Engineering for One Planet

The **Engineering** for **One Planet**
# Framework

Foundational Learning Outcomes to Prepare Engineers
to Protect and Improve Earth and the Life it Sustains (2026)



COMMUNICATION and TEAMWORK

CRITICAL THINKING

LEADERSHIP SKILLS

ENVIRONMENTAL LITERACY

KNOWLEDGE & UNDERSTANDING

SKILLS, EXPERIENCES & BEHAVIORS

DESIGN

SYSTEMS THINKING

RESPONSIBLE BUSINESS and ECONOMY

TECHNICAL SKILLS

MATERIALS

SOCIAL RESPONSIBILITY

ENVIRONMENTAL IMPACT ASSESSMENT

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The **Engineering** for **One Planet**
# Framework

## Overview

### Welcome to the Engineering for One Planet Framework!

Co-created with hundreds of collaborators, the Engineering for One Planet (EOP) Framework is a platform for curricular change, the cornerstone of the EOP initiative, and a tool for supporting systems-level change in engineering education, centering sustainability as a core tenet of the engineering profession, no matter the discipline. It is published under Creative Commons licensing to facilitate adoption.

When educators can draw from a common framework for curricular development across institutions and regions, the rate of change takes off. The EOP Framework provides an interrelated set of learning outcomes for integrating economic, social, and environmental sustainability and related professional skills into any engineering discipline. It comprises 94 (47 core and 47 supplemental) vetted, foundational sustainability learning outcomes that hundreds of academics, engineering professionals, and subject matter experts, among others, have identified as necessary for preparing all graduating engineers — regardless of subdiscipline — with the skills, knowledge, mindsets, and understanding to practice engineering and build solutions in ways that protect and enhance our world.

### Redefining Engineering Excellence

Engineering has always been used to improve the human experience, with a focus on delivering technological excellence. But engineering's potential for excellence is not realized without centering broader environmental, ethical, social, and economic considerations and consequences.

In 2024, Eric Lemelson, Board Member of The Lemelson Foundation, shared in his visionary sustainability definition that "a sustainable world supports thriving ecosystems and the sentient beings that depend on them for their survival and prosperity, including human societies, animals, and plants." In the EOP Framework, "sustainability" is meant in this holistic way, encompassing environmental, social, economic, and cultural considerations and reflecting restorative or regenerative aspirations.

# Overview

Engineering must play a critical role in supporting a thriving future for all inhabitants of our planet. Engineers are needed to address the urgency of the climate crisis, among other environmental and social challenges, and every engineering activity carries an environmental footprint, economic consequence, and societal impact.

It is the role of engineering education to prepare engineers with technical excellence while cultivating their ability to define problems and their root causes, and the skills and mindsets to shape solutions that promote restorative, equitable, and resilient futures for all life on Earth.

## The Role of EOP in Educational Innovation

The EOP Framework is a component of the broader EOP initiative. Working with collaborators from all sectors across the globe, the EOP initiative strives to support the systems-level change needed to integrate sustainability topics into engineering courses, programs, and institutions and to facilitate the transformation of engineering education and ultimately transform engineering practice.

The EOP initiative accelerates curricular changes across engineering disciplines through: free, open-source tools like the EOP Framework and companion teaching guides; grants and training opportunities for educators and researchers; and, support for a network of individuals collaborating on actions for systemic change.

Learn more about the EOP initiative at **EngineeringforOnePlanet.org**.

### The EOP Vision
Sustainability is a core tenet of the engineering profession.

### The EOP Goal
Transform engineering education to ensure all engineers are equipped with the skills, knowledge, mindsets, and understanding to protect and improve our planet and the life it sustains.

### A Tool for Change
Higher education educators and leaders from around the world are using the EOP Framework for curricular change. The EOP Framework provides a common language to help faculty share teaching tools and learn from each other.

# Commonly Asked Questions

## Why do we need to change engineering education?

- Engineering activity has both positive and negative impacts on our world, which are not distributed equally or equitably.

- Employer demand for green skills and sustainability knowledge has outpaced supply; engineers must receive professional preparation in sustainability to address increasing industry demand.

- It is essential that engineering students learn sustainability-focused concepts, tools, methodologies, and mindsets to help create a healthy world where people and nature flourish.

- Engineers must understand the history and implications of racist, classist, colonizing, and patriarchal practices in engineering and social systems, and be prepared to work with communities to eliminate these practices.

- Engineers must understand the social and cultural impacts of their work, and be prepared to help engender environmental, climate, and social justice today and in the future.

- Engineers are in a good position to show effective practical methods to influence policymakers and decision-makers on ways to sustain our resources.

## Why do we need the EOP Framework?

- Engineering educators and administrators from higher education are requesting help to create and disseminate sustainability-forward pedagogy.

- Engineering educators and students want to bring sustainability content into their courses, programs, and departments.

- Engineering faculty want to know what knowledge, skills, experiences, and mindsets their students need to acquire before graduating to prepare them for professional demands, equip them to address sustainability challenges, ensure today's solutions do not become tomorrow's problems, and play a restorative role through engineering.

## What is the EOP Framework?

- A practical implementation tool — rather than a research framework — to serve as guidance and inspiration for educators and accelerate the integration of foundational sustainability knowledge and competencies into engineering education.

- A curated list of core and supplemental sustainability-focused and professional/durable/ leadership learning outcomes organized under nine topic areas.

# Commonly Asked Questions

- A free, open access resource co-created and validated by a community of hundreds of experts and individuals from a range of identities, lived experiences, geographies, and sectors, including academia, industry, nonprofit, government, and philanthropy, and published under a Creative Commons license.

## Who is the EOP Framework for?

People have used the EOP Framework in schools, higher education institutions, and companies around the world, adapting it to disciplines from business to political science. The greatest uptake has been among:

- Engineering faculty, educators, students, and administrators from higher education who want to integrate sustainability education into a diverse array of classes, programs, departments, and institutions.

- Professional engineering educators who want to equip practicing engineers with contemporary skills in and mindsets of sustainability.

- Educators seeking resources for integrating sustainability into other STEM disciplines and K-12 education.

## How is the EOP Framework implemented?

- There is no single recipe or prescriptive approach — each situation will be different — but a combination of multiple faculty creating bottom up change with top down support from deans or department heads is ideal.

- Start with core learning outcomes which are considered most critical by the community.

- New users are encouraged to start small by integrating a single core learning outcome into a single existing, required engineering course.

- To achieve the intent of the EOP Framework, faculty and academic leaders who have used the EOP Framework suggest spreading learning outcomes from each of the nine topic areas across each year of a program, prioritizing core and required courses, and integrating a handful of learning outcomes into each course.

