3. ABET Breadth of Knowledge Considerations for Civil Engineering

Contents

Course Website

http://54.243.252.9/ce-4200-webroot/

Textbooks

1. CEBOK (Free)
2. NCEES Supplied Reference (Free)
3. PPI FE Civil Review (~$29.99) Full price is $160-ish, don't pay full price, you should be able to find one at the reduced price
4. PPI Online Training Exams (~$38) You need to complete an entire exam package by the last day of class. Submit a screen capture of the completion diagnostic score to

recieve credit for this portion of the class.

Readings/References

1. Commentary on the ABET Program Criteria for Civil and Similarly Named Programs (2024) ASCE Civil Engineering Program Criteria Task Committee
2.

Purpose

- Define breadth of knowledge (concept of ...)
- Introduce the importance of breadth in knowledge as required by ABET.
- Emphasize how it prepares students for multidisciplinary challenges in civil engineering.

What is "breadth"?

A search for "breadth" in ASCE (2024) (from search for "breadth") produced 4 matches. These matches are quoted below (a bit useless as excerpts, but illustrative of typical vagueness in your accrededation criteria)

> " ... program (not the PEV) must demonstrate that the specialty area or areas are appropriate to civil engineering in sufficient detail to make a well-reasoned judgment. This judgment must consider the balance of the desirability of curricular innovation against the need for relevant technical **breadth**."
>
> " ... These **breadth** areas should be supported by constituent and stakeholder feedback and connected to the program's educational objectives. Possible justifications for nonstandard specialty areas might include the following:
>
> - ASCE has an institute or technical division, publishes a journal, or sponsors specialty conferences in the technical area.
> - A national or international civil engineering-related professional society has an institute or technical division, publishes a journal, or sponsors specialty

> conferences in the technical area.
> - Civil engineering consulting or contracting firms specialize in the technical area.
> - A technical area has a civil engineering connection with an applicable grand challenge from the National Academy of Engineering (NAE) or other initiatives by national or international engineering organizations.
> - There is an applicable and established program in a technical area within a government agency to identify emerging areas of societal need. Examples could include programs with the Department of Commerce, Department of Energy, Department of Transportation, Department of Energy, Department of Homeland Security, Department of Defense, Environmental Protection Agency, National Science Foundation, or National Institutes of Health. The list above is not inclusive, as many other legitimate, well-reasoned justifications are possible."
>
> " … In general, an advanced physics or chemistry course would not fulfill this requirement's intent because such a course would provide additional depth rather than additional **breadth** of scientific knowledge. Likewise, engineering science, materials science, and thermodynamics courses would not typically fulfill this requirement's intent."
>
> " … A technical core of knowledge and **breadth** of coverage in engineering mechanics and the ability to apply it to solve civil engineering problems are essential for civil engineers. "

A more general definition is:

> Breadth of knowledge refers to the wide-ranging understanding across multiple disciplines, concepts, and perspectives, enabling individuals to recognize interconnections and apply diverse approaches to problem-solving. Rooted in frameworks like Bloom's Taxonomy, it emphasizes **foundational knowledge**, **comprehension**, and the **ability to analyze and synthesize** information from **varied fields** to address complex challenges.

How ABET defines technical knowledge required for civil engineers.

ABET (Accreditation Board for Engineering and Technology) defines the technical knowledge required for civil engineers through its Program Criteria and Student Outcomes, emphasizing both depth and breadth in engineering education. These criteria are specific to civil engineering programs and are detailed in collaboration with professional societies such as the American Society of Civil Engineers (ASCE).

ABET's Student Outcomes for Civil Engineers

> **Note**
>
> The outcomes listed below are literal paraphrasing of ABET-EAC outcomes!

ABET specifies seven broad outcomes that graduates must achieve, emphasizing skills, knowledge, and abilities. Here's how they translate into the technical knowledge expected of civil engineers:

1. **Problem-Solving Skills**: Graduates must demonstrate the ability to:

- Identify, formulate, and solve complex engineering problems using principles of engineering, science, and mathematics.
- Example: Analyzing structural loads to design a safe and cost-effective bridge.

