Engineering for One Planet

Engineering for One Planet Framework:

Quickstart Activity Guide

Powered by The Lemelson Foundation
Prepared in partnership with VentureWell™
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Background & Introduction

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

Purpose:

This easy-to-use implementation guide is designed to minimize the energy needed to engage students with the EOP Framework. This guide provides step-by-step instructions for teaching one core learning outcome from each of the nine topic areas in the EOP Framework (Systems Thinking, Environmental Literacy, Responsible Business and Economy, Social Responsibility, Environmental Impact Assessment, Materials Selection, Design, Critical Thinking, Communication and Teamwork).

Whether you are a new educator or just new to teaching sustainability-related topics, the suggestions below will get you up and running in no time. We have selected one core learning outcome from each of the nine topics in the framework to dive into – with suggestions on content and ways to integrate it into a class session and/or assignment. The references chosen are either freely available to the public or available through most university library systems (local availability may vary).

For more integration examples for your classes, refer to **this chart** from our partner, VentureWell. For a guide to teaching all core EOP Framework learning outcomes refer to the **Engineering for One Planet Framework: Comprehensive Guide to Teaching Core Learning Outcomes**.

Please see the EOP Framework for an explanation of the icons used in this guide. The ABET and United Nations Sustainable Development Goals icons are explained on pages 6 and 7, and the Bloom's Taxonomy icon is explained on page 11 of the framework.

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Topics

Systems Thinking

Knowledge & Understanding

- Environmental Literacy
- Responsible Business and Economy
- Social Responsibility

Technical Skills

- Environmental Impact Assessment
- Materials Selection
- Design

Leadership Skills

- Critical Thinking
- Communication and Teamwork

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Systems Thinking

Systems Thinking Core Learning Outcome 1

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)

The Whole System Mapping design method is a powerful tool that engages students in systems-level thinking and introduces them to a popular method of environmental impact measurement.

6 mins

First, have your students watch this video.

If that's all the time you have, you can stop here and discuss as a class, in small groups, and/or have students reflect on the content in writing. Consider prompts like: *What was the most surprising thing you saw in the video? What was one solution to a more sustainable dryer that didn't involve the dryer at all?*

Whole Systems Design: Introduction to Life Cycle Thinking

2-4 hours

If you have more time, follow the Whole System Mapping exercise.

There are four steps in the Whole System Mapping design method:

- Step 1: Visually map the product's (or service's) system. (Figure 1-below)
- Step 2: Use estimated Life Cycle Assessment (LCA) to set environmental priorities (Figure 2-next page), then balance with business or other priorities.
- Step 3: Brainstorm on the system map you created (helps ideation be more thorough and radical).
- Step 4: Choose winning idea(s) based on your priorities and your estimates of idea performance.

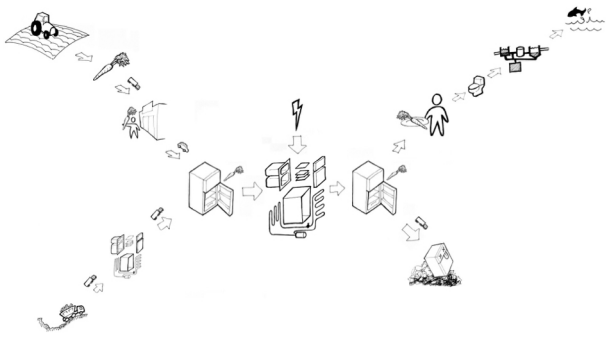

Figure 1: Whole system map of a refrigerator. Image Credit: Faludi MCAD Class (2010)

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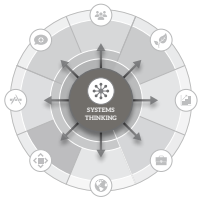
Systems Thinking



