Engineering for One Planet

Engineering for One Planet Framework:

13 Step-by-Step Ideas for Integrating Sustainability into Core Engineering Courses

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Prepared in partnership with the American Society for Engineering Education (ASEE) and co-created by 94 Interdivisional Town Hall (ITH) participants at the ASEE 2023 Annual Conference on June 26, 2023.

Background & Introduction

This guide serves as a companion to the 2022 Engineering for One Planet (EOP) Framework.

Purpose:

Co-created by participants of the ASEE 2023 Annual Conference Interdivisional Town Hall (ITH) in June 2023, this guide provides 13 examples of how to integrate sustainability and leadership core learning outcomes from the EOP Framework into specific core/required engineering courses. This resource was created by engineering faculty for engineering faculty. The guide is designed to aid faculty in making curricular changes intended to educate engineering students on fundamental, ABET-aligned sustainability and professional competencies. Included are curricular examples for each of the nine topic areas in the EOP Framework (i.e., Systems Thinking, Environmental Literacy, Responsible Business and Economy, Social Responsibility, Environmental Impact Assessment, Materials Selection, Design, Critical Thinking, Communication and Teamwork), and each core learning outcome referenced is found in the EOP Framework. The supporting resources are freely available to the public.

Whether you are a new educator or new to teaching sustainability-related topics, the course examples shared in this guide will help jump-start your efforts to bring sustainability into your courses.

We encourage you to access more freely available EOP teaching materials —including step-by-step guides on how to implement the EOP Framework— by visiting the Resources page on the Engineering for One Planet website.

For more sustainability-focused integration examples, refer to this chart from our partner, VentureWell.

The icons ( ) in this guide relate to Bloom's Taxonomy, ABET Criteria 3, and the United Nations Sustainable Development Goals. Please see the EOP Framework (pages 11-12) for an explanation of the icons.

The Lemelson Foundation and Interdivisional Town Hall Participants from the 2023 ASEE Annual Conference (2023). Engineering for One Planet Framework: 13 Step-by-Step Ideas for Integrating Sustainability into Core Engineering Courses. Cynthia Anderson and Cindy Cooper (Eds). The Lemelson Foundation, Portland, Oregon, USA. 23 pages.

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Topics

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Systems Thinking

Course title: Statics or Statics Systems	Course Level: 200-level

Course description: Analysis of forces on particles and rigid bodies in static equilibrium, equivalent systems of forces, etc.

Systems Thinking Core Learning Outcome 3:

Apply relevant concepts from required disciplines to the study of real-world problems and their solutions with empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness. ○ (2, 4, 7)

1-3 hours

Integration Example:

Type of activity: Group or in-class activity; replacement of existing activity.

Present students with an engineering challenge as follows: Reduce the number of bridge struts because the bridge will go over a wildlife preserve. The more struts they have, the more it will increase the "footprint" on the ground, which will cause more disruption to the wildlife in the preserve. This is undesirable to wildlife managers.

Guide students through a classic strut reduction problem to reduce materials and costs, and in this case, impact on the preserve.

This activity replaces an existing activity of this type rather than needing to add new content to a course. The only expansion to existing course materials is a 10-15 minute introduction to sustainable bridge design using the story of the Everglades project by the US National Parks Service in the Tamiami Trail example.

If that's all the time you have, stop here and discuss as a class, in small groups, and/or have students reflect on the content in writing as part of a homework assignment. Consider prompts like: *How would you reduce the footprint/number of strut supports that reach the ground? How can you adjust the span length between struts to reduce the material needed? How does changing the material you are using (i.e., Young's Modulus) impact the amount of material needed? Calculate and compare the carbon footprint of producing a bridge with different materials. How do these results impact your design decisions? What tools and/or techniques can be used in the industry to reduce time, material, waste, etc.?*

Supporting Resources:

- Removing the cork in the bottle: Reconstructing Tamiami Trail to restore water flow to Everglades National Park. (Everglades National Park, article 2021)

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Systems Thinking

Course title: Controls | **Course Level: 300- or 400-level**

Course description: Analysis and design of systems controls.