2. **Engineering Design**: Ability to apply engineering design to produce solutions that meet specified needs, considering public health, safety, welfare, as well as global, cultural, social, environmental, and economic factors.

- Example: Designing a stormwater management system to mitigate flooding in urban areas.

3. **Communication Skills**: Effective communication with diverse audiences, essential for presenting technical information to non-engineers and stakeholders.

- Example: Explaining hydrologic model outputs to a city planning commission.

4. **Ethical and Professional Responsibilities**: Understanding the societal, environmental, and global impacts of civil engineering solutions, along with ethical and professional responsibilities.

- Example: Adhering to sustainable practices while constructing a transportation system.

5. **Teamwork**: Ability to work effectively in teams, providing leadership and fostering collaboration.

- Example: Collaborating with geotechnical and environmental engineers on a landfill design.

6. **Experimentation and Analysis**: Ability to design and conduct experiments, analyze and interpret data, and apply engineering judgment.

- Example: Conducting soil testing to determine bearing capacity for foundation design.

7. **Lifelong Learning**: Recognition of the need for and ability to engage in lifelong learning to stay current with evolving technologies and regulations.

- Example: Keeping up with advancements in hydraulic modeling tools like EPA SWMM.

Civil Engineering Program Criteria (ASCE and ABET)

ABET specifies additional program-specific criteria for civil engineering, requiring graduates to demonstrate technical proficiency in areas such as:

1. **Mathematics, Science, and Engineering Principles**:

- Proficiency in calculus, differential equations, probability, and statistics.
- Application of these principles to solve engineering problems.

2. **Technical Specializations**: Graduates must acquire **depth in at least one technical area** and **breadth across multiple areas of civil engineering**:

- Structural Engineering: Analysis and design of structures to resist loads.
- Transportation Engineering: Planning and design of systems for efficient movement of people and goods.
- Water Resources and Environmental Engineering: Hydraulic and hydrologic systems, treatment plants, and environmental sustainability.
- Geotechnical Engineering: Soil mechanics and foundation design.

- Construction Management: Project planning, scheduling, and cost estimation.

> **Note**
>
> The implication is some level of mastery in one of the specializations, and familiarity (competence) in several other areas. This depth and breath requirement is why you are forced to take classes in topics that are not your favorite thing - as a practical matter no-one (even you) knows what you will work on and have to be able to do in a decade, but it is likely that it will have something to do with one or more of the specializations above.

3. **Standards and Codes**: Familiarity with industry standards and codes (e.g., AASHTO, ASCE Standards) relevant to civil engineering practice.
4. **Real-World Applications**: Ability to integrate technical knowledge into practical, real-world projects that meet constraints like budgets, environmental impacts, and timelines.

> **Note**
>
> The capstone design course(s) are similations of real world application; internships are actual applications.

> **Illustrative Example:**
>
> A civil engineer designs a highway drainage system. ABET requires the engineer to:
>
> - Use math and fluid mechanics to calculate flow rates and channel dimensions (technical knowledge).
> - Apply environmental engineering principles to minimize impacts on local ecosystems.
> - Incorporate communication skills to present the design to stakeholders.
> - Work in multidisciplinary teams to integrate transportation, geotechnical, and environmental aspects.

⚠ **Warning**

This block is under construction

Title

- **Fundamental Areas; Mastery of one == Depth; Functional knowledge in additional one or more == Breadth**:
  - Structural, geotechnical, water resources, transportation, environmental, and construction engineering.
- **Integrative Design**:
  - Importance of combining these areas in project-based learning.
- **Case Study**:
  - Example(s): A dam project requiring hydrology, structural integrity, and environmental impact assessment.

