Engineering for One Planet

Engineering for One Planet Framework:

17 Sustainability-Focused Engineering Course Activities Co-Created by Teaching Faculty

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Co-created *by* teaching faculty *for* teaching faculty

Background & Introduction

Introduction:

This teaching guide serves as a companion to the **Engineering for One Planet (EOP) Framework**. The EOP Framework provides a vetted menu of sustainability and leadership competencies that every graduating engineer, regardless of subdiscipline, needs to acquire to design, code, build, and implement solutions that are socially, environmentally, and economically sustainable.

In response to EOP community requests, several "how to" guides have been developed to provide specific course activities, learning experiences, and resources to support the implementation of student learning outcomes from the EOP Framework into existing engineering courses. The guide is designed to aid faculty in making curricular changes 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 icons ( ) in this guide relate to Bloom's Taxonomy, ABET Criteria 3, and the United Nations Sustainable Development Goals. Please see the EOP Framework for an explanation of the icons.

All of the EOP Framework companion teaching guides have Creative Commons licensing. This is a free, standardized copyright license whereby The Lemelson Foundation and all contributors to the resources have given permission to anyone to use, share, and build upon this work. Faculty are encouraged to use and adapt the activities shared in this guide to best fit their specific teaching and learning purposes. Instructors should use their discretion to adapt the recommended length of time for activities depending on the course, student needs, and depth of understanding. For example, an activity that is suggested to take 30 minutes could be expanded or contracted based on available class time. Similarly, if an activity was developed for a design class, feel free to adapt it so it works in the context of other classes. This guide can also be adopted and adapted for non-engineering disciplines and learners.

The Lemelson Foundation and 2024 Engineering for One Planet (EOP) Workshop Participants (2025). Engineering for One Planet Framework: 17 Sustainability-Focused Engineering Course Activities Co-Created by Teaching Faculty. Cynthia Anderson, Jorge Loyo, Victoria Matthew, and Noé Vargas Hernandez (Eds). The Lemelson Foundation, Portland, Oregon, USA. 60 pages.

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Systems Thinking

1 Definition of Sustainability and its Three Pillars

Contributed by Jorge Loyo

Time to complete activity: 1-2 hrs
Type of activity: Individual reflection combined with small and large group discussion

Detailed description

There is no universal definition of sustainability and different institutions use their own definitions. However, most definitions have common elements, such as the "three pillars" (environmental, social and economic), the use of a systems approach, and the preservation of existing resources for future generations.

In this activity, students compare different definitions of sustainability and identify their common elements. Students reflect on the institutions we entrust to define sustainability and how the term is used interchangeably with 'sustainable development'. They will analyze the different representations of sustainability as a three-component concept and reflect on whether all three are equally important to achieve sustainability.

Part 1: 35 min

Students work together to agree upon a common definition of sustainability:

- Students reflect on their own understanding of the term 'sustainability' (2 min)
- Students share their reflections in small groups (2-3 students) (5 min)
- Student groups agree on two or three institutions that should be responsible to provide an "official" definition of sustainability at the national and international level, and research these definitions online (10 min)
- As a large group, students compare definitions from different institutions, and they discuss and document common themes (5 min)
- As a large group, students develop a common definition of sustainability and discuss the importance of a consensual definition when working on a common problem, especially when their backgrounds are different (10 min)

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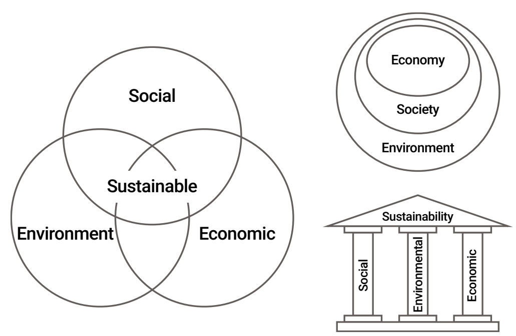
Systems Thinking

Conclude Part 1 of the activity by emphasizing that different institutions define sustainability differently but that they all include a systems approach (e.g., interconnectedness of natural and human systems) and the meeting of current and future human needs within planetary limits. Enrich the discussion by challenging students' assumptions about the meaning of "official" definitions, the institutions that we consider trustworthy to define sustainability, and the underlying value systems or points of view behind the definition(s) the students are proposing.

Part 2: 15 min, plus pre-discussion reading assignment

Students discuss the use of the terms 'sustainability' and 'sustainable development':

- Individual students read Purvis et al. paper as a pre-discussion assignment
- Individual students reflect on main takeaways from the article (2 min)
- Students share their reflections in groups of two or three (3 min)
- As a large group, students discuss how the terms 'sustainability' and 'sustainable development' have been used historically and the consequences of not having a consensual definition of either (10 min)



Part 3: 15 min

Students identify the three pillars of sustainability:

- Individual students are prompted to name the three pillars in an open group (2 min)
- Students draw a representation of the three pillars in small groups (3 min)
- Students share their depiction of the three pillars with the whole group (5 min)
- As a large group, students compare the different depictions and discuss and document differences and commonalities (5 min)

Conclude that sustainability has been represented as a three-component, interrelated concept, with some representations assigning equal value to each component (e.g., in the intersecting circles or Venn diagram and pillar representations), whereas others show the economic component as immersed within the social and environmental components (e.g., the concentric circle model).

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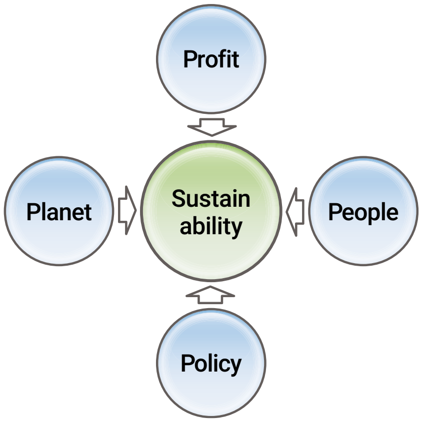
Systems Thinking

Emphasize the interconnections across all components. Alternatively, students can watch the Triple Bottom Line video and discuss whether the three components of sustainability are better represented as having equal value (e.g., Venn diagram or three pillar model) or as the three concentric circles.

For more in-depth discussion, encourage students to discuss the historical origins of the three pillar representation of sustainability and the ambiguous use of the terms sustainability and sustainable development described in the Purvis et al. paper. Extend the activity to include other concepts related to the interrelated components of sustainability, such as the Triple Bottom Line (Profit, People, Planet) or the 4Ps (Purpose, Profit, People, Planet).



Part 4: 20 min

If the course covers sustainability topics extensively, students should review their definition of sustainability at the end of the course. Encourage students to reflect on the group definition of sustainability proposed earlier in the semester, then discuss and develop a revised definition for the group. Alternatively, ask students to write a discipline-specific definition of sustainability (e.g., for chemical engineers, or mechanical engineers).

Supporting Resources

- Triple bottom line (3 pillars): sustainability in business
- Introduction to Sustainability
- Introduction to Sustainability course
- The ABC of Sustainability
- The Age of Sustainable Development
- SDGAcademyX or SDGAcademy
- Purvis, B., Mao, Y. & Robinson, D. *Three pillars of sustainability: in search of conceptual origins*. Sustain Sci 14, 681–695 (2019)

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Systems Thinking

Proposed Assessment Examples

- What are two common elements in different definitions of sustainability? How are they interconnected?
- What is the difference between sustainability and sustainable development?
- Why is the concentric circle diagram representation of the three sustainability pillars generally preferred over the Venn diagram?

Course Integration

Course title: Introduction to Engineering	**Suggested Course Level:** 100

Course description: Students are introduced to engineering through exploration of its history, tools, problem-solving process, and technological advances.

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Systems Thinking C.1.

EOP Framework Learning Outcome description: Explain interconnectedness (e.g., intersecting, related and/or connected systems; human actions and global environmental and social impacts and consequences; synergies and rebound effects) and how all human-made designs and activities rely upon and are embedded within ecological and social systems. ○ (4)

Other EOP Framework Learning Outcomes achieved:
Communication and Teamwork C.3.
Critical Thinking C.6. and A.1.