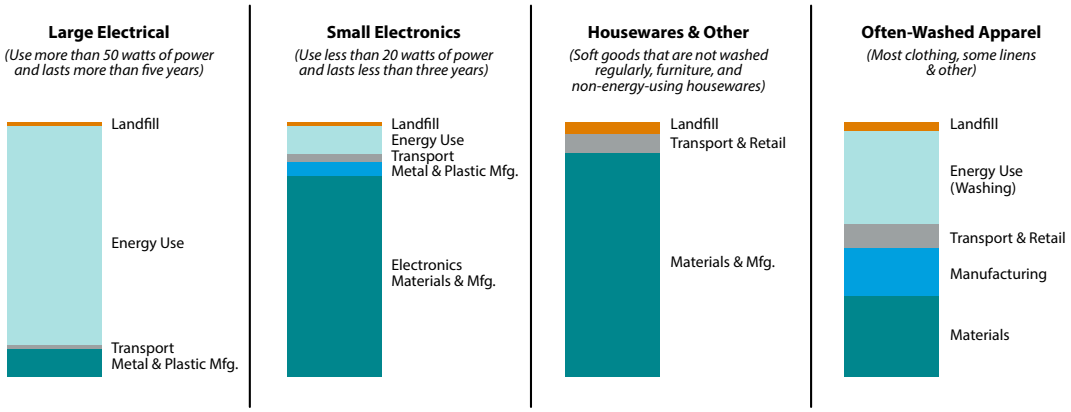


Figure 2: Life cycle analysis for general categories of products

This exercise can be condensed to fit into a single class period, or expanded over several weeks. For example, you might use an existing system map here, and use the generic LCA here along with an environmental, business, or social priority like "reduce lifetime cost of usage" in order to brainstorm new ideas and choose the best ones based on your priorities. Or you might choose a different product without an existing whole system map or LCA, and have students go through each step in detail either inside or outside of class. You can also assign work individually, in groups, or a combination of the two.

Other LO's achieved at the same time

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)

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Environmental Literacy

Environmental Literacy Core Learning Outcome 2

Explain whole life-cycle and closed-loop systems thinking as related to the impact of their work (e.g., understanding of life-cycle burdens of design alternatives) O (4)

The concept of the circular economy relates to thinking of a product lifecycle as a loop instead of a line (Figure 3-below). There are several points on this loop where design and/or business strategies could enable closed-loop production that minimizes environmental impacts.

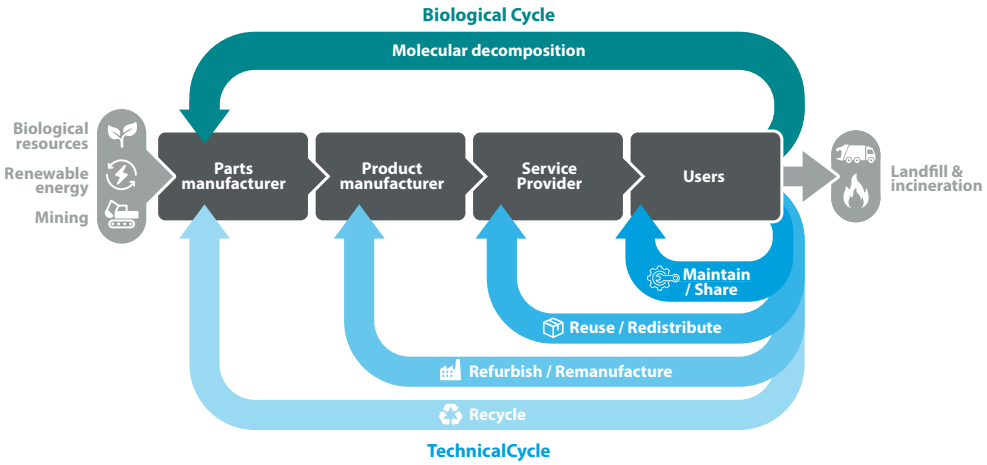

Figure 3: An illustration of the circular economy

8 mins

First, have your students watch the videos below.