- Educators can help themselves to free teaching guides on the Implement EOP webpage. These guides provide teaching tips and links to free online resources that make it easier to integrate learning outcomes from the EOP Framework into existing and new engineering courses.

- Educators interested in broad-scale EOP integration can visit the EOP website to find institutionalization guides, funding opportunities, and faculty training workshops.

# Foundations and Evolutions of the EOP Framework

Efforts to infuse sustainability into engineering education have existed for decades but were often stymied by limited resources and reach. Moving from disparate efforts to collective action, the EOP Framework has synthesized expertise and knowledge from several hundred individuals in higher education institutions, professional engineering associations, public sector agencies, sustainability and climate action organizations, funding organizations, and technology companies to co-create the EOP Framework. The EOP Framework also draws upon numerous related frameworks and definitions (e.g., climate literacy, sustainable engineering, green engineering, green chemistry, and circular economy).

Since its first draft in 2019, the EOP Framework has been revised twice through user, educator, and expert input to reflect engineering's evolving priorities in a changing world. It has been used by faculty worldwide to create and modify hundreds of core, required, and elective classes—reaching tens of thousands of students.



**2017-2019**
Preliminary research and drafting of EOP Framework with input from hundreds of individuals and drawing from existing curricular change efforts and bodies of knowledge

**2020-2022**
• Pilot testing of EOP Framework in five universities
• NSF-funded workshop to develop EOP Strategic Roadmap
• EOP Framework revisions collected from 100+ individuals

**2023**
• Launch of revised EOP Framework independently mapped to ABET and SDG 12
• Launch of 3 EOP Framework companion teaching guides

**2024**
• Launch of 1 EOP Framework companion teaching guide
• Launch of EOP Framework mapped to AHEP4 (UK accreditation)

**2025**
• Launch of 1 EOP Framework companion teaching guide
• Launch of Villanova University's Guide to Institutionalizing the EOP Framework
• Framework feedback from users and experts including 100+ individual contributors

**2026**
• Launch of revised EOP Framework
• Launch of 1 companion teaching guide
• Update strategy

In this version, to streamline the integration of EOP Framework learning outcomes, EOP Framework developers:

- Aligned each EOP learning outcome to measurable verbs from the **2010 Bloom's Taxonomy** (Armstrong 2010)

- Worked in consultation with faculty and independently of ABET to map each EOP learning outcome to the seven required ABET student outcomes, as outlined in the **ABET Criteria for Accrediting Engineering Programs** (ABET 2024)

- Mapped EOP learning outcomes to all 17 **United Nations Sustainable Development Goals** (SDGs; United Nations 2015)

# Foundations and Evolutions of the EOP Framework

## Relevance to Engineering Accreditation

A global STEM accreditation body, ABET defines accepted attainment standards that prepare graduates to enter the professional practice of engineering. Based on requests and input from educators, and working independently of ABET, EOP Framework developers mapped the EOP Framework to ABET's required student outcomes (Table 1).

**ABET** | Engineering Technology Accreditation Commission

## Table 1: ABET Student Outcomes (ABET 2024)

1. *an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics*

2. *an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors*

3. *an ability to communicate effectively with a range of audiences*

4. *an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts*

5. *an ability to function effectively on a team whose members together provide leadership, create a collaborative environment, establish goals, plan tasks, and meet objectives*

6. *an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions*

7. *an ability to acquire and apply new knowledge as needed, using appropriate learning strategies*
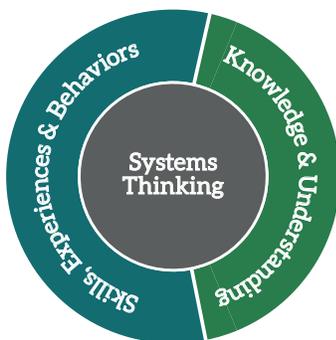
# EOP Framework Structure

## Student Learning Outcomes

The EOP Framework uses ABET's definition of "student outcomes" as follows: "Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program" (ABET 2024).

**The EOP Framework is flexible and adaptable**, making it adoptable by faculty and departments across a diverse range of programs and situations. **Educators are encouraged to modify the depth (i.e., as denoted by Bloom's Taxonomy verbs) and breadth of learning outcomes to be most useful and easily integrated into their courses and programs.**

EOP Framework collaborators considered the following guiding questions to qualify the suggested depth of each learning outcome:

- What level of depth is considered sufficient for a student to demonstrate proficiency in the learning outcome?
- When a student becomes proficient in the collection of core learning outcomes under each topic area, is their overarching knowledge of this topic sufficient?
- When a student acquires all of the core learning outcomes for each topic area, would they graduate with the ability to approach each of the design problems they will face as professionals with the depth and breadth of competencies to be confident and well-equipped to address today's professional and societal sustainability demands?

## Three Categories

Aligning with ABET's definition for student outcomes, the EOP Framework is structured around student learning outcomes under three main categories: Systems Thinking, Knowledge and Understanding, and Skills, Experiences, and Behaviors. Although "mindsets" are not explicitly categorized, acquisition of the EOP Framework learning outcomes also cultivates sustainability mindsets.

# EOP Framework Structure

## SYSTEMS THINKING

Systems thinking is central to and interconnected with all learning outcomes in the EOP Framework. Contributors identified systems thinking from an environmental and social perspective as the most fundamental concept and approach that students must learn. Systems thinking is a critical approach for engineers to: understand that engineering solutions and designs rely upon and exist within systems; identify the impacts and influences of the different and interconnected environmental, economic, and social factors of the design system; recognize that designs themselves are systems; and evaluate short- and long-term implications of their work.
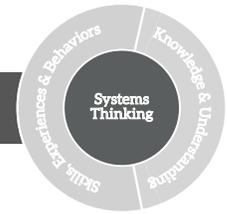
## KNOWLEDGE AND UNDERSTANDING

The learning outcomes listed under the Knowledge and Understanding category are broadly defined by these questions:

- Why should students learn these theories or concepts?
- What is most critically important that students be aware of, be familiar with, learn, know, and understand to become competent, globally responsible engineers, and be prepared to address climate change and other crises?
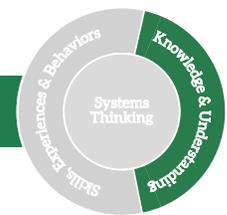
## SKILLS, EXPERIENCES, AND BEHAVIORS

A series of holistic, critical, interdependent, and interconnected skills, experiences, mindsets, and behaviors are divided into topic areas focused on technical skills, including: environmental impact assessment, materials, and design; and, topic areas focused on leadership (i.e., professional, durable) skills, including: critical thinking, and communication and teamwork.