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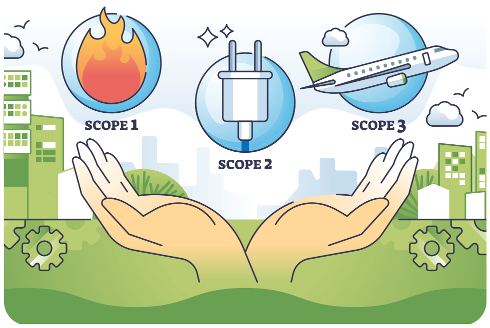
Environmental Literacy

2 Assessing Scope Emissions

Contributed by Dave Wagner

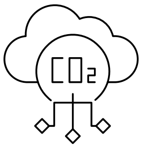
Time to complete activity: 60-75 minutes
Type of activity: Individual or group

Detailed description



Individual carbon footprints can be calculated with online calculators that use life cycle assessment data and provide average responses. A better approximation of an individual's carbon footprint can be calculated from utility bills. This is analogous to scope 2 emissions from a process or corporation. A brief introduction may be required for scope emissions, but the focus could be on other issues related to the topics below. Students can then compare greenhouse gas equivalency (GHGeq) values with peers and reputable resources to see the impact of corporate sustainability measures and transparency.

Part 1: Students calculate their individual scope 2 emissions (15 min)



Calculate
Emission Data

- Use your utility bills and gas station receipts (or estimates) for the last month.
- Calculate your electricity GHGeq by multiplying your use (in kilowatt-hours, kWh) by one. This is approximately equal to the pounds of GHGeq emitted from electricity. If not available, use U.S. Energy Information Administration (EIA) data.
- Calculate your heating GHGeq by multiplying your use in therms (one therm equals 100,000 BTUs) by 12, assumed to be natural gas. This is approximately equal to the pounds of GHGeq emitted from heating. If not available, use U.S. EIA data.
- Calculate your vehicle GHGeq by multiplying your monthly use of gasoline and/or diesel (in gallons) by 20. This is approximately equal to the pounds of GHGeq emitted from transportation. If not available, use U.S. EIA data.
- Sum these three values to determine your approximate scope 2 emissions.

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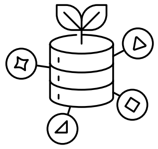
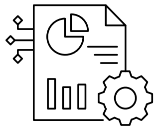
Environmental Literacy

Part 2: Comparison with corporate/NGO data (60 min)



- Pick a company with online sustainability data. Students can find a list of the most data-transparent corporations at the Carbon Disclosure Project's site (e.g., Tetra Pak).
- Find the scope emission data in the company's report (and any other reporting/metrics you find intriguing).

Part 3:



The previous steps could be a standalone assignment if you want students to write their interpretations and findings of scope emissions, GHGeq data/calculations, etc. This could also be an in-class discussion among groups. Students could or could not calculate their own scope 2 emissions, since the main takeaway is likely from the discussion of corporate transparency, reporting, and responsibility. Discussion can be in small groups, or among the entire class.

The discussion could move toward greenwashing (companies highlighting positive aspects of operations while ignoring the negative ones), corporate responsibility, and the societal implications of corporate reporting. Instructors could also introduce aspects of ESG reporting and delve into decision-making for policymakers.

Supporting Resources

- Ecological Footprint Calculator, Global Footprint Network
- Ecological Footprint Calculator, Greenly
- Tetra Pak's 2023 Sustainability Report

Proposed Assessment Examples

- What is your GHGeq relative to heating and vehicle travel? Is this higher or lower than you expected? Why?
- How might the corporation's sustainability decisions impact society?
- Do you think corporations (of a certain size) should be required to report at least some sustainability metrics? Why or why not?

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Environmental Literacy

Course Integration	
Course title: Sustainable Engineering	**Suggested Course Level:** 100 to 400
Course description: This course discusses corporate responsibility and introduces an in-depth module concerning energy and/or air pollution.	

EOP Learning Outcome Alignment
EOP Core Learning Outcome: Environmental Literacy C.4.
EOP Framework Learning Outcome description: Explain the nature and role of energy in the world, our daily lives, and in engineering practices (e.g. is energy literate). ○ (2, 4)
Other EOP Framework Learning Outcomes achieved: Environmental Literacy A.5. Responsible Business and Economy A.5. Systems Thinking A.4.

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Environmental Literacy

3 Mauna Loa CO_2 Emissions Project

Contributed by Amakoe Gbedemah

Time to complete activity: 1-2 hrs, homework assignment
Type of activity: Individual or small group

Detailed description

Greenhouse gases are gases that trap heat in the atmosphere. The main greenhouse gases are:

- Carbon dioxide (CO_2) enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical reactions (e.g., cement production).
- Methane (CH_4) is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices, land use, and by the decay of organic waste in municipal solid waste landfills.
- Nitrous oxide (N_2O) is emitted during agricultural, land use, and industrial activities, combustion of fossil fuels and solid waste, as well as during treatment of wastewater.
- Fluorinated gases are synthetic and are emitted from a variety of household, commercial, and industrial applications and processes. They have no significant natural sources and come almost entirely from human-related activities.

Mauna Loa is one of five volcanoes that form the islands of Hawaii in the U.S. The carbon dioxide data collected at the Mauna Loa Observatory Hawaii site constitutes the longest record of direct measurements of CO_2 emitted into the atmosphere.

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Environmental Literacy

1. The Mauna Loa Data Set (Refer to Supplemental Materials; See Tab 2: Mauna Loa - Data Set) provides the yearly average of CO_2 measured at the Mauna Loa Observatory Hawaii site since 1950. Students use Excel to draw a scatter plot of the data, add a trendline on the graph with a polynomial function of degree 2.
2. In what year will the Mauna Loa Observatory Hawaii site measurements be twice as much as they were in 1950?
3. Students use their model to complete the blank table found in Supplemental Materials (Refer to Supplemental Materials; See Tab 3: Mauna Loa - Table for Completion). What is the difference between the actual data and the data given by the model?

Supporting Resources

- Supplemental Materials, Tab 2: Mauna Loa - Data Set and Tab 3: Mauna Loa - Table for Completion
- Trends in CO_2 at Mauna Loa from NOAA
- Lava Flows from Mauna Loa from 1843-2018 from National Parks Service
- Mauna Loa Volcano Is Erupting
- 2022 Eruption of Mauna Loa Pictures

Proposed Assessment Examples

- Linear regression line is usually used to analyze data. Why do you think we use polynomial function in this case?
- What can we infer about the urgency of addressing CO_2 emissions based on this trend?
- We know that there is no way to prevent the eruption of a volcano, but we still can reduce some of its risks. List 2-3 ways to reduce its risks.

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Environmental Literacy

Course Integration

Course title: Basic Mathematical Modeling	**Suggested Course Level:** 100
Course description: In this course, students are introduced to the field of basic mathematical modeling based on data.	

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Environmental Literacy C.5.

EOP Framework Learning Outcome description: Examine data about environmental issues (e.g., climate change, energy and water use, scarcity and pollution, air quality, waste management, toxicity, etc.) including consideration for past/current/future and local/regional/global impacts. (2, 6)

Other EOP Framework Learning Outcomes achieved:
Critical Thinking C.1.

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Environmental Literacy

4 USA and China CO_2 Emissions Project

Contributed by Amakoe Gbedemah

Time to complete activity: 1 week, homework assignment
Type of activity: Individual or small group

Detailed description

Students explore the U.S. and China CO_2 Emissions Project. The planet's top 10 emitters of CO_2 are China, the United States, India, Russia, Japan, Germany, Canada, Iran, South Korea, and Indonesia. This activity focuses on the top two countries for CO_2 emissions: China and the United States.

Students review provided data found in Supplemental Materials (Refer to Supplemental Materials; See Tab 4: U.S. and China - Data Set) and use them to answer the three exploratory questions provided below. (Hint: use Excel to do the calculations!)

Then students model the amount of CO_2 emitted by the United States and China from 1980 until 2021, respectively, by the polynomial function f and the piecewise function g below:

$$f(t) = .0076t^4 - .6977t^3 + 18.108t^2 - 88.053t + 4668.6.$$

And

$$g(t) = \begin{cases} 99.168t + 1519.5 & 0 \le t \le 16 \\ 23.821t^2 - 779.06t + 9477.3 & 16 < t \le 22 \\ 623.73t - 9681.4 & 22 < t \le 33 \\ -2.1439t^3 + 286.33t^2 - 12301t + 182140 & 33 < t \le 41 \end{cases}$$

Students review the plotted data for visual comparison in the graph provided.