Systems Thinking Core Learning Outcome 2:

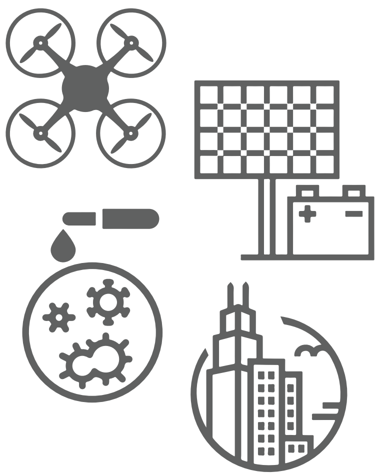
Identify dynamic impacts between and among different parts of the system (i.e., social, environmental, and economic considerations). ○ (4)

3-6 hours

Integration Example:

Type of activity: Student project or multiple homework problems, ideally, spread across several class periods. This activity could replace an existing student project or could be added as new content.

Present students with a series of homework problems or an individual student project focused on grid electrical demand control integration of sustainable energy. Students are challenged to deal with fluctuating demand, misinformation, and communication to customers, etc. Students present final projects to the class.



Source: MIT New Engineering Education Transformation (NEET)

Supporting Resources:

- **Simulink** - Simulink is a block diagram environment used to design systems with multi-domain models, simulate before moving to hardware, and deploy without writing code.
- **New Engineering Education Transformation (NEET) program at MIT**
- Electrical energy systems textbooks

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Environmental Literacy

Course title: Thermodynamics | **Course Level: 200-level**

Course description: Basics of energy as laws of thermodynamic energy conservation.

Environmental Literacy Core Learning Outcome 4:

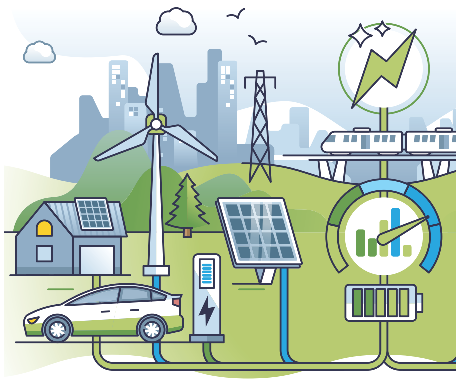
Explain the nature and role of energy in the world, our daily lives, and in engineering practices (e.g. is energy literate). ○ (2, 4)

Semester-long

Integration Example:

Type of activity: Student team project.

Present student teams with a term-length project to design a cycle or system that will conserve thermodynamic energy. Encourage each group to use a different approach and to include context, such as infrastructure needs, to create a successful approach. At the end of the project, student teams present their work and share advantages/disadvantages of the approach, as well as value creation with the approach.



After each student presentation, make time for audience questions and discussion. Consider prompts like: *How does the role of energy in the world influence your approach? How does your approach reduce energy use in our daily lives and/or in engineering practices?*

Supporting Resources:

- Energy Effectiveness (VentureWell's Tools for Design & Sustainability website)
  - Energy Design: Introduction to Energy Use in Design (Autodesk Sustainability Workshop; YouTube)
  - Reduce Friction Energy Losses in Design (Autodesk Sustainability Workshop; YouTube)
  - Reduce Heat Transfer Energy Losses in Design (Autodesk Sustainability Workshop; YouTube)

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Responsible Business and Economy

Course title: Fluids | **Course Level: 300-level**

Course description: Movement of compressible and incompressible media around and through objects.

Responsible Business and Economy Core Learning Outcome 5:

Weigh the near- and long-term costs and value of their work to the environment and society through the sustainable use of resources and engagement with stakeholders. (2, 5)

15 mins to multi-week projects

Integration Example:

Type of activity: Homework assignment, class assignment, or multiple class assignments.