The Skills, Experiences, and Behaviors category is broadly defined by these questions:

- What technical and professional skills must all engineers have to become competent in sustainability?
- What values, behaviors, and ethos of global responsibility to society and culture do students need to experience to practice sustainable and globally responsible engineering?
- What skills and behaviors do students need to experience and practice to be leaders of change by influencing others to practice sustainable engineering within constraints (budgetary or otherwise) of any engineering project?
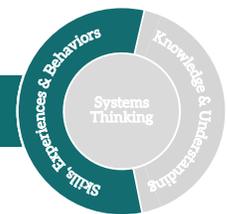
# Nine Topics

There are nine topic areas in the EOP Framework: Systems Thinking; Environmental Literacy; Responsible Business and Economy; Social Responsibility; Environmental Impact Assessment; Materials; Design; Critical Thinking; and Communication and Teamwork. Despite being listed separately, learning outcomes across these topics are interdependent and interconnected. Separating learning outcomes into topic areas makes it easier for educators to identify those most relevant to their teaching areas.

Under each of the nine topic areas, there are both **core** and **supplemental learning outcomes**. Based on feedback from educators and sustainability experts, core learning outcomes are considered the most important for students to cultivate. Supplemental learning outcomes may take core learning outcomes to the next level or reflect additional competencies to be achieved after attainment of core learning outcomes. The assumption is that core outcomes would be integrated first, with supplemental learning outcomes being integrated as resources and interests allow. Adoption of all core and supplemental learning outcomes is ideal, but will not always be possible.
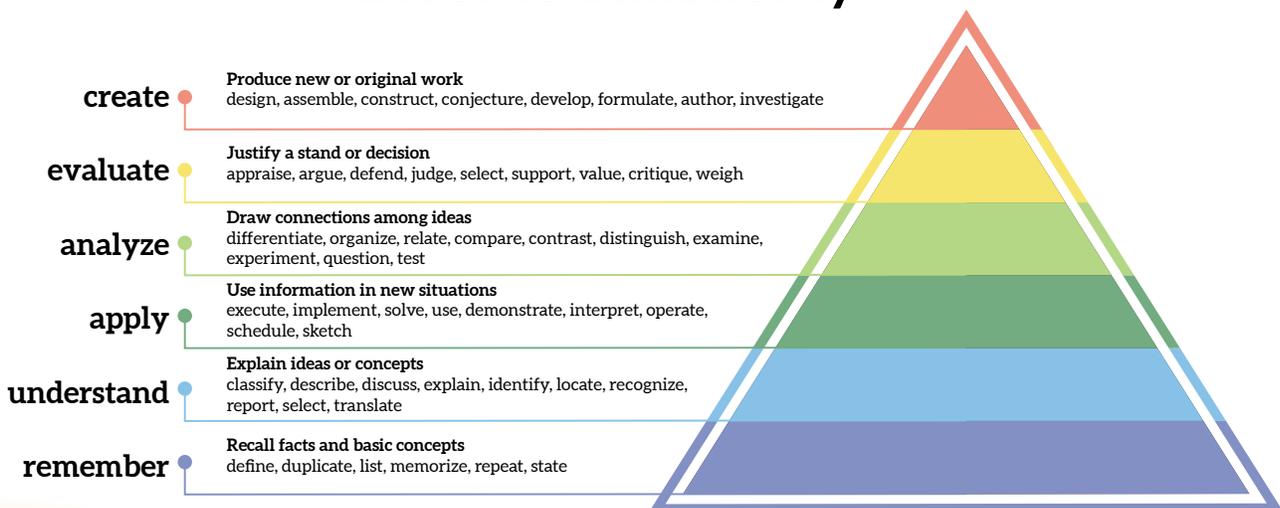
# Nine Topics

Framework learning outcomes are written using measurable verbs that fall into the original six proficiency levels from **Bloom's Taxonomy** which have been collapsed into three levels for use in the EOP Framework, as follows: Low (includes Bloom's Taxonomy levels Remember and Understand), Medium (includes Bloom's Taxonomy levels Apply and Analyze), and High (includes Bloom's Taxonomy levels Evaluate and Create). EOP Framework implementers are encouraged to modify the suggested measurable verb in the learning outcomes to meet their needs. For example, if the learning outcome is suggested at the "Low" Bloom's Taxonomy level and states "*Recognize* opportunities to solve environmental challenges," the instructor could scale up the Bloom's Taxonomy level from Low to High by changing the measurable verb (i.e., "*Critique* opportunities to solve environmental challenges").

[ LOW ]

[ MEDIUM ]
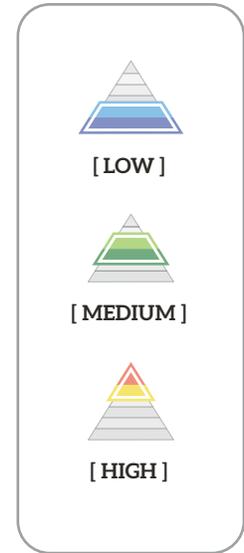
[ HIGH ]

Note: Core vs. supplemental learning outcomes do not correlate with Low or High levels of attainment of Bloom's Taxonomy. Core learning outcomes denote the most important or essential learning, whereas supplemental learning outcomes go beyond what EOP Framework collaborators deemed to be essential.

**For each learning outcome, an instructor should be able to complete the sentence: "After completion of the curriculum, a student should be able to…"**

# Bloom's Taxonomy

**create**
Produce new or original work
design, assemble, construct, conjecture, develop, formulate, author, investigate

**evaluate**
Justify a stand or decision
appraise, argue, defend, judge, select, support, value, critique, weigh

**analyze**
Draw connections among ideas
differentiate, organize, relate, compare, contrast, distinguish, examine, experiment, question, test

**apply**
Use information in new situations
execute, implement, solve, use, demonstrate, interpret, operate, schedule, sketch

**understand**
Explain ideas or concepts
classify, describe, discuss, explain, identify, locate, recognize, report, select, translate

**remember**
Recall facts and basic concepts
define, duplicate, list, memorize, repeat, state

# The EOP Framework

The identifier ⬤ is used to denote which SDGs are directly related to that learning outcome. The identifier ◯ is used to denote which ABET student outcomes from ABET Criteria 3 are aligned with that learning outcome. The EOP Framework lists "what" graduating engineers should know and be able to do. For guides on "how" to teach the core outcomes in the EOP Framework, visit the *Implement EOP webpage*.