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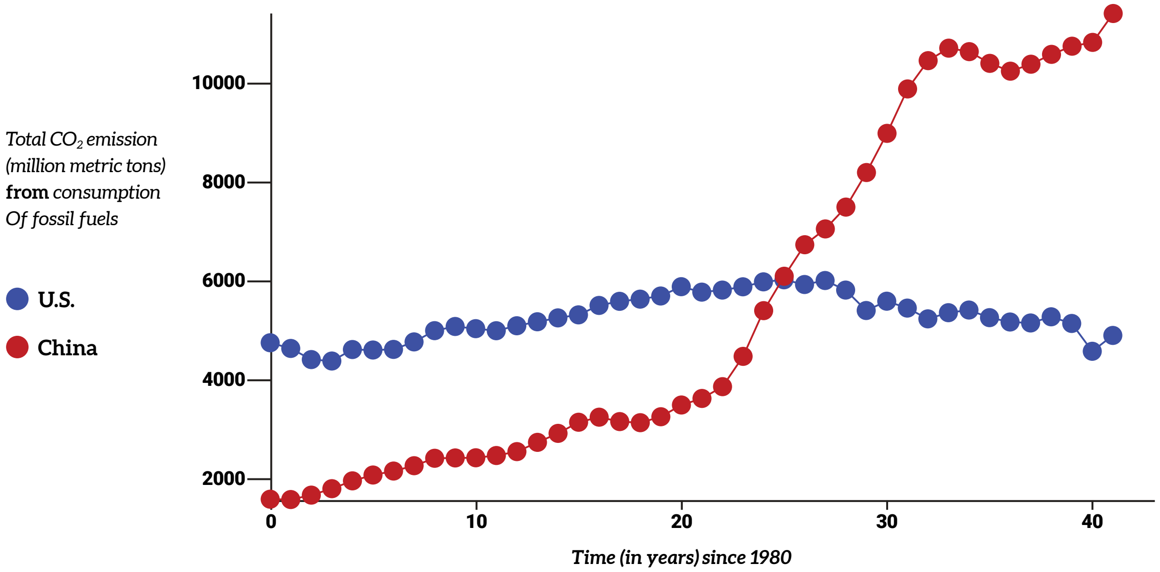
Environmental Literacy



- Looking at the amount of CO_2 emitted by the United States and China from 1980 to 2021, what is striking about it? Give a possible reason.
- Calculate the average rate of change of total emissions from 1980 to 2021 for the United States and China. Give a brief summary and the practical meaning of your results.
- Use the Intermediate Value Theorem to show that there exists a year where the United States and China produced the same amount of CO_2 using the mathematical models provided. Carefully select the interval. As a hint, use the graph provided.

Supporting Resources

- Supplemental Materials, Tab 4: U.S. and China - Data Set

Proposed Assessment Examples

- Why did we use a piecewise function to represent the amount of CO_2 emitted by China?
- Why does the graph representing China's emission of CO_2 have multiple peaks and valleys?
- What are the primary sources of carbon dioxide (CO_2) emissions?

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Environmental Literacy

Course Integration

Course title: Calculus 1

Suggested Course Level: 100

Course description: Students are introduced to the application of the Intermediate Value Theorem through the lens of mathematical modeling.

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Environmental Literacy C.5.

EOP Framework Learning Outcome description: Examine data about environmental issues (e.g., climate change, energy and water use, scarcity and pollution, air quality, waste management, toxicity, etc.) including consideration for past/current/ future and local/regional/global impacts. (2, 6)

Other EOP Framework Learning Outcomes achieved:
Critical Thinking C.1.
Design C.1.

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Responsible Business and Economy

5 Our World in Data SDG Tracker

Contributed by Lisa Bosman

Time to complete activity: 3-hour class
Type of activity: Small team

Detailed description

The Our World in Data Sustainable Development Goal (SDG) Tracker offers a list of targets and indicators for measuring sustainability efforts throughout the world. Each indicator includes a definition, target, research, and additional charts.

Students will work in teams to identify a problem as evidenced by the SDG indicators, recognize current approaches and gaps, and propose a solution. Example activities are provided next.

Part 1: Use the Our World in Data SDG Tracker to identify 3 potential problems (from 3 different SDGs) to target for your module project. Each explanation should be about 200 words and should follow the Claim-Evidence-Reasoning approach.

Part 2: For each problem identified in Activity 1, identify initiatives currently in place to solve those problems. Specifically, be sure to identify one of each: government policy/ initiative, non-profit organization, and for-profit company. For each initiative, list the gaps (e.g., reasons why these initiatives don't completely solve the problem). Each explanation should include about 200 words.

Part 3: Based on Activity 1 and Activity 2, select one problem to work on. Recommend a solution in the form of a B Corp that responds to the problem. Create a company name and logo using generative AI, such as https://www.brandcrowd.com/. Each solution explanation should be about 500 words and include 3 images.

Culminating Module Project: Students work in teams to submit an executive summary. Find project details and rubric in the Supplemental Materials (Refer to Supplemental Materials; See Tab 5: SDG Tracker - Assignment Details and Tab 6: SDG Tracker - Rubric for Executive Summary).

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Responsible Business and Economy

Supporting Resources

- Our World in Data UN SDG Tracker
- Supplemental Materials, Tab 5: SDG Tracker - Assignment Details and Tab 6: SDG Tracker - Rubric for Executive Summary

Proposed Assessment Examples

- How can the SDG indicators be used to assess, evaluate, and justify the need for sustainable business models?
- How can the SDG tracker be used to assess changes over time across countries?
- Which indicator was the most surprising to you? What indicators may be missing?

Course Integration	
Course title: Leadership Strategies for Quality and Productivity	**Suggested Course Level:** 400
Course description: This course is a study of how organizational leaders create an environment conducive to high levels of employee self-motivation, quality, and productivity. Emphasis is placed on process, systems thinking, and evidence-based decision making.	

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Responsible Business and Economy

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Responsible Business & Economy C.4.

EOP Framework Learning Outcome description: Demonstrate awareness of alternative forms of capital beyond financial resources (including natural, human, social, and physical) and awareness of emerging economic systems intended to promote environmental and social responsibility in economic thinking (e.g., Doughnut Economics, circular economy, etc.).

Other EOP Framework Learning Outcomes achieved:
Responsible Business and Economy C.1.
Critical Thinking A.2.
Communication and Teamwork C.1.

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Social Responsibility

6 Autonomous Vehicle Trolley Problem

Contributed by Krystal Colón, Alireza Mohammadi, Archana Shashidhar Mysore, Christopher Papadopoulos, *and* Anand Shetty

Time to complete activity: 1 hour
Extend to a semester-long project for senior level robotics courses
Type of activity: Individual or small teams

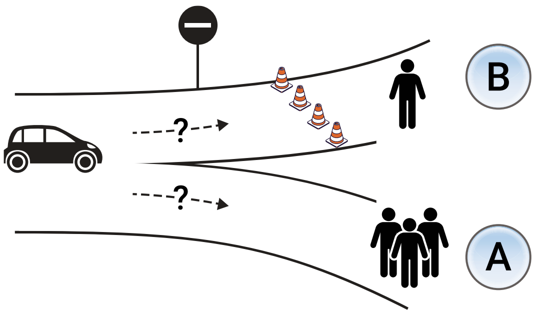
Detailed description

Challenge your students to utilize and strengthen their critical thinking skills to work through the following thought experiment which codifies the classic "Trolley Problem."

Scenario for students to consider:
You are hired to design the AI for a driverless car. You need to train the algorithm for the autonomous vehicle to avoid harm. In a situation where a collision with a pedestrian is impending:

- How should the AI be trained to reduce harm? Avoid harm?
- How should AI be trained to decide whether to avoid harm to the pedestrian or a passenger?

Use flipped classroom style where students have to read through/watch the provided Supporting Resources before coming to the classroom. Then ask students to discuss the question prompts and design decisions within the team or with other students (if not in teams). Finally, ask students to write a short summary of their discussion and present it to the class.