Share a traditional hydrostatic dam design problem with students. As "h" increases, "t" must also increase but potential energy increases. How high should the dam be? Lead class discussion about the sustainability impacts of dams. Consider asking: *Where will you build the dam? What community and cultural impacts should be considered when building in this location? How will the changing climate influence your design? How will climate change influence the landscape of the location/region?*

Source: 10 Massive Dam Failures Caught On Camera (YouTube)

Supporting Resources:

- Provide in-person/video demonstration of a balloon going through depth
- Climate is Increasing Stress on Thousands of Aging Dams Across the US (The Conversation; article 2023)
- 10 Massive Dam Failures Caught on Camera (YouTube)

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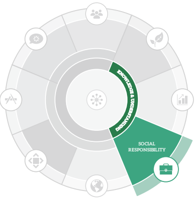
Social Responsibility



Course title: Introduction to Computer Programming	Course Level: 100-level
Course description: Introduction to algorithmic thinking and implementation to learn the basic programming skills of any language.	

Social Responsibility Core Learning Outcome 2:

Recognize and is empathetic to ethical implications relative to social impact of their work. ○ (4)

Week-long

Integration Example:

Type of activity: Group assignment.

Provide three different design proposals for students to review and reflect upon as a group. Proposals will have ethical implications in the real world. Students write up readability, logic, content arguments as a team and present their findings to the class.

Supporting Resources:

- Three proposals created by instructor
- Current/recent news/media articles about specific topics outlined in proposals
- Engineering ethics textbooks
    - For example, Engineering Ethics: Concepts and Cases - Harris et al. (2018)

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Environmental Impact Assessment

Course title: Introduction to Engineering — **Course Level: 100-level**

Course description: Survey course on basics of engineering.

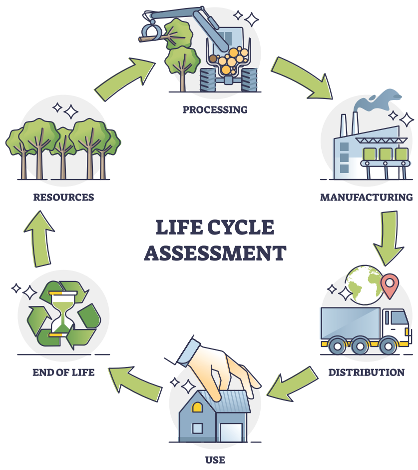
Environmental Impact Assessment Core Learning Outcome 1:

Explain high-level environmental impact assessments (e.g., basic life-cycle assessments and life-cycle hazards; i.e., how they work, what information they require, how to incorporate their findings into their work). ○ (2)

4-8 hours

Integration Example:

Type of activity: Student project.



Utilize any current course project in a traditional Introduction to Engineering course and add at least one component that involves analyzing the environmental impact of a product. Preselect -or have students select- an existing product to measure at least one component of its lifecycle to measure the environmental impact (e.g., raw material, transportation, disposal, etc.). Students present their findings to the class. Discuss as a class, in small groups, and/or have students reflect on the content in writing as part of a homework assignment. Consider prompts like: *How would you reduce the environmental impact of your product, knowing what you know now? What was most surprising to you during this activity? Why?*

Supporting Resources:

- Measuring Sustainability (VentureWell's Tools for Design & Sustainability website)
    - LCA Lecture (Jeremy Faludi; YouTube)
- Inventing Green: A Toolkit for Sustainable Design (VentureWell)

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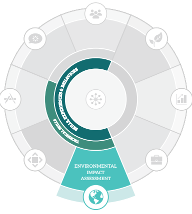
Environmental Impact Assessment



Course title: Introduction to Circuits | **Course Level: 200-level**

Course description: Fundamentals of circuit analysis including circuit elements, current/voltage/power, etc., and basic introduction to circuit design and considerations in circuit construction.

Environmental Impact Assessment Core Learning Outcome 4:

Question complex or contradictory information to make decisions among trade-offs (i.e., What is the cost of the decision? Who and what will be most impacted by the decision? Are marginalized communities part of the decision?). ○ (2, 4)

1-2 hours

Integration Example:

Type of activity: Student team project. Students begin the project with in-class discussion and instructor support, and then finish outside of class as a homework assignment.