# Systems Thinking

## CORE

1. Explain interconnectedness (e.g., intersecting, related, and/or connected systems; human actions, infrastructure, and global environmental, climate, and social impacts, risks, future impacts, and consequences; synergies and rebound effects) and how all human-made designs and activities rely upon and are embedded within ecological, physical, climate, and social systems ○ (2, 4) ✴ (4, 11-13, 17)

2. Analyze dynamic impacts and interactions between and among different parts of the system (i.e., social, environmental, economic, physical, political, and cultural considerations), feedback loops, unintended consequences, and cross-sector dependencies, and how interactions impact design and operational decision-making ○ (1, 2) ✴ (9, 11-13, 17)

3. Apply relevant concepts and frameworks from across disciplines to the study of real-world problems — and their solutions — with ethical discernment and empathetic consideration for uncertainties; communities/societies, environmental, energy, and climate justice; and cultural awareness ○ (2, 4) ✴ (4, 10, 13, 16, 17)

4. Create solutions that are viable, inclusive, and equitable and that consider the scale of the activity/product/infrastructure relative to local ecosystems and planetary boundaries (i.e., carrying capacities, tipping points, environmental and social thresholds and allocations, etc.); consider the potential roles of bio-inspired, nature-based, and regenerative solutions ○ (2, 4) ✴ (6, 7, 9, 11, 12-15)

5. Create designs that include communities/societies, environmental ecosystems, and the diversity of 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) ✴ (9, 11-15)

# Systems Thinking

## SUPPLEMENTAL

1. Explain key concepts in system dynamics (e.g., upstream and end-of-pipe factors), the impacts of system dynamics on communities/societies and design solutions, and how system dynamics can help to improve design solutions ○ (2) ◉ (4, 9, 11-13)

2. Design safe, just, and context-appropriate solutions for dynamic, real-world problems in partnership with communities using human- and life-centered design and system dynamics, including feedback loops, tipping points, and system resilience ○ (2, 4, 5) ◉ (3, 9-11, 13, 16)

3. Create visual system maps (e.g., causal loop diagramming, system dynamics simulations, etc.) ○ (6, 7) ◉ (4, 9, 11-13, 17)

4. Critique common system archetypes (e.g., limits of growth, drifting goals, tragedy of the commons, etc.) ○ (1, 4) ◉ (4, 8, 9, 11-13)

# Environmental Literacy

## CORE

1. Demonstrate sustainability literacy — i.e., understand the interconnectedness of environmental, social, and economic systems; understand various definitions and historical contexts of environmental, social, and economic sustainability (e.g., United Nations Sustainable Development Goals, Brundtland report, Triple Bottom Line, Four Pillars of Sustainable Development, Earth Charter, etc.), greenwashing, greenhushing; understand the triple crises of equity, climate, and nature; be able to think critically and solve problems; promote sustainable practices; and participate actively in creating a safe, sustainable, resilient, and equitable world ○ (4, 7) ☼ (1-17)

2. Articulate 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) ○ (2, 4) ☼ (4, 9, 11-13)

3. Examine key global ecosystem cycles and services and Nature's Contributions to People (e.g., water, carbon, energy, and nitrogen/phosphorus cycles, as well as nutrient cycling, soil formation, pollination, waste decomposition, etc.), how they are interconnected, their relationship to nature, biodiversity, and climate change, and how they impact design solutions ○ (1, 2) ☼ (6, 9, 13-15)

4. Demonstrate energy literacy — i.e., understand the nature and role of energy sources (primary vs. secondary) and energy data (direct and indirect); how energy is used (embodied vs. operational); how electrical circuits work and are used (e.g., voltage, regulation, grids, microgrids, etc.); how efficiently energy is converted and stored (e.g., batteries); and how energy effectiveness strategies and energy-use decisions affect renewable use, carbon footprint, and overall energy used throughout the solution life cycle ○ (1, 2, 6) ☼ (7, 9, 11-13)

5. Demonstrate data literacy — i.e., understand, assess, critique, verify, and effectively utilize data and reporting (e.g., United Nations Global Compact, Global Reporting Initiative, etc.) about environmental and social issues (e.g., biodiversity loss; climate change, carbon accounting, and greenhouse gas emissions; energy and water use; pollution and toxicity; air quality; waste management; etc.) including consideration for past/current/future and local/regional/global impacts and without greenwashing ○ (4, 6) ☼ (4, 12-17)

# Environmental Literacy

## SUPPLEMENTAL

1. Explain abiotic assets (e.g., fossil fuels, minerals, metals), flows (e.g., wind and solar energy, water, air, etc.), and biotic natural capital (e.g., ecosystems, biodiversity, etc.), and the function of key ecosystem services including provisioning services (e.g., agriculture/food, water, etc.), regulating and maintenance services, cultural services, and supporting services (e.g., material cycles, energy cycles) ○ (1, 2) ◉ (2, 6, 12, 14, 15)

2. Apply environmental laws, ethics, and policies (i.e., frameworks, regulations, legislations, etc.) at regional, national, and global levels, and consider ethical, social, environmental, energy, and climate justice, and cultural implications beyond current environmental compliance and geopolitical boundaries ○ (2, 4) ◉ (12-17)

3. Demonstrate climate literacy — i.e., understand the essential principles of Earth's climate system and that the climate crisis is urgent, global, complex, and caused by human activity and primarily through the burning of fossil fuels; understand and know the differences between weather, climate, and direct/indirect causes of climate change; understand scope 1, 2, and 3 emissions; recognize credible information about climate change, know where to find it and how to use it for resilience planning and create climate mitigation and adaptation solutions; communicate about climate change and climate data in accurate and effective ways; and able to make informed decisions related to climate change ○ (1, 4, 6) ◉ (7, 11-13)

# Responsible Business and Economy

## CORE

1. Recognize opportunities and demand for circular, inclusive, and sustainable business models, such as models that leverage product durability (e.g., renting, upgradeability, repairability, modularity, resale, etc.) and reduce energy and water usage, protect consumers and their privacy, reflect and include the interests and needs of diverse users and consumers, and reflect and include ethical, safety, and justice considerations ⭘ (2, 4) ⬤ (7-13)

2. Examine risks and opportunities related to changing social, economic, political, ecological, energy, and climate systems on their work (e.g., extended costs, value, trade-offs, partnerships, regulations, policies, energy hotspots, etc.) exploring approaches to change from inside and outside of their experience, discipline, region, and country, etc. ⭘ (2, 7) ⬤ (7-9, 11-13, 17)

3. Demonstrate awareness of how different revenue and business models can positively or negatively influence environmental and social systems (e.g., circular economy models, shared ownership models, service models, leasing with take-back instead of asset sales for planned obsolescence; employee-owned, public-private partnerships, business-NGO collaboration models, etc.) ⭘ (2, 4) ⬤ (7-13, 17)