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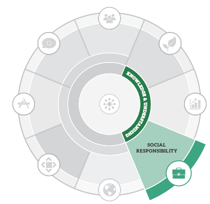
Social Responsibility



Supporting Resources

- 1965: Isaac Asimov's 3 Laws of Robotics
- IBM Video on Responsible AI
- Trolley Problem, Wikipedia
- Self-Driving Cars: Ethical Responsibilities of Design Engineers
- What is an Autonomous Vehicle?
- When Self-Driving Cars Don't Actually Drive Themselves
- Moral Machine

Proposed Assessment Examples

- How did you consider (weigh and balance trade offs) the consequences of the design of the AI training algorithm? List 3 potential intended and unintended consequences of your design.
- What are some ethical choices that may be required when designing the AI training algorithm?
- In what ways do you think your biases and values would influence your design decisions?

Course Integration	
Course title: Introduction to Engineering	**Suggested Course Level:** 100
Course description: Provides introduction to engineering analysis and design. Incorporates teamwork and engaging activities.	

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Social Responsibility

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Social Responsibility C.2.

EOP Framework Learning Outcome description: Recognize and be empathetic to ethical implications relative to the social impact of their work. ○ (4)

Other EOP Framework Learning Outcomes achieved:
Environmental Impact Assessment C.4.
Responsible Business and Economy C.3.
Critical Thinking C.6.
Critical Thinking A.1.
Critical Thinking A.6.

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Social Responsibility

7 Design Justice Investigation

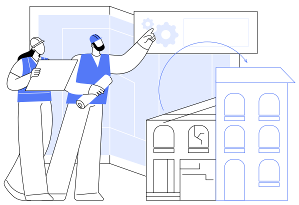
Contributed by Minal Mistry

Time to complete activity: Variable, project design evaluation from scoping to implementation
Type of activity: Group and small team (desirable) or individual

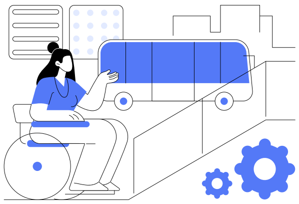
Detailed description

Students evaluate the design justice implication and potential for the proposed student concept, design, or implementation plan. This activity promotes intentional, iterative critical evaluation of assumptions and design parameters to engender lasting inclusive and equitable design practices and outcomes.

In this activity, students will center people — the voices of those who are directly affected by the design process — and iteratively evaluate their design or engineered solution to enhance well-being.



- Identify known structural injustice within your assignment: Effects and outcomes that can enhance and/or degrade the human experience selectively depending on who one is. For example, for a walkable neighborhood plan, consider for whom the space might — and might not — be comfortable.



- Engaging with underserved communities: Engage in responsible and constructive ways when developing products or systems for communities that have historically been negatively impacted or marginalized, such as communities of color and rural areas.

- Reducing imposed risks and harms: Identify potential risks and harms by proactively identifying unintentional risks to the user and local communities.

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Social Responsibility

- Empowerment and resilience (increasing human rights): Ensure that designs allow people to do tasks they were unable to do before.
- Critical evaluation: Have your design, plan, or proposal reviewed by others in the class or students from a different section.

Supporting Resources

- Designing Spaces for Racial and Cultural Justice, Bryan C. Lee Jr.
- Design Justice Network
- Design for Freedom
- What Reading Design Justice Has Taught Me About User-centered Design

Proposed Assessment Examples

- How does making design choices based on established parameters such as efficiency, cost, performance, and/or quantification of impacts affect embodied (in)justice?
- What surprised you about your design choices with regards to perceived inclusivity (who was/wasn't involved)?
- How has human-centered design thinking affected your project from inception to finished product?

Course Integration	
Course title: Introduction to Design	**Suggested Course Level:** 100 and higher. Suitable for all levels for design build/engineering courses. Essential for upper level courses.
Course description: Work collaboratively to critically consider each design choice to promote inclusive, equitable and just outcomes that serve specific unserved needs.	

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Social Responsibility

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Social Responsibility C.4.

EOP Framework Learning Outcome description: Recognize that some communities (e.g. communities of color, rural communities, etc.) have historically been negatively impacted and/or intentionally marginalized, and continue to be disproportionately negatively impacted by engineering activities. (2, 4)

Other EOP Framework Learning Outcomes achieved:
Systems Thinking C.1., C.3., C.5.; and A.1.
Social Responsibility C.3., C.5., C.6.; A.1., and A.3.
Design C.3.; A.1., and A.2.
Critical Thinking C.1., C.2., C.4.; A.1., A.2., A.4., and A.7.
Communication and Teamwork C.4.; and A.3.

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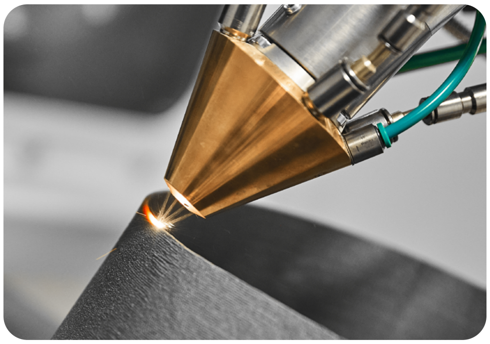
Environmental Impact Assessment

8 Sustainability Investigation in Additive Manufacturing

Contributed by Yang Zhang

Time to complete activity: 4 weeks
Type of activity: Group project

Detailed description



Students explore the process and outcomes of additive manufacturing, for example, Fused Deposition Modeling (FDM) which is a 3D printing process that uses a thermoplastic filament to create objects layer by layer. Consumptions in FDM 3D printing include the material used for the raw filament to print the product, electricity use during the 3D printing process, as well as the use and the end of life of the printed product. Students are encouraged to research the environmental and economic impacts of the FDM 3D process using the Supporting Resources below and additional sources of their choosing.

Supporting Resources

- FDM 3D Printing Introduction
- Choosing Greener Materials
- Ultimate guide to sustainable 3D printing materials
- Suárez, L., Domínguez, M. *Sustainability and environmental impact of fused deposition modelling (FDM) technologies.* Int J Adv Manuf Technol 106, 1267–1279 (2020)

Proposed Assessment Examples

- Is 3D printing environmentally friendly? Economically friendly? Why or why not?
- How does changing the raw filament material influence the environmental impact of the 3D printed product?
- How much environmental impact would be reduced if we were able to reduce or reuse the printing waste?

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Environmental Impact Assessment

Course Integration

Course title: Engineering Practices and Principles	**Suggested Course Level:** 200 or 300

Course description: Engineering project-based learning (open-ended) with emphasis on project control and engineering design processes. Special emphasis will be placed on professional, ethical, global, environmental, and contemporary issues.

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Environmental Impact Assessment C.1.

EOP Framework Learning Outcome description: Explain high-level environmental impact assessments (e.g., basic Life-Cycle Assessments (LCAs) and life-cycle hazards; i.e., how they work, what information they require, how to incorporate their findings into their work). ○ (2)

Other EOP Framework Learning Outcomes achieved:
Communication and Teamwork C.3.
Materials Selection C.1., A.3.
Responsible Business and Economy A.2.

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Materials Selection

9 Material System Dimension

Contributed by Minal Mistry

Time to complete activity: Variable, ongoing throughout course and/or pre-work or post completion sustainability evaluation for engineering assignments
Type of activity: Individual or team work

Detailed description

Students explore the origin of materials typically used by engineering professionals to understand sustainability dimensions of various materials, and to critically examine the social and ecological dimensions of the physical materials that make up products and services.

- Product selection: Select one product that has an engineered design to examine the product's material system dimension (e.g., a more simple material system such as soft drink can or a more complex material system such as a refrigerator).
- Resources: Where do the main source materials for a product come from? For example, where does the source material for an aluminum can come from? What is aluminum made of? Consider geography, extractive activity, raw or virgin materials, etc.
- Technical Material: What is the typical process of making the source material from the raw resources? For example, a product that relies on aluminum has a process that involves bauxite mining to ingot production and rolling to produce a usable form of aluminum.
- Environmental Dimension: What are the associated potential environmental (embodied) impacts of those materials?
- People and Place: Identify all the known and potential hidden ecological and human effects — short-term and long-term in social dimension — for the production of this product.