Students analyze the tradeoffs involved in designing a simple lighting circuit using a power source, resistor, and LED by following these steps:

1. Students work in small teams/groups to design the circuit and choose reasonable parameters.
2. (Time/class format permitting) Student teams share out designs to the class.
3. Instructor-led class discussion to encourage students to consider all of the non-technical factors involved in the engineering design process. Consider these prompts: What factors did you include in your decision process? Did you think about material sourcing? Environmental impacts such as carbon emissions or waste energy costs? Community needs or impacts of the above on vulnerable populations?
4. Students then revisit their designs taking the above factors and discussion into consideration. Consider this prompt: How will you deal with trade-offs between both technical and non-technical factors?
5. Students continue the process as a homework assignment. For homework, students re-do their design with their team then write up your results. Could extend this by having student teams present their modified results.

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Materials Selection

Course title: CAD / Mechanical Design	Course Level: 100-level
Course description: Learn about the design of mechanical components that meet engineering requirements	

Materials Selection Core Learning Outcome 5:

Design with lower impact, natural materials (e.g., earth, bamboo, agro-waste, etc.) with an aligned degree of knowledge of industrial materials (e.g., iron, steel, aluminum, etc.). ○ (2)

Semester-long

Integration Example:

Type of activity: Student project (team or individual).

Challenge students to identify and utilize alternative, environmentally-friendly 3D printing materials through an individual or team project. This project could be expanded into another semester if students engage in the design of the alternative material(s).

Supporting Resources:

- Plastic Pollution - Kurzgesagt (YouTube)
- Algix Algae 3D printer (3Dprintlife.com)
- Leverage a partnership with an industry or manufacturing partner

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Design

Course title: Thermodynamics | **Course Level: 200-level**

Course description: Relations between heat, work, temperature and energy including heat exchange, energy flows, refrigeration cycles.

Design Core Learning Outcome 1:

Execute technical analyses to choose strategies that maximize the positive and minimize the negative environmental and social impacts in order to achieve design goals. (2, 6)

60 minutes

Integration Example:

Type of activity: Prepared homework assignment (e.g., take home assignment to do calculation) followed by single, in-class discussion of their findings.

Source: How Coal Fired Thermal Power Stations Work (YouTube)

Students learn to balance carbon sequestration considerations by calculating and comparing carbon dioxide production and use of energy with an object/product. Students calculate CO2 production and a thermo analysis of carbon generated by a coal power plant compared to energy produced with alternative energy sources (e.g., solar). Lead discussion of design decisions based on carbon and energy calculations, and encourage students to consider social and environmental impacts. Note: This assignment could be extended beyond a homework assignment where students conduct research and have multi-week discussion about alternative energy solutions.

Supporting Resources:

- How do Coal-fired Power Stations Work? (YouTube)
- How Coal Fired Thermal Power Stations Work (YouTube)
- How do Solar Panels Work? Richard Komp (TedTalk)
- Journey to the Heart of Energy - How a solar power plant works (YouTube)
- Renewables vs. Fossil Fuels: The True Cost of Energy - Engineering with Rosie (YouTube)

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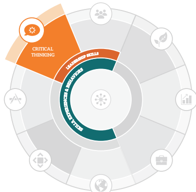
Critical Thinking



Course title: Introduction to Computational Methods **Course Level: 100- and 200-level**

Course description: Approaches to engineering problems with computational tools and numerical methods.

Critical Thinking Learning Outcome 5:

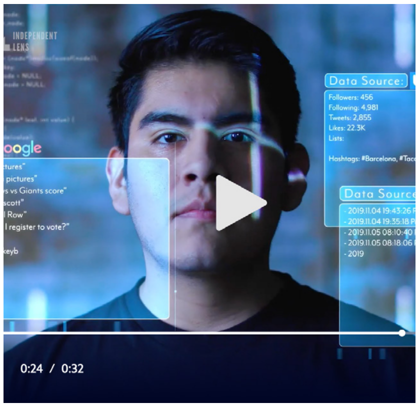
Examine norms, biases, and values that underlie one's behaviors (i.e., normative thinking and cognitive dissonance). ○ (4)

60 minutes

Integration Example:

Type of activity: Individual assignment.