Supportive Knowledge Areas

1. Mathematics and Natural Sciences:

Mathematics and natural sciences form the bedrock of civil engineering, providing the quantitative tools and physical principles essential for problem-solving in engineering design. Key Disciplines:

- Calculus:
  - Fundamental for analyzing rates of change and solving optimization problems.
  - Application: Designing drainage systems where flow rates vary over time requires integration to calculate accumulated volumes or flow profiles.
- Differential Equations:
  - Models dynamic systems in civil engineering, such as groundwater flow, vibration in structures, and fluid dynamics.
  - Application: Predicting pollutant dispersion in rivers involves solving partial differential equations (PDEs) to understand concentration changes over time and space.
- Physics:

  - Essential for understanding forces, motion, energy transfer, and material behavior.
  - Application: Structural analysis requires mechanics to predict how beams and columns deform under loads.
- Chemistry:
  - Provides insight into material properties, corrosion, and environmental processes.
  - Application: In water treatment, knowledge of chemical reactions helps in selecting coagulants for removing impurities.

Real-World Problem-Solving:

> An example is the design of a wastewater treatment facility:
>
> - Mathematics: Calculating inflow and outflow rates using differential equations to balance mass flows.
> - Physics: Modeling sedimentation tanks based on fluid mechanics.
> - Chemistry: Optimizing the dosing of chemicals for disinfection and pH control.

2. Broader Technical Skills:

Modern civil engineers must leverage computational tools and emerging technologies to enhance productivity, accuracy, and sustainability. Programming and Computational Tools:

- Excel:
  - Widely used tool for data analysis, visualization, and engineering calculations, often serving as a **quick alternative** to more specialized software.
  - Application Examples:
    - Hydraulic Calculations: Sizing pipelines using the Hazen-Williams equation with automated iterations in spreadsheet tables.
    - Stormwater Design: Using Excel to apply the Rational Method for calculating peak runoff and sizing drainage pipes.
    - Data Visualization: Creating charts for flow vs. time relationships or presenting cost analysis for project budgeting.

- Optimization: Leveraging Solver to optimize pipe diameters, storage tank sizing, or material costs.

Why Excel?:

- Easy to learn and implement without specialized training. (Even board-room executives are capable of operating simplistic Excel models!)
- Offers integration with VBA (Visual Basic for Applications) for advanced automation.

An opinion regarding Excel:

Its a bit overrated in terms of functional awesomeness. Excel has substantial limitations in model size and if the model contains VBA macros, it is essentially un-shareable. Cloud based storage makes it even worse (to share a spreadsheet outside your enterprise network). Microsoft kind of shot itself in the foot with Office 365. It is currently under beta testing as an interface to python (my gut is that Microsoft will drop VBA, once they have a viable python kernel that interfaces with Excel - that represents a second time in Excel history when MS changed the Macro Programming features, which deprecates anything pre-1994 as completely useless, and anything pre-2025 will begin to degrade. Python itself shares this lack of backward compatability as Python 2.7 is a different language than Python 3.10+. I guess actual users will have to learn to live with intentional obsolence in software.

- MATLAB:
  - Widely used for numerical modeling and data visualization.
  - Application: Simulating structural dynamics under earthquake loading.
- Python:
  - Favored for its versatility and libraries like NumPy, Pandas, and Matplotlib.
  - Application: Automating hydrologic model calibration or analyzing traffic patterns.
- GIS (Geographic Information Systems):
  - Enables spatial analysis and mapping.

  - Application: Identifying flood-prone areas and optimizing the location of stormwater infrastructure.

3. Emerging Technologies:

- Artificial Intelligence (AI):
  - AI enhances predictive capabilities in civil engineering.
  - Application: Using machine learning to forecast traffic congestion or identify patterns in structural health monitoring.
- Sustainability Tools:
  - Lifecycle assessment software (e.g., SimaPro, OpenLCA) evaluates environmental impacts.
  - Application: Selecting materials and processes with minimal carbon footprint for a bridge project.