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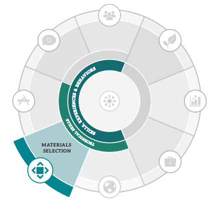
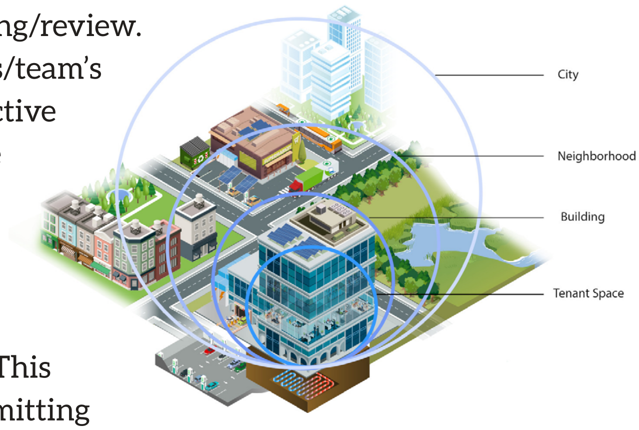
Materials Selection



Ongoing practice (Peer Review and Peer Learning): Students exchange completed assignments with each other prior to submitting to the instructor for grading/review. Each student/team reviews another student's/team's assignment and offers reflective and constructive review of sustainability parameters using the definition of sustainability adopted in the course. Students may have the opportunity to modify their assignment (physical or via written/visual) based on suggestions before submitting the final output to the instructor. This activity offers learning opportunities for submitting written critical reviews, accepting critical reviews, and incorporating appropriate suggestions into their work.



Supporting Resources

- Systems & Life Cycle Thinking
- How are plastics made?
- How is steel made?
- How is aluminum made?
- Fair labor practices
- Human Rights: Mining and Metals

Proposed Assessment Examples

- Why does material selection matter to sustainability outcomes?
- How do environmental and social dimensions relate to engineering solutions?
- How is the system affected by material selection and design choices and their assumptions?

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Materials Selection

Course Integration

Course title: Sustainability Dimensions of Materials	**Suggested Course Level:** 200 and above

Course description: Complementary activity for use in a variety of engineering coursework that involves material selection and allows students to expand critical review and peer learning.

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Material Selection C.1.

EOP Framework Learning Outcome description: Identify potential impacts of materials (e.g., embodied energy, emissions, toxicity, etc.) through the supply chain — from raw material extraction through manufacturing, use, reuse/recycling, and end of life — with a focus on minimizing negative impacts to the planet and all people (i.e., especially those who have been intentionally marginalized). (2, 4)

Other EOP Framework Learning Outcomes achieved:
Material Selection C.3., A.6., A.7.
Critical Thinking C.6., A.3.
Systems Thinking C.1., C.2.
Social Responsibility C.3., A.1.

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Materials Selection

10 LCA in Manufacturing

Contributed by Reese Simancek, Emma Telepo, *and* Sam Walsh

Time to complete activity: 2 weeks (final project)
Type of activity: Individual or small group

Detailed description

Students use Life Cycle Assessment (LCA) to compare different manufacturing processes.

Part 1: Students are introduced to and learn how to use manufacturing process tools, including computer numerical control (CNC) machines, programmable logic controllers (PLC), robots, and 3D printers. Students are introduced to an LCA tool (e.g., Ansys Grant EduPack LCA tool). Students learn how material selection for product design influences the material properties of the design, such as strength, durability, power, recyclability, and disassembly. Linear (cradle-to-grave) vs. circular (cradle-to-cradle) design is discussed.

Part 2: Students design objects and utilize manufacturing process tools to physically create design prototypes to explore, test, and critically evaluate:

- What is the best tool/machine to use? Why?
- What is the best material to use? Why?
- What design decisions/tradeoffs are being made? Why?

Part 3: Students use an LCA tool to compare the outcomes of different materials selection and manufacturing processes:

- How does the material selected impact the manufacturing process?
- How does the material selected change the product's integrity?
- How does circular vs. linear design influence the design process?
- What changes can be made to the material or production to improve design for recyclability, disassembly, light-weighting, etc.?

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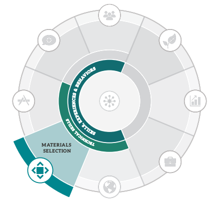
Materials Selection



Supporting Resources

- Ansys Granta EduPack
- openLCA
- Grab Cad
- Ender (opensource) 3D Printer
- Measuring Sustainability, VentureWell

Proposed Assessment Examples

- What are the strengths and weaknesses of LCA?
- What are the benefits and limitations of Cradle-to-Cradle (circular design) vs. Cradle-to-Grave (linear design)?
- List 3 ways that materials selected for use in various manufacturing processes (e.g., CNC, 3D printing, etc.) influenced their physical properties (e.g., strength, durability, etc.).

Course Integration	
Course title: Computer Integrated Manufacturing	**Suggested Course Level:** 400
Course description: Learn to use CNC, PLC, robots, and 3D printers. Design objects and learn how to program and utilize tools to manufacture them.	

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Materials Selection

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Materials Selection C.4.

EOP Framework Learning Outcome description: Compare materials properties (e.g., chemical, physical, and structural properties) and performance aligned with end-use application. ○ (2)

Other EOP Framework Learning Outcomes achieved:
Environmental Impact Assessment C.1.
Environmental Impact Assessment C.4.
Materials Selection A.8.
Design A.3.
Responsible Business and Economy A.2.

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Design

11 Heuristic Strategies for Rapid Ideation in the Industrial Design Process

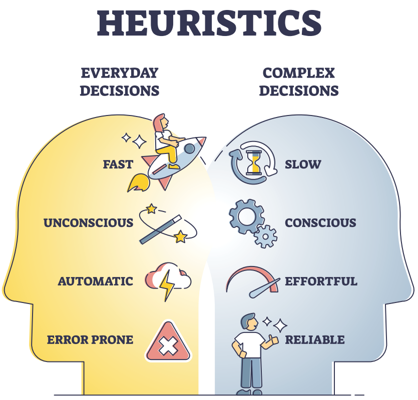
Contributed by Jonathan Abarbanel

Time to complete activity: 1 class session to 1 week
Type of activity: Individual with group review

Detailed description

Sustainable Industrial Design can be dauntingly complex for students faced with the task of integrating user-focused research insights, project constraints and goals, as well as life cycle analysis implications (materials, sourcing, manufacturing processes, distribution, usage, end-of-life concerns etc.). This can lead to "analysis paralysis," making it difficult for students to know how to begin ideating potential design solutions. Introducing heuristics gives students a simplified, rules-based entry into rapid idea generation that can energize and inspire the creation of many potential design ideas in a short period of time. This output then feeds into a more deliberative, criteria-driven refinement and validation of ideas using the project research insights and goals.

Part 1: (In-class) 30 min
Introduce the general topic of heuristics and their application to product design ideation. Then, introduce the heuristic strategy topic of "Footprints" to be used for a design sprint: every physical product has a literal footprint as well as an environmental footprint. Changing one can change the other. Designing a product to take up less space can have multiple beneficial effects on its environmental impacts. Note that Footprints heuristics are a small subset of a much larger collection of heuristic strategies for sustainable design. The module could be expanded to have the students develop their own set of heuristics.



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Some footprint heuristic strategies to inspire ideation:

- Expand/Collapse: Allow the product to get bigger and/or smaller to accommodate different modes of use (can affect user experience [UX], maximize shipping efficiency).
- 2D to 3D: Create a 3D object using 2D materials through bends, twists, creases, joints, etc. (can simplify manufacturing, reduce material impacts, reduce waste, affect UX).
- User Assembly: Design a product that can be assembled by the user (UX, shipping efficiency).
- Ship & Store: Design a product that can be flattened, rolled, folded etc. for efficient shipping and storage by the user in between uses (can affect UX, maximize shipping efficiency).

Introduce the one-week assignment format:
Design Topic (instructor discretion and course dependent). Chosen by the students individually or after a class discussion on what makes an appropriate topic for this challenge. It could be predetermined by the instructor, and/or related to the larger theme of the course. Some suggested topics: Furniture, Housewares, Lifestyle Products:

- Generate 1 page (8.5"x11" horizontal) of thumbnail-quality ideation sketches for each of the 4 footprint heuristic strategies listed above. Sketches should demonstrate visual exploration of ideas with any necessary keyword call-outs to help describe the concepts.
- Identify a favorite concept for each heuristic strategy (4 total) and create a one-page design sketch for each, going into further detail and exploring additional concept development.
- Optional - create a quick physical mockup of the four favorite concepts. These can be aesthetic representations, material explorations or proof-of-concept functional mockups. Remember to take photos of the mockup process.