4. Demonstrate awareness of alternative forms of capital beyond financial resources (including natural/ecological, human, social, and physical resources) and their limits, and demonstrate awareness of emerging economic systems intended to promote environmental, social, and global responsibility in economic thinking (e.g., Doughnut Economics, circular economy, etc.) ⭘ (2, 4) ⬤ (8-15, 17)

5. Weigh the short- and long-term social and environmental costs and value of their work ⭘ (2, 4) ⬤ (8, 9, 11-15)

# Responsible Business and Economy

### SUPPLEMENTAL

1. Explain alternative business, revenue, and entrepreneurship models (e.g., circular economy, B Corps, product service systems, sharing economy platforms, cooperatives, indigenous practices/sensibilities, etc.) ○ (2, 4) (1, 5, 7-13, 17)

2. Explain sustainable, circular, restorative, and regenerative practices to consumers ○ (2, 4) (7-9, 11-15)

3. Locate appropriate funding sources and approaches for public infrastructure by working with local communities ○ (2, 5) (6-11, 13, 17)

4. Apply management and measurement systems (e.g., Environmental, Health, and Safety (EHS), Global Reporting Initiative (GRI), International Organization for Standardization (ISO), etc.) as tools to enable systematic integration of sustainability impact management into business practices ○ (4, 6) (3, 8, 9, 12, 13, 16, 17)

5. Judge supply chain agents, vendors, etc., from environmental, social, equity, diversity, inclusion, and justice perspectives ○ (4) (5, 8-10, 12, 13, 16, 17)

6. Compare economic trade-offs in sustainability efforts (e.g., between energy efficiency, performance, and cost) and how financial trade-offs may apply differently to a variety of people within each unique value chain ○ (2, 4) (7-13)

7. Evaluate financial incentives for sustainable engineering, including carbon pricing, green investment funds, regulatory compliance, and ESG (Environmental, Social, and Governance) criteria ○ (2, 4, 7) (7-9, 11-15, 17)

# Social Responsibility

## CORE

1. Understand the United Nations Sustainable Development Goals as a framework for advancing social sustainability solutions and initiatives as a globally responsible designer/engineer ○ (4, 7) ⊙ (1-17)

2. Recognize and empathize with ethical, climate, environmental, and social justice implications relative to social and cultural impacts of their work ○ (4) ⊙ (3, 5, 10, 11, 13, 16)

3. Analyze how engineering activities directly and indirectly cause positive and negative social and cultural impacts throughout the design life cycle, both to workers producing the products (e.g., labor practices, livelihood, health, etc.) and to communities, society, and non-human life (e.g., resources acquisition, waste production and management, traditional/cultural methodologies, etc.) ○ (4) ⊙ (1, 3, 5, 8-12, 16)

4. Examine the ways in which some communities and populations (e.g., low income, children, elderly, women, people with disabilities, people of color, etc.) have historically been and continue to be negatively impacted and/or intentionally marginalized and underserved and continue to be disproportionately negatively impacted by engineering activities ○ (4) ⊙ (1, 3, 5, 10, 11, 13, 16)

5. Evaluate the role of social responsibility and environmental, energy, and climate justice in the engineering profession (e.g., policies, laws, social justice, public health, national security, etc.) ○ (4) ⊙ (3, 5-7, 10-13, 16)

6. Assess cultural, local, and global implications and influences in the context of their work (e.g., cultural expressions and sensitivities, services and goods procurement, heritage site appreciation, Indigenous Sovereignty, etc.) as well as equity awareness (e.g., gender, sex, race, ethnicity, sexual orientation, socioeconomic class, etc.) ○ (4) ⊙ (5, 8, 10-12, 16)

7. Create robust, dynamic, and resilient social systems and transdisciplinary networks ○ (2, 5) ⊙ (8-11, 16, 17)

# Social Responsibility

## SUPPLEMENTAL

1. Recognize the breadth of social and environmental justice issues, indigenous rights, laws, policies, and commitments (e.g., Global Compact (GC)) ○ (4) ◉ (1, 3, 5, 10, 13-17)

2. Recognize social and cultural implications related to local, regional, and global materials and energy use (e.g., land changes, surface and groundwater use and pollution, air pollution, energy production and use, toxins, labor rights, land tenure, etc.) as a global citizen ○ (2, 4) ◉ (1, 3, 6-8, 10-15)

3. Recognize how climate change impacts are disproportionately borne by low-income, marginalized, underserved, and vulnerable groups (e.g., children, elderly, women, people with disabilities, people of color, etc.) due to historical and present-day disparities that reduce their capacity to prepare for, recover from, and adapt to climate impacts, and that these populations often live in the poorest regions of the world that emit less carbon dioxide ○ (4) ◉ (1, 3, 10, 11, 13, 16)

# Environmental Impact Assessment

## CORE

1. Explain high-level environmental impact assessments (e.g., Life Cycle Assessments, carbon accounting, energy impact assessments, and life cycle hazards), how they work, their scope, what information they require, how to incorporate their findings, and why they matter ○ (2, 6) ⊙ (6, 7, 9, 11-15)

2. Recognize current reporting standards, eco-labelling systems, and certificates (e.g., EPEAT, Energy Star, LEED, etc.) for sustainable production and consumption, including outside their geography, that could be used to improve their work ○ (2, 7) ⊙ (7, 9, 11-13)

3. Interpret assessment metrics and broader environmental, social, and economic implications of their work ○ (2, 4, 6) ⊙ (3, 7-9, 11-15)

4. Examine complex or contradictory information to explain, prioritize, and make decisions among trade-offs (e.g., What are the cost, performance, and resource implications of the decision? Have relevant people been included in the process? Are marginalized and underserved communities part of the process and decision-making? Who and what will be most impacted by the decision?) ○ (2, 4) ⊙ (8-13, 16, 17)

## SUPPLEMENTAL

1. Discuss relative impact reduction vs. absolute impact reduction (e.g., reduction in greenhouse gases (GHGs) emitted by a vehicle per mile vs. reduction of GHGs emitted annually by the factory producing the vehicles) ○ (2, 6) ⊙ (7, 9, 11-13)

2. Assess Environmental, Health, and Safety standards (e.g., chemical hazard assessments, how to research chemical safety, etc.) data, and specifications for inputs, outputs, and performance levels of engineered products and services ○ (4, 6) ⊙ (3, 6, 8, 9, 12-16)

3. Evaluate Life Cycle Assessment, Techno-Economic Assessment, energy assessments, or other assessment tool outcomes at various scales of length (local and global effects), time (acute and chronic effects), and impacts (second and third order impacts, time-delayed impacts, etc.) ○ (2, 6) ⊙ (7-9, 11-15, 17)