Design for Lifetime Introduction & Overview

How to Design for Durability

If that's all the time you have, you can stop here and discuss as a class, in small groups, and/or have students reflect on the content in writing. Consider prompts like: *What was the most surprising thing you saw in the video? What are the basic steps in the life cycle of a product?*

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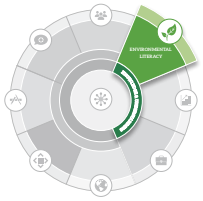
Environmental Literacy



1-3 hours

If you have more time, have students watch the other videos and review the content and quick reference guides. Then have your students follow the Circular Economy exercise. In the exercise, they will follow five steps that will help them develop environmental literacy skills while brainstorming business models that could turn a product into a service for lifetime and sharing.

- 1) Brainstorm business models to turn your product into a service for lifetime and sharing
- 2) Narrow down your brainstorm options to 3–4 winning ideas
- 3) For each winning idea, sketch and estimate the material reduction of that option
- 4) Choose one winning idea and illustrate it
- 5) Document your decision and brainstorm

This exercise can be condensed to fit into a single class period, or expanded over several weeks. For example, you might use an existing product here, or you might brainstorm a new or revised product using the same tools. You could also use the example as a case study. You can also assign work individually, in groups, or a combination of the two.

Other LO's achieved at the same time

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)

Environmental Impact Assessment Core Learning Outcome 3

Interpret broader energy, climate, water, wastewater, air pollution, and land-use implications of their work by conducting basic environmental impact assessments (e.g., Life-Cycle Assessments, carbon footprints, etc.) ○ (6, 7)

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Responsible Business and Economy

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)

The Business Model Canvas (from the book Business Model Generation by Osterwalder and Pigneur) is a template used for developing new business models and documenting existing ones. The **Presidio Business Model Canvas Sustainability Booster** by Prof. Marsha Willard is an overlay for the standard Business Model Canvas. It's an exploratory tool designed to help you boost the sustainability of a given business model.

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
Competitors Vendors/Suppliers Employees NGO's Communities Government/Regulators Owners/Investors/ Grantors Industry Transformation Organizational Structure	Product/Service Design Processes Facilities **Key Resources** Materials Water Energy	Broad Benefit Mindful Impact Customer Behavior Branding Sustainability	Honoring Customers Transparency Emerging Needs **Channels** Impact Accessibility	Importance Access

Cost Structure	Revenue Streams
Return on investment Externalities	Sources of revenue Distribution of revenue

Figure 4: This chart summarizes the sustainability-related questions that the Business Sustainability Booster adds to the nine segments of the standard Business Model Canvas.

6 mins

First, have your students watch this video.

If that's all the time you have, you can stop here and discuss as a class, in small groups, and/or have students reflect on the content in writing. Consider prompts like: *What was the most surprising thing you saw on the list? Was there anything missing that you expected to see?*

Presidio Business Model Canvas Sustainability Booster

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Responsible Business and Economy

2-4 hours

If you have more time, have students review the full Presidio Business Model Canvas Sustainability Booster. Then have your students choose an existing organization to use it with. This could range from an existing multi-national corporation to a student-led startup. There may be an existing Business Model Canvas for the organization, or your students may need to create one. Then, have students use the booster on each of the nine sections of the Business Model Canvas, or perhaps choose a subset of the sections. This exercise can be condensed to fit into a single class period, or expanded over several weeks depending on how thoroughly you want to apply the booster. You can also assign work individually, in groups, or a combination of the two.

Other LO's achieved at the same time

Social Responsibility Core Learning Outcome 7

Create robust, dynamic, and resilient systems and transdisciplinary stakeholder networks ○ (2,3,5)

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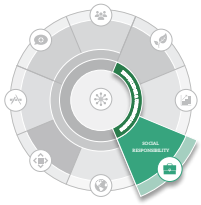
Social Responsibility



Social Responsibility Core Learning Outcome 3

Describe how engineering activities directly and indirectly cause positive and negative social/cultural impacts throughout the design life-cycle, both to workers producing the products (i.e., labor practices, livelihood, health, etc.) and to communities, society, and non-human life (i.e., resources acquisition, waste production and management, traditional/cultural methodologies, etc.) ○ (2,4)