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Part 2: (In-class) time can vary, up to 20 min/student (10-minute student presentation followed by 10-minute class discussion)

Students present work to the class, followed by a discussion of the work.

Guidance for student presenters:

- Present your four favorite design concepts
  - Describe your concept — what it is and what it does
  - How does your concept follow the heuristic design strategy?
  - How does your concept affect the sustainability footprint of the product?
  - How would you refine the concept further?
- Class discussion
  - Has the presenter effectively utilized the heuristic design strategy?
  - How could the design be changed or refined to minimize sustainability impacts?

Supporting Resources

- Kramer et al. (2014) *A Case-Study Analysis of Design Heuristics in an Upper-Level Cross-Disciplinary Design Course.*
- Design Heuristics: Strategies to Inspire Ideas
- Heuristic. Wikipedia, Wikimedia Foundation, 27 Aug. 2024

Proposed Assessment Examples

- Do the design sketches effectively communicate the underlying thinking related to the footprints heuristics?
- Was the student able to effectively explain their exploration of design concepts to the class?
- Were the class review participants able to contribute meaningful critique and discussion of presented concepts?

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Design

Course Integration

Course title: Design for Sustainability	**Suggested Course Level:** 300 to 400

Course description: A mid- to advanced-level design/engineering course that requires rapid ideation as part of the initial design process.

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Design C.2.

EOP Framework Learning Outcome description: Design for the environment and society based on discipline-specific technical skills (e.g., light-weighting, design for repairability and durability, design for upgradeability, design for disassembly, flexibility, and reuse, design for part or whole recovery, etc.). (2)

Other EOP Framework Learning Outcomes achieved:
Communication and Teamwork C.1.
Critical Thinking C.1.

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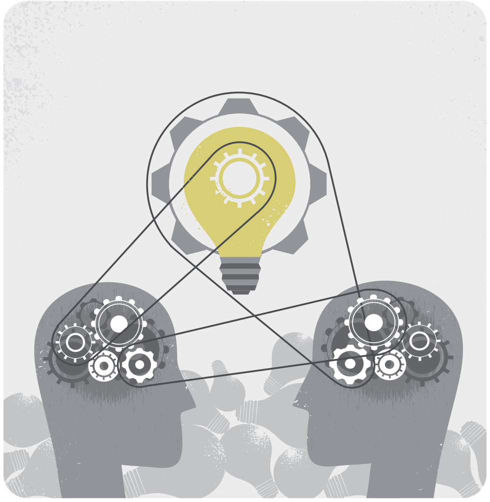
Design

12 Sustainable Invention

Contributed by Paul Egan

Time to complete activity: 1-3 hours
Type of activity: Small group (3-5 students)



Detailed description

Sustainable Inventions

The goal of the module is to teach students the TRIZ design process to create sustainable inventions. TRIZ is a systematic means of generating innovative solutions to problems often used in engineering design. Although TRIZ is a generalized innovation tool, its use for sustainable engineering design can be emphasized.

Day 1 - Learning TRIZ

Part 1: Teaching TRIZ basics (10-15 mins)
Explain the history of TRIZ and how it relates to engineering design as a more reliable systematic process to generate innovative ideas than basic brainstorming. These videos provide a history of TRIZ (45 min) and how to use TRIZ (7 min).

Part 2: Sustainable design principles (10-15 mins)
Explain basic sustainable design principles. For instance, light-weighting a product, improving shipping efficiency, reducing the amount of materials, improving energy efficiency, etc.

Part 3: Guided examples of TRIZ process (15-20 mins)
Show examples of TRIZ solutions for an example design problem. Use the TRIZ matrix to solve design contradictions and have students brainstorm new design concepts based on identified principles from each contradiction. Discuss in class how innovations and TRIZ principles are related to three pillars of sustainability for environmental, economic, and societal considerations.

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Day 2 - Applying TRIZ

Part 4: 10-15 mins

Students are either assigned a design problem, continue with a design problem assigned earlier, or identify their own. Students first recognize contradictions in their design, such as identifying customer and engineering requirements that oppose one another. For example, a contradiction for an electric vehicle may be that it needs a longer range and a high towing/cargo capacity; or designing a solar panel that generates more electricity while reducing materials usage.

Part 5: 10-15 mins

Students use the **TRIZ matrix** to find design principles for each contradiction. Multiple contradictions should be analyzed because TRIZ does not always output helpful solutions for each contradiction. **triz40.com** can help find TRIZ principles for contradictions using the matrix.

Part 6: 20-25 mins

Students generate solutions for contradictions to improve their designs. Lateral thinking is encouraged to apply each principle to the design even if it is not obvious how the design could benefit. By generating many different designs, creative solutions can be mixed and matched. Students are encouraged to understand each TRIZ design principle and apply all of them to their designs.

Day 3 - TRIZ Reflections

Encourage students to individually and as a group assess their TRIZ generated designs and determine whether they resulted in improved solutions for sustainability. Have them consider their designs in the context of different transdisciplinary issues such as government, technology, cultural, and economic factors. Groups should create a short PowerPoint highlighting their design problem, contradictions, innovations, and reflections.

Supporting Resources

- **Dr. Egan's recorded slides for teaching TRIZ**
- **Spreafico (2021) *Advantages of TRIZ in Sustainability Through Life Cycle Assessment***
- **Russo & Spreafico (2020) *TRIZ-based Guidelines for Eco-improvement***

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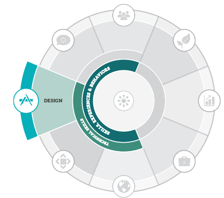

Proposed Assessment Examples

- What general design principles can make a design sustainable?
- Is a systematic design method such as TRIZ beneficial for generating sustainable innovations?
- Which TRIZ principles result in design innovations that improve both the environmental and social sustainability of a design?

Course Integration

Course title: Engineering Design	**Suggested Course Level:** 300 to 400

Course description: Upper-level course where some foundational principles of engineering are known so students may solve complex design problems with beneficial societal impact.

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Design C.2.

EOP Framework Learning Outcome description: Design for the environment and society based on discipline-specific technical skills (e.g., lightweighting, design for repairability and durability, design for upgradeability, design for disassembly, flexibility, and reuse, design for part or whole recovery, etc.). ○ (2)

Other EOP Framework Learning Outcomes achieved:
Design A.4.

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Design

13 The Impact of Climate Change on Structural Design and Resiliency

Contributed by Amanda Bao

Time to complete activity: 3-5 hours, homework assignment
Type of activity: Group of 2-3 students

Detailed description

As a homework assignment, students identify the changes in snow loads, wind loads and seismic loads in the US over the past 30 years and address the disparities in communities' exposure and resilience to disasters depending on a community's social vulnerability, economic conditions, and social capacity. Social sustainability and diversity, equity and inclusion (DEI) impact on engineering decisions will be incorporated.

Part 1: Choose a geographical location, and use the ASCE-7 Hazard Tool to compare the changes of snow loads, wind loads, and seismic loads in this location over the past 30 years.

Part 2: The communities suffering the most damages from disasters often struggle with insufficient infrastructure services, such as degraded electric power systems, deteriorated water and sanitation systems, inadequate transportation networks, and aging school buildings. Social vulnerability can be represented by higher percentages of racial and ethnic minorities, financial difficulty, elderly, uninsured households, homeless, disability, and language barriers. The resilience of these communities is usually weak due to inadequate social and economic resources to prepare for, withstand, adapt to, and recover from a disaster.

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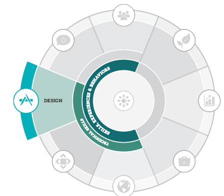

Pick one disaster (such as blizzard, hurricane, flood, earthquake, etc.) in the selected geographical region, identify the location/community where the most damage occurred, and explain why. Discuss the environmental, social, and economic dimensions of sustainable and resilient design.

Part 3: Prepare a 5-min in-class presentation to share the findings.