# Materials

## CORE

1. Identify potential impacts of materials and materials design (e.g., embodied and operational energy, energy demand, greenhouse gas emissions, toxicity, natural resource use, labor impacts, etc.) through materials screening and selection process throughout the supply chain and life cycle — from raw material extraction through manufacturing, use, reuse/recycling, and end of life — with a focus on making design and operational decisions to minimize negative impacts to nature and all life ○ (1, 2) ⊛ (6, 8, 9, 11-15)

2. Recognize current environmental assessment research and gaps in data and research for materials, materials screening and selection, materials design, and materials systems ○ (7) ⊛ (9, 11-15)

3. Critique the environmental and social impacts and audits of design-appropriate materials (e.g., technical considerations including strength, weight, cost, toxicity, extraction impacts, material compatibility, thermal and structural properties, among others) as part of the screening and selection process with a sustainability ethos, including materials, systems, and processes to make decisions about whether to use existing or design new materials ○ (1, 4) ⊛ (8-15, 17)

4. Compare materials properties (e.g., chemical, physical, and structural properties using thermodynamics, kinetics, the interrelated materials tetrahedron, etc.) aligned with sustainable design end-use application ○ (1, 2) ⊛ (7-9, 11-15)

5. Demonstrate sustainable design literacy — i.e., select materials for design alternatives and trade-offs that enable a long functional lifetime, promote circularity, support nature-based and regenerative solutions, reduce energy consumption and reduce/prevent hotspots, have net zero greenhouse gas emissions impact, cause minimal or no environmental and social harm, and/or are restorative to social, cultural, and environmental systems ○ (2, 4) ⊛ (4, 7-9, 11-15)

6. Design with materials to create product and infrastructure solutions that are regenerative and/or reduce negative social and environmental impacts (e.g., consider natural materials) with an aligned understanding of traditional industrial materials (e.g., iron, steel, aluminum, etc.) and innovations that reduce fossil fuel consumption (e.g., recycled steel, green concrete, etc.) ○ (2, 4) ⊛ (7, 9, 11-16)

# Materials

## SUPPLEMENTAL

1. Implement tools, resources, and data assessments (e.g., AI, Open LCA, Sustainability Computer Simulation, process simulation, circularity metrics, digital twins, Ashby plots, footprint tools, Integration Computational Manufacturing Engineering, materials databases, Material Input per Unit of Service, etc.) to identify, screen, document, and mitigate potential social and environmental impacts of materials/materials design/supply chain throughout the entire life cycle — from raw material extraction through transportation, processing, manufacturing, use, reuse/recycling, and end of life — with a zero waste, circular, regenerative, and/or restorative perspective ○ (6, 7) ◉ (7-9, 11-15, 17)

2. Examine the implications of material consumption at scale, including how material selection and supply chain can influence the scale of positive or negative impacts on sustainable design ○ (2, 4) ◉ (8, 9, 11-15, 17)

3. Demonstrate materials literacy — i.e., understand materials origins, properties, and life cycle; understand materials composition at macro- and micro-materials levels; be aware that macro materials include those with structural properties (e.g., concrete, metals, plastics, etc.) and functional properties (e.g., chemicals and solid/liquid/intermediary states); be aware that substances of concern can be bound up in engineered materials, composites, and products (often micro materials, chemicals, and nanoparticles) ○ (4, 7) ◉ (4, 7-9, 11-15)

4. Analyze innovation gaps in existing materials options and identify ways to spur appropriate research and development ○ (7) ◉ (8, 9, 12-15, 17)

5. Apply a systems perspective and calculate the embodied and operational energy of materials to make informed decisions ○ (2, 6) ◉ (7, 9, 11-13)

6. Evaluate Environmental, Health, and Safety (EHS) standards, assessments, laws (e.g., Safety Data Sheets, Globally Harmonized System, Occupational Safety and Health Administration compliance, Restriction of Hazardous Substances, Waste from Electrical and Electronic Equipment, Registration, Evaluation, Authorization and Restriction of Chemicals regulation, ecotoxicity, chemical hazard assessments, etc.), and green chemistry aspects of materials ○ (4, 6) ◉ (3, 6, 8, 9, 12-16)

7. Balance trade-offs of using AI (large computational models) to explore new materials and innovation gaps with AI's environmental and social implications (e.g., energy and water use, location of data storage infrastructure, ethics of AI data sourcing, etc.) ○ (4, 7) ◉ (7-10, 12, 13, 16, 17)

# Design

## CORE

1. Execute technical analyses (e.g., Life Cycle Assessment, Techno-Economic Assessment, etc.) to choose strategies that maximize positive impacts and minimize negative environmental and social impacts to achieve design and operational goals ○ (2, 6) (7-9, 11-15)

2. Design — including materials design — using a systems thinking approach for the environment and society based on discipline-specific technical skills and circular design strategies (e.g., light-weighting, repairability, durability, upgradeability, disassembly, reuse/recycling, flexibility, resiliency, extreme affordability, for part or whole recovery to eliminate waste, etc.) ○ (2) (7-9, 11-15)

3. Create long-term, systems thinking-based approaches for tackling urgent challenges (e.g., climate mitigation and adaptation), preventing negative environmental and/or social impacts (e.g., reduction in greenhouse gas emissions, reduction in energy and resource use, greater resilience, etc.), including use of innovative and disruptive solutions within supply chains, design of new technologies and materials, use of nature-based solutions, etc. ○ (2, 4) (7, 9, 11-17)

# Design

## SUPPLEMENTAL

1. Recognize local craft traditions, indigenous knowledge systems, and vernacular practices, and innovate viable, inclusive, equitable, and regenerative solutions and processes ○ (4) ◉ (1, 5, 8, 10-15, 17)

2. Implement user experience/participatory studies (e.g., design thinking, human-centered design, community-based projects, etc.), social impact assessments, and persuasive design strategies to cultivate sustainable behavior and to meet user/community needs in responsible, novel, improved, ethical, resilient, long-lasting, and sustainable ways ○ (3, 4) ◉ (3, 5, 10-13, 16)

3. Design using rapid prototyping and iteration with approaches that incorporate whole life cycle, systems thinking, and systems dynamics concepts in mind (e.g., feedback loops, complex cause-effect chains, cascading effects, inertia, tipping points, legacy, resilience, adaptation, etc.) ○ (2, 6) ◉ (7-9, 11-13)

4. Develop creative transdisciplinary, culturally-appropriate ideas and solutions in engineering contexts, along with social and cultural values by working across disciplines ○ (3, 5) ◉ (5, 8-13, 16, 17)

5. Create solutions for use with alternative economic models (e.g., circular economy, Doughnut Economics, sharing economy, etc.) ○ (2, 4) ◉ (7-9, 11-17)