Students work with data sets from a variety of sources (air, water, soil, radiation, etc.). Students practice cleaning, organizing, and plotting data, then analyze data for bias on different parameters (location/proximity to pollution sources/natural radiation in geologic formation/socioeconomic status, etc.). This fits into the class by having something meaningful to look at when practicing coding skills, reading in data, and data visualization. Suggested flow of activity: 20 min discussion in class and video to introduce the context of environmental data sets, homework problem, then 20 min debrief during the next class session. Consider prompts for discussion or think-pair-sharing activity: *Where else could bias in data have an impact on outcomes?*



Source: Coded Bias documentary (Netflix)

Supporting Resources:

- Coded Bias documentary (Netflix)
- How I'm Fighting Bias in Algorithms by Joy Buolamwini (TedTalk)
- A Look at Cancer Alley, Louisiana (Subject to Climate; Climate Change Lessons by Teachers website)
- Seek examples about PFAS such as Teflon
- AirNow.gov for air quality data in different regions/zip codes
- RadNet US EPA

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Communication and Teamwork

Course title: Statics or Mechanics	Course Level: 100- or 200-level

Course description: Study of the conditions of equilibrium for stationary structures. Principles of vectors, forces, moments, free-body diagrams.

Communication and Teamwork Learning Outcome 4:

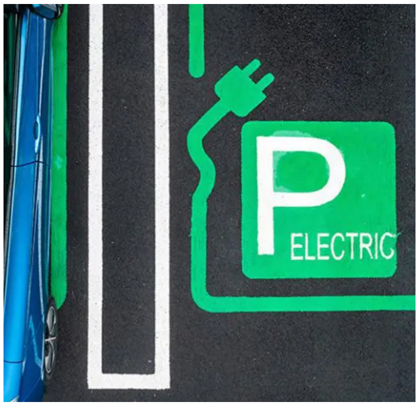
Demonstrate self-awareness and understanding of unconscious bias. ○ (5)

60 minutes (single class period)

Integration Example:

Type of activity: In-class lecture and discussion.

Create examples/case studies for students of different engineering majors where forces have changed due to climate change (e.g., parking garage with EVs, water-related issues with more rainfall, hurricane force winds, etc.). Emphasize and address implicit/unconscious bias in these examples. Review case studies with students. Open to whole class or small group discussions. Consider discussion prompts like: *Implicit or unconscious bias is a form of bias that occurs automatically and unintentionally that affects judgements, decisions, and behaviors… What bias(es) did you recognize in yourself that you were unaware of? How did it make you feel? How will the experience change the way you approach your next engineering problem?*



Source: Image by frimufilms on Freepik

Supporting Resources:

- **Building for Hurricanes: Engineering Design Challenge** (NASA Precipitation Education website)
- **The Benefits of Installing Electric Vehicle Charging Stations in Commercial Parking Garages** (Parklio.com; blog)

Conclusion

Contributor Acknowledgment

We want to thank the 94 faculty that attended and actively engaged in the Interdivisional Town Hall (ITH) event at the ASEE annual conference on June 26, 2023. During this 30-minute event, participants co-created each of the specific course examples provided in this guide. They not only demonstrated how quickly curricular changes can be devised by using the EOP Framework and companion teaching guides, but also that sustainability can be integrated into a variety of required and core engineering courses. We are delighted to share the outcomes of the session to help future engineering educators in their quest to infuse sustainability and leadership competencies into core engineering curriculum to help to change the course of engineering education.

Thank you to Dr. Jenna Carpenter (Founding Dean & Professor, Campbell University and ASEE 2022-2023 President) and Dr. Michael Milligan (ABET CEO) for suggesting Engineering for One Planet as a topic, and thank you to the ASEE 2023 ITH Co-chairs for the opportunity to host this session: Dr. Lynn Albers, Dr. Micah Lande, and Dr. Bala Maheswaran.

