.
					Lesson 27: Guest Lecture
		2.1, 2.5	1, 2, 3	27.A	Engage with a Senior Leader to discuss how sustainable infrastructure development can contribute to current policy.
5			4	27.B	Receive EDP Team Assignments.
					Lesson 28: Engineering Design Process I – Overview
2	1.a.iv	5.4	4	28.A	Explain the term engineering design.
2	1.a.iv	5.4	4	28.B	Discuss the stages of the engineering design process.
2	1.a.iv	5.4	4	28.C	Understand the role of design thinking for Professional Engineers and Army Officers.
					Lesson 29: Engineering Design Process II – Team Dynamics and Project Management
5			4	29.A	Discuss the stages of team development.
5	1.d.i	5.4	4	29.B	Discuss different methods and tools for project management.
5		5.4	4	29.C	Outline team roles and responsibilities using a Team Charter.
					Lesson 30: Engineering Design Process III – Project Requirements & In-Class Working Session
2	1.a.iv	5.4	1, 2, 4	30.A	Identify client, customers, and/or stakeholders for a proposed design.
2	1.a.iv	5.4, 5.4.1, 5.4.2	1, 4	30.B	Describe the need which a proposed design will satisfy.
2	1.a.iv	5.4, 5.4.2	2, 4	30.C	Use the STEEP-C framework of Safety, Technological, Economic, Environmental, Political/Legal, & Cultural to conduct a stakeholder analysis and develop project requirements.
2	1.a.iv	5.4, 5.4.1, 5.4.2	4	30.D	Develop objectives and constraints for a proposed design.
2, 7	1.a.iv	2.5, 5.4, 5.4.2	4	30.E	Conduct a literature review to frame the problem and define sustainability in terms of the triple bottom line.
					Lesson 31: Engineering Design Process IV – Problem Statement & In-Class Working Session
2	1.a.iv	5.4, 5.4.1	4	31.A	Organize design objectives using an objectives tree.
2	1.a.iv	5.4, 5.4.1	4	31.B	Prioritize primary objectives using pairwise comparison.
2	1.a.iv	5.4, 5.4.2	4	31.C	Incorporate needs, objectives, and constraints into a well-crafted problem statement.
					Lesson 32: Engineering Design Process V – In-Progress Review & Out-of-Class Working Session
2, 3, 5	1.a.iv	5.4, 5.4.5	4	32.A	As a team, communicate progress in the Engineering Design Process to date and the way ahead to your instructor in 10 minutes or less.
					Lesson 33: Engineering Design Process VI – Engineering Specifications & In-Class Working Session
2	1.a.iv	5.4, 5.4.3	3, 4	33.A	Develop engineering characteristics associated with project requirements.
2, 6	1.a.iv	5.4, 5.4.3	4	33.B	Use the House of Quality tool to correlate and prioritize engineering characteristics.
2, 7	1.a.iv	2.5, 5.4, 5.4.3	4	33.C	Conduct benchmarking to assess state-of-the-art and set sustainability goals.
					Lesson 34: Engineering Design Process VII – Functional Analysis & In-Class Working Session
2	1.a.iv	5.4, 5.4.3	4	34.A	Explain the difference between functions and means.
2	1.a.iv	5.4, 5.4.3	1, 4	34.B	Develop a comphehensive list of functions for an infrastructure project.
2	1.a.iv	5.4, 5.4.3	1, 4	34.C	Arrange functions hierarchiacally using Functional Decomposition.
					Lesson 35: Engineering Design Process VIII – Generating Alternatives & In-Class Working Session
2	1.a.iv	5.4, 5.4.3	4	35.A	Describe different ideation techniques.
2	1.a.iv	2.5, 5.4, 5.4.3, 7.5	4	35.B	Use ideation techniques to develop multiple means for established functions.
2	1.a.iv	5.4, 5.4.3	4	35.C	Organize means and functions using a morphological chart.
2	1.a.iv	5.4, 5.4.3	4	35.D	Combine means into coherent concepts.
2	1.a.iv	5.4, 5.4.3	4, 5	35.E	Communicate concepts using concept sketches.
					Lesson 36: Engineering Design Process IX – Decision Making & In-Class Working Session
2, 4	1.a.iv	2.4, 5.4, 5.4.4	1, 4	36.A	Use decsion support tools to objectively compare alternatives.
2, 6	1.a.iv	5.4, 5.4.4	4	36.B	Create utility curves to rate performance against engineering specifications.
2, 6	1.a.iv	5.4, 5.4.4	4	36.C	Explore qualitative comparison methods.
					Lesson 37: Engineering Design Process X – Preliminary Design Review
2, 3, 5	1.a.iv	5.4, 5.4.5	4, 5	37.A	Convey design decisions and receive feedback through a preliminary design review.
					Lesson 38: Engineering Design Process XI – Detailed Design
1, 2, 3	1.a.iv	5.4, 5.4.5	4, 5	38.A	Convey design intent using plans and specifications.
					Lesson 39: Course Review
	1.a.iii	2.1, 2.4	1	39.A	Create a mind map to organize your learning in CE300X this semester.
					Lesson 40: Term-End Exam (Final Exam)
1, 2, 3, 4, 5, 6, 7	1.a.i, 1.a.ii, 1.a.iii	2.1, 2.4, 4.2, 5.1, 5.4, 7.4	1, 2, 3, 4	40.A	Demonstrate the required level of achievement in learning objectives from Lesson 1 through Lesson 39.

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