6. Design infrastructure and products that account for increasing climate risk, variability, and vulnerabilities due to extreme events (e.g., extreme heat, flooding, hurricanes, sea level rise, etc.) to enhance strategies for adaptation and build resilient infrastructures, systems, and communities ○ (2, 4) ◉ (9, 11, 13-15, 17)

# Critical Thinking

## CORE

1. Define problems comprehensively with consideration of uncertainties and long-term environmental and social consequences, both intended and unintended ⭕ (1, 4) 🌀 (3, 8-15)

2. Practice being self-reflective, valuing and guarding the environment, being empathetic, bringing an inclusive mindset, and cultivating intercultural competence to advance equitable and effective change for all life ⭕ (4) 🌀 (5, 10, 11, 13, 16)

3. Understand that their values are both shaping and being shaped by the designs, technologies, and innovations they create, implement, and scale ⭕ (4) 🌀 (4, 9, 11-13, 16)

4. Recognize that every person has a role in sustainability and climate resilience planning and action, and has the right and need to be informed about the environmental/social/economic impacts of the products they purchase, consume, and discard, including the understanding of fossil fuels as the main cause of climate change ⭕ (4) 🌀 (4, 11-13)

5. Examine social norms, cultural values, and implicit biases that underlie their behaviors (e.g., normative thinking, cognitive dissonance, etc.) and how these influence ethical and equitable decision-making and adaptive responses to sustainability challenges, including climate change ⭕ (4) 🌀 (5, 10-13, 16)

6. Critique complex ethical, cultural, and values-based thinking and choices, employing empathy and considering justice when evaluating conflicts of interest, trade-offs, timescales, and uncertain knowledge within problem constraints ⭕ (4) 🌀 (5, 10-13, 16)

# Critical Thinking

## SUPPLEMENTAL

1. Discuss varying standpoints with integrity, authenticity, and empathy for different perspectives, opinions, views, cultures, and lived experiences, etc. (i.e., normative thinking) ○ (3, 4) ◉ (5, 10, 11, 16)

2. Identify issues and actions of environmental and social priority to respond to urgent challenges, such as dependency on fossil fuels and the climate crisis ○ (4) ◉ (7, 11-13)

3. Implement sustainability-related qualitative and quantitative research into ethical and equity-oriented decision-making processes ○ (4, 6) ◉ (4, 10-13, 16, 17)

4. Distinguish the consequences of their actions and how to deal with risks and changes (i.e., apply the precautionary principle) ○ (4) ◉ (3, 11-16)

5. Compare the pros, cons, and trade-offs of incremental versus radical innovations to foster ethical and equitable discernment and decisions/solutions that reduce dependency on fossil fuels and prioritize environmental and social well-being over short-term economic gains ○ (2, 4) ◉ (7-13, 16)

6. Demonstrate Artificial Intelligence (AI) literacy — i.e., understand the social, environmental, and global impacts and responsible use of digital infrastructure and AI technology (e.g., cloud computing, energy and water use, data storage, Generative AI and Large Language Models, Transformers, Reinforcement Learning, and other AI-driven systems) and be able to critically assess AI-generated data and outputs for accuracy and credibility (detect misinformation) to be informed, adaptable, and ethically aware participants in an AI-enabled future ○ (4, 6, 7) ◉ (4, 7-9, 10, 12, 13, 16, 17)

7. Demonstrate motivation, curiosity, and creative and critical thinking to support resilient, flexible, and agile thinking and behaviors ○ (7) ◉ (4, 8, 9, 11-13, 16)

8. Prioritize appropriate and sustainable designs and solutions based on the context of the problem and in collaboration with experts and the people, lives, and ecosystems that impact and are impacted by the designs and solutions ○ (2, 5) ◉ (3, 8, 9, 11-17)

9. Evaluate possible, probable, and desirable futures for diverse people, societies, and cultures, to create their own visions for the future (i.e., futures literacy) ○ (4, 7) ◉ (4, 8-13, 16, 17)

# Communication and Teamwork

## CORE

1. Communicate using culturally appropriate and audience-specific written, graphic/visual, oral, storytelling, and/or interpersonal communication skills (e.g., clear, concise, calls to action, key takeaways, etc.) to define the problem, convey technical ideas to experts, non-experts, and decision-makers, and to negotiate, persuade, influence, and/or advocate for effective innovations and known solutions, principles, values, goals, and targets ◯ (3) ✺ (4, 5, 10-13, 16, 17)

2. Develop a culturally-sensitive and resilient identity (e.g., values, beliefs, morals, interests, self-efficacy, emotional intelligence, empathy, humility, courage, agency, tenacity, optimism, ethics-based personal code of conduct, navigating personal moral injury and dilemmas, self-learning, etc.) that supports wellbeing, ecological belonging, and creative leadership potential to enable and advance positive change through inspirational sustainability visioning, persuasion, and advocacy ◯ (4, 5) ✺ (3-5, 10, 11, 13, 16)

3. Demonstrate ability to work within, empower, and function well on teams and across disciplines (e.g., actively engage, ask questions, listen with a willingness to process and learn, navigate tensions and complexity constructively, build coalitions, change roles, etc.) to advance sustainability initiatives ◯ (5) ✺ (4, 5, 8-13, 17)

4. Demonstrate self-awareness and understanding of unconscious bias that may impact environmental and climate equity and justice ◯ (4) ✺ (5, 10, 11, 13, 16)

5. Prioritize projects, schedules, and time, and manage people justly, equitably, and inclusively ◯ (5) ✺ (5, 8, 10-12, 16)

6. Champion sustainability-focused values and approaches to maintain the integrity of design criteria across environmental, ecological, and human dimensions ◯ (3-5) ✺ (3, 4, 8, 9, 11-16)

# Communication and Teamwork

### SUPPLEMENTAL

1. Explain technical and engineering concepts, assumptions, and evidence (e.g., Life Cycle Assessment and Techno-Economic Assessments outcomes) in lay terms to the public, government, and clients/customers to influence understanding and acceptance of environmental, social, and cultural considerations, impacts, and decision-making ○ (3) ◉ (4, 11-13, 16, 17)

2. Build lasting and respectful relationships and networks (i.e., through strong inter- and intrapersonal skills) to advance sustainability efforts ○ (3, 5) ◉ (4, 5, 8, 10-13, 16, 17)

3. Investigate solutions to individual, institutional, and systemic implicit bias ○ (4) ◉ (5, 10, 11, 16)

4. Apply systematic, disciplined, and collaborative project management methodologies in order to effectively manage teams and themselves ○ (5) ◉ (8, 9, 11-13, 17)

5. Demonstrate ability to relate and adapt to, interact with, collaborate on, and lead multidisciplinary teams, effectively representing an engineering perspective in a comprehensible manner through real-world, hands-on, project-based work ○ (5) ◉ (4, 5, 8-13, 17)

# Conclusion

A cornerstone of the broader EOP initiative, the EOP Framework is a practical tool for educators seeking to update their courses and embed sustainability across all engineering education to rapidly meet evolving professional demands and create a thriving future. Educators from a variety of disciplines, settings, and schools around the world have used it to modify and/or create hundreds of core, required, and elective courses, equipping tens of thousands of students with greater capabilities to improve our planet and the life it sustains.