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APPENDIX

On June 26, 2023, during the Interdivisional Town Hall (ITH) event at the 2023 ASEE Annual Conference, 94 participants divided into random teams worked together to create the 13 teaching examples found in this guide. Participants were given a brief 10-minute introduction to the history and background of the EOP initiative. Teams were formed with the people sitting at the same tables. Each table was pre-assigned one of the nine topic areas from the EOP Framework (e.g., Systems Thinking). Then teams were guided through a 5-step process with a worksheet (see below) to capture their ideas for the integration of a single core learning outcome from the EOP Framework —of their choice— into an existing core engineering course of their choice. Within 30 minutes each team produced a curricular example. Each of the teams' examples were reviewed, edited and curated as part of this guide.

EOP Framework Topic Area Worksheet

SAMPLE

Systems Thinking

EOP Framework | **Comprehensive Teaching Guide** | **Quickstart Activity Guide**

Activity Instructions

- **Step 1:** Add your information to the Contributors Form (separate sheet).
- **Step 2:** As a team, select a core/required engineering course* that your team is familiar with and interested in integrating sustainability into.
    - *Pick a course that is not a design course (e.g., Heat Transfer, Dynamics,...)
    - Enter relevant information into the Course Form below
- **Step 3:** Using the **EOP Framework** and as a team, select a core learning outcome from the Systems Thinking topic area to bring into your selected course.
    - Capture relevant information into the Learning Outcome Form below
- **Step 4:** Using the **Comprehensive Teaching Guide** for inspiration, come up with your own ideas of activities/assignments that you could do in your chosen course to introduce sustainability to your students. For example, an activity could be a reading and discussion question, a video that introduces a sustainability methodology, a replacement example or scenario that has a sustainability focus, etc.
- **Step 5:** Discuss ideas as a team and **select one activity/assignment** to bring sustainability into your course.
    - Capture relevant information into the Activity Form below

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Course Form

Title of Core/Required Engineering Course:	
Level of Course:	
Brief description of course (no more than 2 sentences):	

Learning Outcome Form

EOP Core Learning Outcome (LO) from Topic Area:	
Reason this LO was selected:	
ABET student outcome(s) achieved denoted by ABET circle & number (1-7 or N/A):	

Activity Form

Briefly describe the activity and/or assignment you will bring into your course. Is it a modification of an existing activity/ assignment or is it new?	
Approximately how much time will this activity take (e.g., how many minutes, hours, class days, etc.)?	
What supporting learning resources will be utilized for this activity (e.g., videos, reading materials, physical equipment, etc.?)	
Bonus! How will you measure the success or assess student learning from this activity?	

Reflection for discussion:

Was the activity harder or easier than you expected?	Will you change something that you are teaching?

References

The Lemelson Foundation (2022). **The Engineering for One Planet Framework: Essential Sustainability-focused Learning Outcomes for Engineering Education (2022)**. Cynthia Anderson and Cindy Cooper (Eds). The Lemelson Foundation, Portland, Oregon, USA. 28 pages.

The Lemelson Foundation (2023). **Engineering for One Planet Framework: Comprehensive Guide to Teaching Learning Outcomes**. Cynthia Anderson, Cindy Cooper, and Dustyn Roberts (Eds). The Lemelson Foundation, Portland, Oregon, USA. 26 pages.

The Lemelson Foundation (2023). **Engineering for One Planet Framework: Quickstart Activity Guide**. Cynthia Anderson, Cindy Cooper, and Dustyn Roberts (Eds). The Lemelson Foundation, Portland, Oregon, USA. 22 pages.

Engineering for One Planet

Join the EOP Initiative

Everyone interested in this work is encouraged to join and participate in the EOP initiative. Visit EngineeringforOnePlanet.org for teaching tools, information about grants, and curricular change examples, to sign up for the EOP Newsletter, or to apply to become an EOP signatory.

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