The Social Accountability 8000 (SA8000) standard is one of several certifications measuring social sustainability of factories and organizations. It was developed in 1997 by Social Accountability International (SAI), using values from the Universal Declaration of Human Rights, International Labor Organization conventions, and the United Nations Convention on the Rights of the Child. As such, it deals with worker rights, not local communities, state-level, or other social concerns. This directly addresses the first part of the learning objective above that refers to "workers producing the products." SA8000 is a checklist of nine categories:

1) Child labor
2) Forced or compulsory labor
3) Health and safety
4) Freedom of association and right to collective bargaining
5) Discrimination
6) Disciplinary practices
7) Working hours
8) Remuneration
9) Management system

20-40 mins

First, have students review the full SA8000 list of criteria.

If that's all the time you have, you can stop here and discuss as a class, in small groups, and/or have students reflect on the content in writing. Consider prompts like: *What was the most surprising thing you saw on the list? Was there anything missing that you expected to see?*

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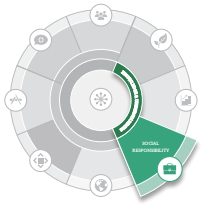
Social Responsibility



2-4 hours

If you have more time, follow the SA8000 labor certification exercise.

To do this, students will need to select an appropriate organization to evaluate. This could range from an existing multi-national corporation to a student-led startup.

1) Read the certification criteria
2) Use a spreadsheet to score your organization according to SA8000 (abridged)
3) Interpret your results

Students can review this example for more guidance.

Other LO's achieved at the same time

Responsible Business and Economy Core Learning Outcome 2

Examine risks and opportunities related to changing social, economic, political, and ecological systems on their work (e.g., extended costs, value, trade-offs, partnerships, regulations, policies, etc.) ○ (2,7)

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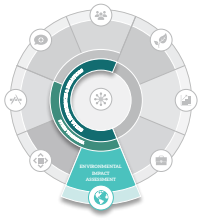
Environmental Impact Assessment



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)

The Sustainability Assessment for Innovators within VentureWell's **Inventing Green: A Toolkit for Sustainable Design** is a set of questions designed to foster environmentally responsible design. It can be used to assess the impact of an existing innovation or as an ideation tool. There are 18 questions divided into three phases of an invention's life-cycle:

1) Supply Chain: Sourcing, Manufacturing, and Distribution
2) Product Use
3) End-of-Life

1. Supply Chain **2. Product Use** **3. End-of-Life**

Each guiding question follows this prompt: *Does your product/service reduce direct environmental impacts by being designed to….* So, for example, the first question in the first of the three phases would be read as:

> *During the Sourcing/Manufacturing/Distribution phase, would your product reduce direct environmental impacts by being designed to reduce resource consumption, especially virgin materials inputs? For example, could non-virgin materials be utilized in the manufacturing process (recycled, reused, or feedstock material(s) that were a waste product from another product or industry)?*

These questions are then answered on a 5 point scale as noted below:

1 = We HAVE NOT considered this for our business

2 = We MIGHT consider this for our business

3 = We ARE considering this for our business

4 = We HAVE considered this for our business

5 = We are WORKING ON this for our business

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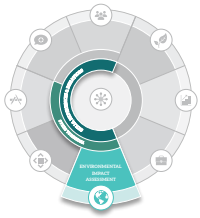
Environmental Impact Assessment



30 mins

Have your students choose an existing product. Then have them choose one question from each of the three phases of an invention's life-cycle and assign a ranking. You could have students do this individually or in small groups. Compare results as a class and discuss opportunities for moving closer to a 5 on each of the question scales.

2-4 hours

Begin with the exercise above, but continue through all 18 questions. You can stick with an existing product, or use a product the students are already working on (this would work well as an exercise run in parallel with an entrepreneurship or product design course!). Have students record and present results.