## Join the EOP Initiative

Incorporate the EOP Framework outcomes into your courses, programs, departments, and institutions. Visit **EngineeringforOnePlanet.org** for teaching tools, information about grants, curricular change examples, and to sign up for updates about grants, events, and other resources via **LinkedIn** and the **EOP Newsletter**.

## Acknowledgement of Collaborators and Contributors

Collaboration and collective intelligence have fueled EOP since its inception. The initial research for the EOP initiative included hundreds of individuals and began in 2017. It led to the co-creation of the first draft of the EOP Framework, which was pilot-tested in 2020-2022. Since then, editors of the EOP Framework have evolved and revised it through hundreds of conversations, research interviews, surveys, and nearly 2,000 direct comments to the document. Hundreds of experts and individuals — from a range of identities, lived experiences, geographies, and sectors, including academia, industry, nonprofit, government, and philanthropic sectors — informed and updated the EOP Framework's core and supplemental sustainability-focused student learning outcomes.

We have come a long way together — and the journey will continue. Visit **EngineeringforOnePlanet.org** to see the **List of Collaborators and Contributors** who helped to create and update the EOP Framework.

Thank you to everyone who took the time to contribute. We are deeply grateful for the collaborative energy that has grown throughout this project.

We also thank the U.S. National Science Foundation for generously supporting the revision of the EOP Framework in 2022. *The opinions, findings, and conclusions, or recommendations expressed in this work are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.*

# Conclusion

## About VentureWell™

VentureWell, founded in 1995, has spent 30+ years supporting tens of thousands of innovators to solve the world's most pressing challenges through science- and tech-driven innovation. It achieves this by providing funding and training to early-stage entrepreneurs, supporting STEM educators, and building ecosystems to accelerate the commercialization of groundbreaking technologies. Since its founding, VentureWell has trained over 19,000 individuals, launched more than 6,000 ventures, engaged 1,200+ institutions, and awarded over $30 million in grants, with ventures collectively raising $7+ billion in investment. With partnerships including the National Science Foundation, the National Institutes of Health, and nearly 400 higher education institutions, VentureWell has become a powerful global force for change, strengthening the US innovation economy and championing place-based innovation.

To learn more about VentureWell's work and resources, visit venturewell.org.

## About The Lemelson Foundation

Founded in 1992 by prolific U.S. inventor Jerome "Jerry" Lemelson and his wife Dorothy, The Lemelson Foundation is dedicated to advancing social and economic prosperity through invention. Guided today by members of the Lemelson family, the Foundation recognizes the urgent need for innovative solutions that balance technological progress with planetary health. To meet this need, the Foundation launched the Engineering for One Planet (EOP) initiative in 2020. EOP is a strategic effort to foster a future where engineering is not only a driver of innovation but also a powerful catalyst for environmental sustainability and social equity.

Based in Portland, Oregon, The Lemelson Foundation has committed over $350 million in grants and investments to organizations worldwide, cultivating the ingenuity of those who will ensure technological advancement and environmental stewardship are intrinsically linked. To learn more, please visit lemelson.org.

# Resources

EOP Resources are available for free online at Engineering for One Planet.

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# Glossary of Terms

*Except when otherwise noted, definitions listed in the Glossary of Terms were generated by the EOP Framework contributors, including individuals from a cross-section of identities, backgrounds, sectors, and experiences.*

## COMPLEX ENGINEERING PROBLEMS (ABET 2024)

Complex engineering problems include one or more of the following characteristics: involving wide-ranging or conflicting technical issues, having no obvious solution, addressing problems not encompassed by current standards and codes, including many component parts or sub-problems, involving multiple disciplines, or having significant consequences in a range of contexts.

## DIVERSITY

Diversity exists when varied characteristics are consistently present, honored, and lifted up within a group.

## ENGINEERING DESIGN (ABET 2024)

Engineering design is a process of devising a system, component, or process to meet desired needs and specifications within constraints. It is an iterative, creative, decision-making process in which the basic sciences, mathematics, and engineering sciences are applied to convert resources into solutions. Engineering design involves identifying opportunities, developing requirements, performing analysis and synthesis, generating multiple solutions, evaluating solutions against requirements, considering risks, and making trade-offs, for the purpose of obtaining a high-quality solution under the given circumstances. For illustrative purposes only, examples of possible constraints include accessibility, aesthetics, codes, constructability, cost, ergonomics, extensibility, functionality, interoperability, legal considerations, maintainability, manufacturability, marketability, policy, regulations, schedule, standards, sustainability, or usability.

## ENVIRONMENTAL INJUSTICE (USGCRP 2024)

Environmental actions, behaviors, laws, and policies that have not been fair, that have limited meaningful involvement in environmental decision-making, or that have unjustly allocated the risks and benefits of environmental action across communities, most often based on race, color, national origin, income, and gender identity, among others.

# Glossary of Terms

## *EQUITY*

Equity occurs when barriers to access and power based on one or more aspects of identity are examined and removed.

## *INCLUSION*

Authentically seeking out and engaging historically excluded individuals and/or groups with opportunities to thrive.

## *JUSTICE*

Fair treatment, access, opportunity, and advancement for all people, achieved by intentional focus on their disparate needs, conditions, and abilities.

## *RESPONSIBLE BUSINESS and ECONOMY*

Ability to operate as environmentally and socially responsible as possible within the constraints of the current business model.

## *SOLUTION, WORK, or DESIGN*

In this document, "solution," "work," or "design" refers to anything that an engineer creates, codes, builds, implements, or invents, including, but not limited to, products, designs, projects, technologies, software, materials, and solution services.

## *STUDENT OUTCOMES (ABET 2024)*

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program.

## *SUSTAINABILITY (Lemelson 2024)*

A sustainable world supports thriving ecosystems and the sentient beings that depend on them for their survival and prosperity, including human societies, animals, and plants.

**Join the EOP Initiative powered by The Lemelson Foundation.**

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, discover **EOP Resources**, and to sign up for the **EOP Newsletter**.

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