3. Humanities and Social Sciences:

Engineering solutions do not exist in a vacuum. Humanities and social sciences equip engineers with the ability to understand societal needs, communicate effectively, and navigate policy frameworks. Importance of Understanding Societal Impact:

- Ethics and Policy:
  - Engineers must consider public safety, welfare, and environmental justice.
  - Example: Ensuring equitable access to safe drinking water in underserved communities.
- Communication Skills:
  - Vital for conveying technical concepts to non-technical stakeholders.
  - Example: Presenting a flood mitigation plan to local governments and residents.

Real-World Example:

> Transportation Planning:
>
> - A new highway project must integrate public safety, environmental considerations, and stakeholder input.
> - Social Sciences: Engaging with communities to minimize disruptions and enhance benefits.
> - Humanities: Incorporating cultural and historical significance of affected areas into the design.

Professional Skills and Ethical Responsibility

Interpersonal and Communication Skills

Importance of Teamwork and Leadership

In civil engineering, projects are rarely the work of a single individual. Success often depends on effective teamwork and leadership. Engineers must collaborate with diverse professionals, including architects, planners, and contractors, to deliver complex projects efficiently and ethically. Key aspects include:

- **Teamwork**: Collaborative problem-solving, shared responsibility, and fostering an inclusive environment for idea exchange.
- **Leadership**: Setting goals, providing direction, and motivating teams while ensuring accountability and adherence to professional standards.

Exercise:

Role-Playing: Conflict Resolution in a Multidisciplinary Team

1. **Scenario**: A conflict arises during the design phase of a large urban infrastructure project. The structural team recommends a material that is cost-effective but difficult

to source locally, while the environmental team proposes an eco-friendly alternative that exceeds the budget.

2. **Objective**: Teams role-play to negotiate a solution that balances cost, sustainability, and practicality. Participants take on specific roles (e.g., project manager, environmental engineer, structural engineer).
3. **Outcome**: Develop a consensus-driven resolution plan and present it to the group.

Ethics in Engineering

> **Warning**
>
> We have several sections devoted to ethics, here it is just a broad overview.

Overview of NSPE Code of Ethics

The National Society of Professional Engineers (NSPE) Code of Ethics outlines principles that guide engineers in upholding safety, public welfare, and professional integrity. Key tenets include:

- **Public Safety**: Engineers must prioritize the health, safety, and welfare of the public.
- **Competence**: Undertaking only those tasks for which they are qualified.
- **Integrity**: Avoiding deceptive acts and conflicts of interest.
- **Accountability**: Ensuring transparency and honesty in all professional interactions.

Ethical Dilemma Scenario:

Balancing Budget Constraints with Safety Requirements

1. **Scenario**: An engineer is tasked with designing a pedestrian bridge for a small town. The budget is constrained, and the contractor suggests using substandard materials to cut costs. However, these materials could compromise the long-term safety of the structure.
2. **Discussion Questions**:

- What steps should the engineer take to address the budget constraints without compromising public safety?
- How can the engineer communicate the risks effectively to stakeholders?

3. **Objective**: Participants analyze the ethical dilemma, reference the NSPE Code of Ethics, and propose a solution that prioritizes safety and public trust.

Global and Societal Context

Far-Reaching Consequences of Civil Engineering Projects

Civil engineering projects, such as infrastructure design, impact communities on a global scale. These projects influence economic growth, environmental sustainability, and public health. Engineers must consider:

- Long-term effects on the environment and society.
- Cultural and societal factors that may affect project acceptance.
- Equitable access to resources and infrastructure for all.

Example:

Sustainable Urban Planning

1. **Scenario**: A city plans to expand its public transportation system to reduce traffic congestion and lower carbon emissions. Engineers are tasked with designing the system while considering:
    - Accessibility for underserved communities.
    - Minimizing the displacement of residents during construction.
    - Ensuring energy-efficient technologies in the system's operations.
2. **Outcome**: The project becomes a model for sustainable urban development, balancing economic growth with environmental stewardship and social equity.

Recap

- ABET's vision for a well-rounded engineer.
- Breadth of knowledge as a cornerstone of civil engineering education.

Discussion

- Allocate time for audience questions and discussion.The

End of Section