3-5 days

You may even want to expand this exercise over several weeks. For example, you might dedicate a week to each of the phases of the invention's life-cycle, and start with an existing product before having students apply the assessment to their own work.

Other LO's achieved at the same time

Environmental Literacy Core Learning Outcome 2

Explain whole life-cycle and closed-loop systems thinking as related to the impact of their work (e.g., understanding of life-cycle burdens of design alternatives) ○ (4)

Environmental Impact Assessment Core Learning Outcome 3

Interpret broader energy, climate, water, wastewater, air pollution, and land-use implications of their work by conducting basic environmental impact assessments (e.g., life-cycle assessments, carbon footprints, etc.) ○ (6,7)

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Materials Selection

Materials Selection Core Learning Outcome 6

Select materials for design alternatives and trade-offs that enable a long functional lifetime, have net zero greenhouse gas emissions impact, either minimal or no environmental and social harm, or are restorative to social, cultural, and environmental ecosystems ○ (2)

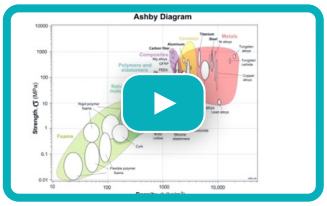
In order to select greener materials, it's important to understand what makes materials more or less sustainable.

8 mins

Have students watch the following three videos.

Green Materials: How to Select Non-Toxic Building Materials

Environmental Properties of Materials: Materials Selection



Physical Properties of Materials: Materials Selection

If that's all the time you have, you can stop here and discuss as a class, in small groups, and/or have students reflect on the content in writing. Consider prompts like: *What was the most surprising thing you saw in the videos? Is aluminum greener than steel? You can also bring up the quick reference charts (example below) on metals, wood, and plastic for discussion.*

1-4 hours

If you have more time, consider having students do an exercise in finding greener materials. They should review the content first, then follow the exercise. The goal of the exercise is to find an alternative material that could replace a high-environmental-impact material in a given product, and get a cost estimate for it.

They will follow four steps:

1) Decide on a material in your product to replace
2) Explore material libraries or other resources to find exciting green materials
3) Get price quotes
4) Document your findings

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Materials Selection

You can have students choose an existing product (this would work well in a strength of materials or materials engineering course), or use a product the students are already working on (this would work well as an exercise in an entrepreneurship or product design course). Have students discuss and present results.

Other LO's achieved at the same time

Materials Selection Core Learning Outcome 1

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)

Materials Selection Core Learning Outcome 4

Compare materials properties (e.g. chemical, physical, and structural properties) and performance aligned with end-use application ○ (2)

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)

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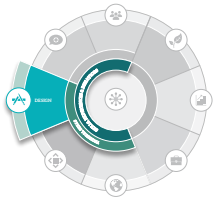
Design



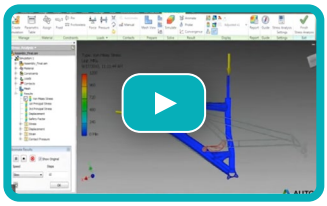
Design Core Learning Outcome 2

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)

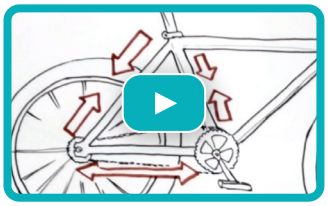
One way to reduce the environmental impact of a design is simply to use less material. Light-weighting is one of many skills that can be used to make designs more environmentally friendly by using less material to achieve the same design requirements.

12 mins

Have your students watch the following videos.



Introduction to Lightweighting and Material Reduction



Lightweighting 1: Hollow Parts, Reinforcements, and Trusses

If that's all the time you have, you can stop here and discuss as a class, in small groups, and/or have students reflect on the content in writing. Consider prompts like: *What was the most surprising thing you saw in the video? How can you decide where to remove material in an existing design?*

1-3 hours

If you have more time, follow the Lightweighting exercise. The exercise will take you through five steps:

1) Brainstorm ways to radically reduce your product's physical material use
2) Narrow down your brainstorm options to 3-4 winning ideas
3) For each winning idea, sketch and estimate the material reduction of that option
4) Choose one winning idea and illustrate it
5) Document your decision and brainstorm

This exercise can be condensed to fit into a single class period, or expanded over several weeks. For example, you might use a product with an existing whole system map for step 1, or you might choose a different product without an existing whole system map and have students go through each step in detail either inside or outside of class.