Supporting Resources

- ASCE 7 Hazard Tool
- The Social Benefits of Sustainable Design
- Resilience of Critical Structures, Infrastructure, and Communities

Proposed Assessment Examples

- How has the change in snow loads over the past 30 years impacted the structural design in this region? Propose a long-term design solution to tackle the snow load change.
- How does climate change impact the design snow load in this region?
- What is the trend for wind load changes in this region over the past 30 years?

Course Integration	
Course title: Structural Steel Design	**Suggested Course Level:** 400
Course description: The Structural Steel Design course focuses on the design of structural members and frames and their connections in steel structures.	

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EOP Learning Outcome Alignment

EOP Core Learning Outcome: Design C.3.

EOP Framework Learning Outcome description: Create long-term approaches for tackling environmental problems (e.g. climate mitigation and adaptation) or preventing negative environmental and/or social impacts including creative solutions within supply chains. O (6)

Other EOP Framework Learning Outcomes achieved:
Social Responsibility C.7.
Communication & Teamwork C.3.

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Critical Thinking

14 Introduction to Sustainability Metrics and Mapping

Contributed by Heidrun Mumper-Drumm

Time to complete activity: 8 hours over 5 weeks

Type of activity: Individual work followed by presentation to class and discussion; can be adapted as a team activity

Detailed description

Having defined sustainability (e.g., "New" Brundtland Definition, 3-E's, 4-P's, Triple Bottom Line, etc.), the next step is to become familiar with how sustainability is measured and mapped. In this five-week activity, students are introduced to and will use footprints and habitat mapping to measure, make comparisons and represent sustainability. Preparatory activities take place in-class with instructor-led instructions to information and are completed as homework, followed by class presentations.

Week 1: (1 hour)

Students are introduced to the concept of an eco-footprint as a measure of an individual's ecological impact.

- What is an eco-footprint? What is measured? What is the unit of measurement?
- How would you use an eco-footprint calculator to research inputs?
- How would you apply an eco-footprint to cities, countries, etc.?

Assignment for Week 2:

Research & Calculate: Calculate your eco-footprint

- Use an eco-footprint calculator and your individual or household data as input to calculate your eco-footprint. The results will be summarized automatically on the final page in hectares or acres and in the number of Earths.
- Screen-capture the results and format your eco-footprint result as a single page. Include a title, definition of eco-footprint, your name, and the date.

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Critical Thinking

Week 2: (1 hour)
Students are introduced to the concept of a carbon footprint as a measure of an individual's climate impact.

- What is a carbon footprint? What is measured? What is the unit of measurement?
- How do you use a carbon footprint and research inputs?

Assignment for Week 3
Research & Calculate: Calculate your carbon footprint

- Using a carbon footprint calculator and your household/personal data as input, calculate your carbon footprint. You will need your utility bills and your air miles.
- Screen-capture the results and format your carbon footprint results as a single page. Include a title, definition of carbon footprint, your name, and the date.

Week 3: (3 hours)
Students are introduced to the concept of an ecosystem as an individual's habitat.

- What is a habitat made up of? What elements, functions and relationships exist in a habitat?
- Where does your water come from? Where does your energy come from? What forms of energy do you use? Where does your waste go? What is the habitat's geological history and human history? What are the names of five native plants and five invasive plants in the habitat? What is the dominant climate?

Assignment for Week 4
Begin Habitat Map Assignment: Research information that represents your habitat and related data

- Conduct online research and visit a location that represents your habitat and collect on-the-ground field data. (Instructor: This can be a class field trip.)
- Keep track of your references to be included with your final habitat map.

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Critical Thinking

Week 4: (3 hours)
Students finalize their research and create a diagram/illustration of their habitat, using the data that they have obtained. During class time, any questions or observations can be discussed as a class or in small groups/pairs.

Assignment for Week 5
Research & Diagram: Represent your habitat using data

- What do you imagine your habitat looks like? How could you visually communicate this?
- Finalize your research and create a map that represents your habitat. Use relevant metrics and information to create a diagram of the state of your habitat. Strive to make your mini-poster not only accurate and complete, but also visually memorable.
- All information must be supported by the references you have collected.
- Format your habitat map to fit on a page in landscape orientation. Include a title, name and the date, as well as references.

Students present their habitat map during class and are asked to discuss what is missing from their map, and what they would include. Discuss other ecosystem essentials such as education, healthcare, community, etc. that are not usually included.

Supporting Resources

- Eco-footprint Calculator
- Cool California Carbon Footprint Calculator
- Air Miles Calculator

Proposed Assessment Examples

- Not all metrics work well in all cases. Which footprint calculator is most appropriate for measuring consumption?
- Which footprint calculator is most appropriate for measuring climate impact?
- What is missing from your habitat map? Hint: What contributes to well-being that has not been included?
- Reflect on the process of making a visual habitat map describing your ecosystem. How did creating a habitat map raise your awareness of the ecosystem you live

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Critical Thinking

in? Did it impact your self-awareness, empathy for, and/or guardianship of the environment? Please be specific.

Course Integration

Course title: Introduction to Sustainability	**Suggested Course Level:** 100 or 200
Course description: A foundation in sustainability and design that introduces the student to related vocabulary, metrics, principles, and design research, tools, and process.	

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Critical Thinking C.2.

EOP Framework Learning Outcome description: Report being a self-aware and reflective practitioner with values, empathy, and guardianship of one's environment. (4)

Other EOP Framework Learning Outcomes achieved:
Communication & Teamwork C.1.
Environmental Literacy C.5.
Critical Thinking C.1.

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Critical Thinking

15 Sustainability Agents for Change: Consulting and Organizational Leadership

Contributed by Christopher Papadopoulos *and* Joan Graniela Ramírez

Type of activity: Small team

Detailed description

Sustainability goals can be achieved by implementing new policies, postures and practices at any of several levels: international, national, regional, municipal, community, organizational, or individual. In this activity, students become change agents for sustainability consultants by inviting local institutions to utilize the Design Thinking Process (DTP) to discuss, ideate, and develop sustainability solutions relevant to their context.

Examples of consulting opportunities include working with a student or civic association to develop new sustainability goals and practices, a local business to improve the design or delivery of a product or service, a local government to determine how new policies, programs, or opportunities should be developed, or a local school to develop an educational module

This activity follows the five stages of the Design Thinking Process: Empathize, Define, Ideate, Prototype, and Test. Depending on the focus of the course and the available resources, different stages and levels of completion of the DTP will be achieved through the consulting opportunity.

Part 1: Background (0.5-2 weeks)
Provide an overview of the process used by corporations, governments, and other organizations to embed sustainable practices into their leadership structures and policies (e.g., ESG). Use open discussion or a brainstorming session to prompt questions, such as:

- Who are leaders in developing sustainable solutions?
- What is a stakeholder? Who are the stakeholders of the organization(s)?

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Critical Thinking

- Are organizational claims of sustainability targets and policies credible or are they greenwashing?
- How can organizations be convinced to adopt sustainable practices?
- What are the incentives and obstacles?

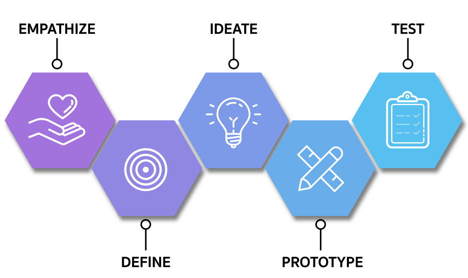
It is expected that as an outcome of Part 1, students will realize that making change is much more than devising a new policy, device or material from afar and that, instead, it will involve dialogue and relationship building before concrete solutions are proposed. This leads to a discussion about Stage 1 (Empathy) of the DTP. Before proceeding, depending on time, case studies could be read and evaluated for further background.

Part 2: Invitation Letter (1 week)
Students write a short letter to invite an organization to be a consultee. The letter should not propose solutions or problem statements but should include a statement of the students' participation in a class project, overall interest in sustainability, and interest in working with the organization (or the corresponding sector) as a pro bono consultant. If the letter will be sent to more than one organization simultaneously (to increase the chance of the acceptance), then the letter should include a statement indicating that the consultancy will be accepted based upon availability. It is appropriate, but not required, for the instructor to suggest organizations to contact.