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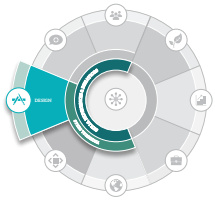
Design



You can also assign work individually, in groups, or a combination of the two. There are also emerging tools in some CAD programs that enable something called topology optimization that can streamline light-weighting of individual parts. Check out the **Autodesk content on this topic** and the **SolidWorks content**.

☑ ***Other LO's achieved at the same time***

Systems Thinking Core Learning Outcome 1
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)

Systems Thinking Core Learning Outcome 5
Create designs that include communities/societies, environmental ecosystems, and the life they sustain while keeping systems dynamics concepts in mind (e.g., feedback loops, complex cause-effect chains, cascading effects, inertia, tipping points, legacy, resilience, adaptation, energy systems and flows, etc.) ○ (2,4)

Environmental Literacy Core Learning Outcome 2
Explain whole life-cycle and closed-loop systems thinking as related to the impact of their work (e.g., understanding of life-cycle burdens of design alternatives) ○ (4)

Social Responsibility Core Learning Outcome 3
Describe how engineering activities directly and indirectly cause positive and negative social/cultural impacts throughout the design life-cycle, both to workers producing the products (i.e., labor practices, livelihood, health, etc.) and to communities, society, and non-human life (i.e., resources acquisition, waste production and management, traditional/cultural methodologies, etc.) ○ (2,4)

Materials Selection Core Learning Outcome 3
Critique the environmental and social impacts of designs created by others ○ (6)

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)

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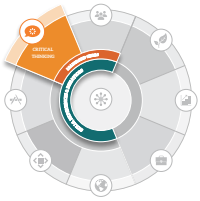
Critical Thinking



Critical Thinking Core Learning Outcome 5

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

Most people want to be good people, but most of us also have a hard time doing that. However, designers can influence user behavior towards more sustainable lifestyles. For example, the average European has roughly half the environmental footprint of the average American not because of better engineering, but because of more sustainable choices and behaviors (e.g. living in multi-unit housing close to work and shops radically reduces car trips, road infrastructure, building energy, and building material per person). Persuasive design is the art of making your product's user interactions nudge people in a desired direction. This can be subtle or powerful, and requires critical thinking to ensure you're helping your users, not hurting them. Persuasive design includes strategies for increasing the user's ability and/or motivation to do the desired behavior.

9 mins

Watch these three short videos.

Introduction to Persuasive Design

Persuasive Design: Ability

Persuasive Design: Motivation

If that's all the time you have, you can stop here and discuss as a class, in small groups, and/or have students reflect on the content in writing. Consider prompts like: *What was the most surprising thing you saw in the video? What is one strategy for increasing a user's motivation to do the desired behavior?*

1-4 hours

If you have more time, follow the Green Persuasion exercise. You will need a product to start with - either one you're working on, or you can choose something that already exists. The exercise will take you through four steps:

1) Brainstorm designs to change user behavior using the rules of brainstorming (see figure #4-below). You can use the Persuasive Design Quick Reference Guide to help.
2) Narrow down your brainstorm options to three or four winning ideas
3) Estimate idea impacts, and choose one final idea to move forward with
4) Document your decision and brainstorm

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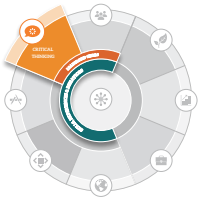
Critical Thinking



This exercise can be condensed to fit into a single class period, or expanded over several weeks. For example, you might use an existing product for the Green Persuasion exercise, or you may use the Persuasive Design Quick Reference Guide to come up with an entirely new product. You can assign work individually, in groups, or a combination of the two.

how to brainstorm: RULES

DEFER JUDGEMENT

HEADLINE

BE VISUAL

GO FOR VOLUME

Build on the Ideas of Others

Stay on TOPIC

Encourage WILD IDEAS

ONE CONVERSATION at a time

Other LO's achieved at the same time

Communication and Teamwork Core Learning Outcome 4

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

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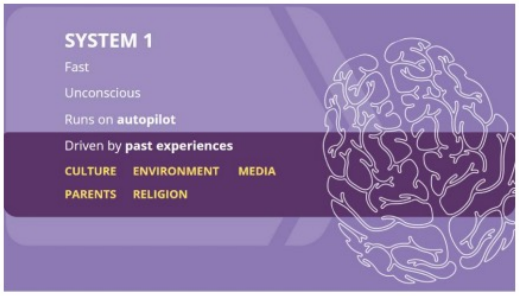
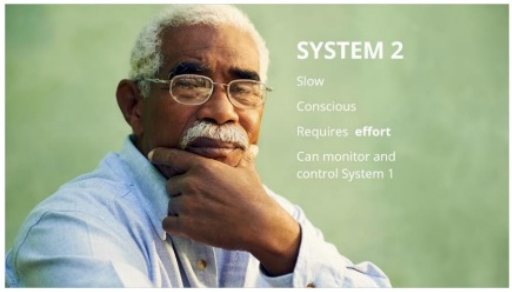
Communication and Teamwork

Communication and Teamwork Core Learning Outcome 4

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

Many of us have the best intentions of being inclusive in all we do, but our underlying biases can still get in the way, often without us even knowing. Luckily, there are effective, evidence-based tools to reduce the effect of bias, and to keep it out of our decision-making. In order to do this, we need to learn what bias is, how to recognize it, and how to minimize its impact.





Unconscious bias, also called implicit bias, is a form of bias that occurs automatically and unintentionally that affects judgements, decisions, and behaviors. Implicit bias is our brain's attempt to be efficient. Author Daniel Kahneman calls our brain's automatic, shortcut thinking system, "System 1." System 1 is the "gut reaction" system of thinking. Our second thinking system—System 2—is our thoughtful and deliberate system of thinking. We spend most of our daily lives in the fast mode of thinking—or System 1. System 2 only gets involved when we encounter something unexpected that System 1 can't automatically process. System 2 is responsible for our individual decision making, reasoning and beliefs.

10 mins

Explore implicit bias with your students.

More than one hundred different types of implicit bias have been described in the literature. One of the most common types is stereotyping. Take an Implicit Association Test (IAT) such as the Gender-Science IAT (there are many others to choose from as well, including a Gender-Career IAT, Race IAT, Asian IAT Disability IAT and more) to begin to deconstruct some of your own stereotypes.

If that's all the time you have, you can stop here and discuss as a class, in small groups, and/or have students reflect on the content in writing. Consider prompts like: *What was the most surprising thing you realized based on the IAT results? How do they make you feel?*

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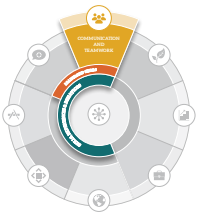

Communication and Teamwork

1-2 hours

Have your students take the NIH Implicit Bias - Full Course.

This course consists of 3 modules:
1) Foundations (20 mins)
2) Mitigating Bias (20 mins)
3) Creating a Culture of Inclusive Excellence (30 mins)

This fantastic course describes and cites many examples of unconscious bias examined in the literature, and discusses how being aware of our biases can help us modify our behavior. Finally, it covers methods for creating psychological safety and enhancing engagement that foster an environment of inclusive excellence.

Other LO's achieved at the same time

Communication and Teamwork Core Learning Outcome 5
Examine norms, biases, and values that underlie one's behaviors (i.e., normative thinking and cognitive dissonance) ○ (4)

Engineering for One Planet

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