Part 3: Training (1-2 weeks)
Depending on the allowable time and resources, students should receive at least a basic training about the DTP–in particular, some practice with interviewing and observations is recommended.

Part 4: Implementation (1-2 months)
Once the consultee is established, the student team should begin to work with that organization to initiate the first stage process to dialogue, ask questions, and conduct observations or other research.

DESIGN THINKING PROCESS



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Supporting Resources

- Design Thinking by Mindful Marks
- The Power of Asking the Right Questions
- What is Design Thinking?
- Sustainability Strategy: Backcasting from Success
- Sustainability Strategy: Planning in 4 Steps
- c40 Cities
- Gond et al. (2024). *Consultants as Discreet Corporate Change Agents for Sustainability: Transforming organizations from the outside-in*
- Wilkerson & Trellevik (2021). *Sustainability-oriented Innovation: Improving problem definition through combined design thinking and systems mapping approaches*

Proposed Assessment Examples

- What strategies worked best to help persuade the consultee to make a change? What barriers are most likely to impede progress?
- Were you in a situation where your initial recommendation was challenged? How did you handle this, and what adjustments did you make?
- How do you envision the organization changing or benefiting long term from ongoing partnerships with student consultants?

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Critical Thinking

Course Integration

Course title: Creating a Sustainable World (Introduction to Sustainability)	**Suggested Course Level:** 100

Course description: Creating a Sustainable World provides an introduction to sustainability through the following themes: (1) sustainability definitions and frameworks, including the UN treaties; (2) earth systems cycles and planetary boundaries; (3) circular economy; (4) energy and materials usage patterns; (5) water, agriculture, and land use; (6) career planning and development from a sustainability perspective; (7) selected topics; and (8) systems thinking, critical thinking, and communication.

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Critical Thinking C.6.

EOP Framework Learning Outcome description: Critique complex ethical and values-based choices, employing empathy when evaluating conflicts of interest, trade-offs, and uncertain knowledge and contradictions within problem constraints.
(4)

Other EOP Framework Learning Outcomes achieved:
Responsible Business & Economy C.1, C.2.
Responsible Business & Economy C.2.
Communication & Teamwork C1, C2, C3
Critical Thinking C.1, A.1, A.3.

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Communication and Teamwork

16 Learning by Reading Research Papers Related to Sustainability Focused on Quantum Computing and AI

Contributed by Li Chen

Time to complete activity: 5-8 hours
Type of activity: Individual and group discussion

Detailed description

Students choose from a selection of papers provided to them (see suggested list below), then read and write essays about their selected paper. Students explore sustainability and quantum computing and/or AI by writing essays to deepen understanding about the following AI topics:

- Modern AI chips and power use
- Sustainability and energy savings related to Quantum Computing and AI
- The need for efficient algorithms to be developed or considered for different problems (e.g., not only deep-learning algorithms)
- Deep-learning research in AI and the impacts on the future

Supporting Resources

- Ikonen, J., Salmilehto, J. and Möttönen, M. *Energy-efficient quantum computing.* NPJ Quantum Inf 3, 17 (2017)
- Strubell, E., Ganesh, A., and McCallum, A. Energy and Policy Considerations for Deep Learning in NLP
- Martin, M., et al. *Designing Energy-Efficient Quantum Computers Through Prediction and Reduction of Cooling Requirements for Cryogenic Electronics*
- Brownell, V. (CEO, D-Wave), *Quantum Computing Could Change the Way the World Uses Energy*
- Hsu, J. *How Much Power Will Quantum Computing Need?*

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Communication and Teamwork

Proposed Assessment Examples

- How might quantum computing change the way the world uses energy?
- Is there potential energy savings in using quantum computing and AI? Why or why not?
- Why is it important to utilize efficient algorithms for different problems, and not only deep-learning algorithms, for example?

Course Integration	
Course title: Introduction to Quantum Computing	**Suggested Course Level:** 400 or graduate course
Course description: Quantum computing is an interdisciplinary field that lies at the intersection of computer science, mathematics, and physics. In this course, we will have a special session to discuss energy effectiveness of quantum computing.	

EOP Learning Outcome Alignment
EOP Core Learning Outcome: Communication and Teamwork C.1.
EOP Framework Learning Outcome description: Communicate through audience-specific written, graphic/visual, oral, and interpersonal communication skills. (3, 5)
Other EOP Framework Learning Outcomes achieved: Critical Thinking C.1. Environmental Impact Assessment C.1.

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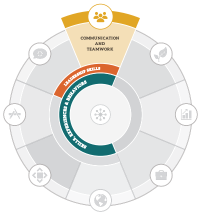
Communication and Teamwork



17 Think-Pair-Share EOP Framework Topic Areas Activity

Contributed by Medha Dalal, Ryan Milcarek *and* Jackelyn Lopez Roshwalb

Time to complete activity: 5 mins per class (may do every class, weekly, or randomly as time permits)
Type of activity: Individual and pairs

Detailed description

Instructor preparation:
Create a deck of six cards with one of the following EOP Framework topic areas on each card: Systems Thinking, Environmental Literacy, Responsible Business and Economy, Social Responsibility, Environmental Impact Assessment, and Materials Selection. Generate a list of statics-related problems for students to consider, reflect upon, organize their ideas, and share. Example statics problems include, but are not limited to: design a bridge, design a flyover, design a truss system, or other simple setup encountered in homework examples.

Introduce the students to the EOP Framework topic areas, either as homework or in class, to ensure they understand the topics and are prepared to think critically about them and discuss them as part of the Think-Pair-Share activity below.

Think-Pair-Share (TPS) Activity:

Instructor:

- Share a problem from the generated list.
- Draw a card from the six-card deck and announce the topic area for discussion for the next few minutes. (For illustrative purposes we will use the topic area of Systems Thinking.)

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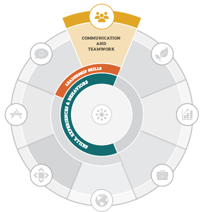
Communication and Teamwork



Students:

- As Individuals (1 min): students spend 1 minute thinking about how the topic area (e.g. systems thinking) relates to the specific statics problem shared by the instructor.
- In pairs (2 mins): students turn to their neighbor, a nearby student, or are randomly assigned (if in online setting) and take turns (1 min each) to share their ideas about how the topic area (e.g., systems thinking) relates to the specific statics problem shared by the instructor.
- As a class (2 mins): using "popcorn" style share-out, spend a few minutes capturing student reflections about how the topic area (e.g., systems thinking) relates to the specific statics problem shared by the instructor.

Supporting Resources

- Think-Pair-Share Activity Overview, Kent State University
- Popcorn and Round Robin Style Sharing

Proposed Assessment Examples

- Why is this EOP Framework topic area (e.g. systems thinking) important to think about when considering statics problems?
- In the TPS activity, did you prefer to work alone to think about your own ideas or think together with another student? Why?
- How did the TPS activity strengthen your ability to sell, pitch, and/or explain your thoughts/ideas?

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Communication and Teamwork

Course Integration

Course title: Statics	**Suggested Course Level:** 100 or 200
Course description: Fundamentals of force balance for a stationary system.	

EOP Learning Outcome Alignment

EOP Core Learning Outcome: Communication & Teamwork C.1.

EOP Framework Learning Outcome description: Communicate through audience-specific written, graphic/visual, oral, and interpersonal communication skills. 1) Demonstrate ability to sell, pitch, and explain ideas and advance learning. (3, 5)

Other EOP Framework Learning Outcomes achieved:
Critical Thinking A.1.
Communication & Teamwork C.3.

Conclusion

Contributor Acknowledgment

We want to deeply thank each of the workshop participants who co-created the 17 activities shared in this guide. On June 23, 2024, 16 faculty engaged in a two-hour, in-person EOP workshop at the ASEE annual conference. During the workshop — led by Cynthia Anderson (Alula Consulting) and Medha Dalal, Allison Wolf, and Archana Mysore, all from Arizona State University — participants worked together in small groups to co-create three of the course activities provided in this guide. On September 20, 2024, 11 faculty actively participated in a three-hour virtual EOP workshop hosted and led by the EOP Network's Course Activities Committee — Jorge Loyo, Noé Vargas Hernandez, Cynthia Anderson, and Victoria Matthew — to contribute to and workshop 14 of the activities shared in this guide.

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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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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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